Foreign exchange developments and the minerals industry

Raputsoane, Leroi

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Leroi Raputsoane*

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Abstract

This paper analyses the reaction of the minerals industry to foreign exchange *developments* in South Africa. This is achieved by augmenting a Taylor (1993) rule type central bank monetary policy reaction function with the foreign exchange rate. The results provide evidence that, following an a percentage point increase in foreign exchange rate, output of the minerals industry decreases and bottoms out after 3 months. The results further show that the effect of an increase in foreign exchange rate on output of minerals industry is statistically significant up to 5 months. The results are consistent with the dominant currency pricing paradigm, with the U.S. dollar being the most dominant currency, hence appreciation of the dollar against other currencies predicts a decline in the volume of trade between these countries. Most currencies, including the rand, follow a freely floating exchange rate regime with little direct or indirect intervention for the purpose of influencing their exchange rates. As a result, the exporters and importers could use the available strategies and financial instruments to manage the exchange rate risk and to minimise the adverse movements in prices of international trade transactions.

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Keywords: Foreign exchange rate, Minerals industry, Economic cycles

*Leroi Raputsoane, lraputsoane@yahoo.com, Pretoria

Introduction

A well known puzzle in empirical macroeconomics is the disconnect between floating exchange rates and fundamental variables, such as economic growth, current and capital accounts, or balance of payments, inflation and interest rates etc. The apparent weak linkage between nominal exchange rates and macroeconomic fundamentals, also known as the exchange rate disconnect puzzle, is contested in macroeconomics, according to Obstfeld (2000) and Engel and West (2005). The weak relationship between macroeconomic fundamentals and nominal exchange rates was first established by Meese and Rogoff (1983a), Meese and Rogoff (1983b) and is documented in Hartley (1983), Meese and Rogoff (1988), Froot and Rogoff (1995), Taylor (1995), Frankel and Rose (1995) as well as Chen and Rogoff (2003), and surveyed in Obstfeld (2000) and Cheung et al. (2005), among others. The exchange rate disconnect puzzle is similar to the stock price disconnect puzzle, or the phenomenon that stock markets tend to move wildly with no sizable contemporaneous effects on the real economy, in that exchange rates are also volatile in comparison to the models of the underlying macroeconomic fundamentals.

Macroeconomic theory postulate that foreign exchange rates are relative prices of national currencies hence they are determined by the interaction of supply and demand in foreign exchange markets under a freely floating exchange rate regime, as discussed in Fleming (1962), Mundell (1963), Dornbusch (1976), Obstfeld (1996) and Obstfeld (2001), implying the role of macroeconomic fundamentals. Conventional macroeconomics suggests that a country's balance of trade is affected by the exchange rate where the exchange rate depreciation, or devaluation, can lead to an improvement in the balance of trade, while the opposite is true for the exchange rate appreciation, or revaluation. Since 2000, the south African currency, the rand, has consistently depreciated against the U.S. dollar, from around 6 rands to one dollar to around 18 rands to one dollar in 2023. Thus the rand has depreciated by a cumulative 200 percent in the past two decades. As with the exchange value rand, the South African minerals industry output stagnated in real terms, while it has declined progressively as a percentage of Gross Domestic product (GDP), in recent decades. Paradoxically, the aggregate economy has grown at rates of about 4 percent between 2000 and 2010 as well as about 2 percent on average since 2000.

Most transactions in international trade are invoiced in a few currencies, according to Gopinath et al. (2020), Gopinath and Stein (2021) and Gopinath et al. (2022), yet standard macroeconomic models assume that such prices are set in either the producer's or the destination's countries currencies. These currencies, also called vehicle currencies, include the U.S. dollar, pound sterling and the Euro, with the U.S. dollar playing the most dominant role. This paradigm of pricing of international trade transactions is called the Dominant Currency Pricing (DCP) and is discussed in Goldberg and Tille (2008), Gopinath (2015), Devereux et al. (2017), Gopinath et al. (2022). The Dominant Currency Pricing (DCP) contrasts with Producer Currency Pricing (PCP), discussed in Obstfeld and Rogoff (1995)), where transactions are priced in the exporter's currency, or Local Currency Pricing (LCP), discussed in Betts and Devereux (2000) and Devereux and Lane (2003), where transactions are priced in the importer's currency. These paradigms of pricing international trade transactions are surveyed in Corsetti et al. (2010), while Cook and Devereux (2006), Devereux and Shi (2013) as well as Cook and Patel (2023) discuss the implications of vehicle currencies in pricing international trade transactions.

Chadwick et al. (2015) and Ricci (2005) document a common movement between the currencies of Emerging Market Economies (EMEs), including the rand, where, on average, the correlations between the exchange values of currencies are high. The movements in the exchange value of the dollar, thus, explain the direction of emerging markets exchange rates, vise versa, hence under the Dominant Currency Pricing (DCP), the U.S. dollar is the major driver of global trade. The U.S. dollar appreciation against all other currencies predicts a decline in the volume of total trade between countries in the rest of the world. It also means that exchange rate depreciations, or appreciations, make U.S. exports cheaper, or expensive, while it mainly raises, or lower, mark ups and hence profits for other countries. Macroeconomics literature highlights the importance of different shocks, that include demand and supply side shocks, while it also emphasises the effects of these shocks during the different phases and components of the economy. According to Blanchard et al. (1986), Shapiro (1987), Blanchard and Quah (1988), Shapiro and Watson (1988), Quah (1988), Kydland and Prescott (1990), Gali (1992) as well as Romer (1993), the short term, or transitory, economic fluctuations are determined by demand shocks, while the long term, or permanent, economic fluctuations are determined by supply shocks.

Conventional macroeconomic models, thus, distinguish between alternative “anchors” to stabilise the cyclical behavior of economic activity. The short term, or transitory, economic fluctuations emanate from changes in monetary, financial and fiscal policies as well as consumer and business sentiment. The long term, or permanent, economic fluctuations emanate from the nominal rigidities that include changes in technological advancement, privatisation, deregulation as well as multilateral agreements. The short term economic fluctuations are, therefore, determined by demand side shocks, while long term economic fluctuations are determined by the supply side shocks. Demand side and supply side economic management paradigm suggest the need to decompose the macroeconomic indicators into their transitory and permanent components. A discussion on the isolation of economic variables into the short and long run components can be found in Kydland and Prescott (1990), Romer (1993) and Stock and Watson (1999). Hodrick and Prescott (1997), Baxter and King (1999) and Christiano and Fitzgerald (2003), as will be discussed, provide the methodological aspects. Diebold and Rudebusch (1970) and Romer (1993) further argue that the different economic sectors respond differently to endogenous and exogenous economic shocks as well as to the long run and short run disturbances.

This paper analyses the reaction of the minerals industry to foreign exchange *developments* in South Africa. This is achieved by augmenting a Taylor (1993) rule type central bank monetary policy reaction function with the foreign exchange rate. Understanding the reaction of the minerals industry to foreign exchange *developments* over the economic cycle is important to mining authorities and policymakers alike. As opposed to the macroeconomics literature, the European Central Bank (ECB) (2012) and Morgan Stanley Capital International (MSCI). (2014) contend that, the investment literature distinguishes between types of industries, categorised into defensive, cyclical and sensitive industries, based on how they respond to economic fluctuations over the economic cycle. Consequently, the exchange rate disconnect puzzle, as discussed in Meese and Rogoff (1983a) and Meese and Rogoff (1983b) as well as the Dominant Currency Pricing (DCP), as discussed in Goldberg and Tille (2008) as well as Gopinath (2015), among others, suggest a negligible effect of the exchange rate on macroeconomic fluctuations, ceteris paribus, and thence on output of mining and quarrying. Nevertheless, Raputsoane and Todani (2009) and Gupta et al. (2016) find the existence of a robust long run relationship as well as a time varying response of the rand exchange rate to macroeconomic fundamentals, respectively.

The paper is organised as follows. The next section discusses the data and is followed by the specification of the model and the estimation technique. The subsequent section presents the empirical results and last is the conclusion, together with recommendations and areas of further research.

Data

Monthly data spanning the period January 2000 to December 2023 is used to analyse the reaction of the minerals industry to foreign exchange *developments*. The variables comprise mining and quarrying output, inflation rate, monetary policy interest rate and foreign exchange rate. Mining output is Gross Value Added (GVA) of the mining and quarrying, or the minerals industry. Inflation rate, or the change in annual Consumer Price Index (CPI), is the annual headline consumer price inflation. Monetary policy interest rate, or central bank interest rate, is the short term policy rate, also called repurchase rate, and is the rate at which private sector banks borrow from the central bank. Foreign exchange rate is the South African rand to U.S. dollar spot exchange rate. The data on mining output and inflation rate was sourced from Statistics South Africa, while data on the interest rate and foreign exchange rate was sourced from the South African Reserve Bank. The descriptions the variables are presented in Table 1. Mining output is denoted $GVAMng$, inflation rate, is denoted $CPIRate$, monetary policy interest rate, is denoted $CBRate$, while $FXRate$ denotes foreign exchange rate.

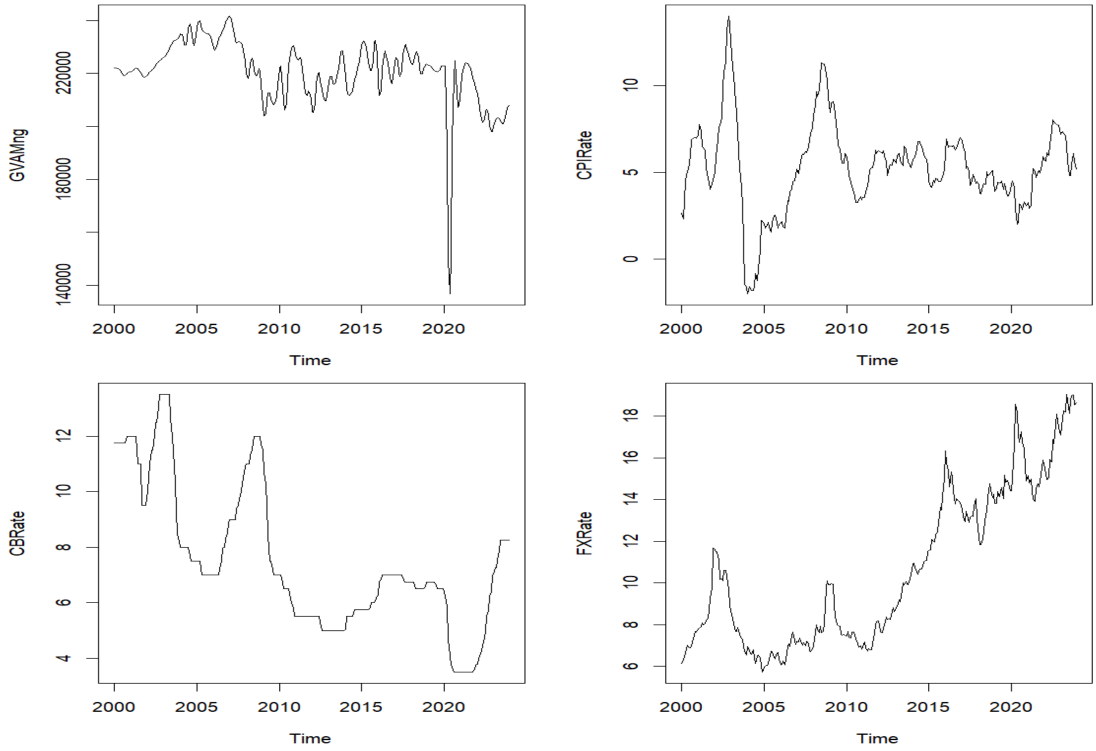
Variable	Denotation	Description
Mining output	GVAMng	Gross Value Added (GVA) of the mining and quarrying, or minerals, industry
Inflation rate	CPIRate	Inflation rate, or annual Consumer Price Index (CPI), is the annual headline consumer price inflation
Interest rate	CBRate	Central bank policy rate and is the rate at which private sector banks borrow from the central bank
Foreign exchange rate	FXRate	South African rand to U.S. dollar spot exchange rate

Notes: Data sourced from Statistics South Africa and South African Reserve Bank. Output of mining and quarrying is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $FXRate$ denotes foreign exchange rate.

Table 1: Description of the variables

The evolution of the variables are depicted in Figure 1. Output of the mining and quarrying industry increased between 2003 and 2007, where it reached a peak, and decreased significantly to 2009. The decrease in output of the mining and quarrying was due to the onset of the Global financial crisis in late 2008. Output of the mining and quarrying industry then increased, albeit volatile, from 2010 to 2015 where it subsequently decreased from 2016 to 2023, and more so in 2022 and 2023. The significant decrease in output of the mining and quarrying in 2020 was due to the onset of the Covid 19 pandemic. Inflation rate, or the change in annual Consumer Price Index (CPI), increased from 2000 and reached a peak in 2003 where it decreased significantly and bottomed in 2004. Inflation rate increased again between 2005 and 2008 before it decreased between 2009 and 2011. The indicator then remained range bound but volatile between 2012 and 2021 where it then spiked in in 2022 before decreasing in 2023. The movements of the central bank monetary policy interest rate closely mirrored the movements in inflation rate during the sample period between 2000 and 2023. However, the interest rate, which is the rate at which private sector banks borrow from the central bank, was generally in a down ward trend between 2000 and 2023 with notable spikes and peaks in 2003, 2008 and 2003, while the opposite is true in 2005, 2013 as well as in 2021. The central bank interest rate increased substantially from early 2022 to counteract the rising consumer price inflation in the same period.

Foreign exchange rate maintained an upward trend, on average, between 2000 and 2023, or throughout the sample period, albeit volatile. Foreign exchange rate accelerated notably from 2000, peaking in 2002. The decrease witnessed in 2003 was followed by an increase in 2005 and a peak in 2008. The exchange rate decreased again in 2009 and bottomed out in 2011, while it accelerated consistently



Notes: Data sourced from Statistics South Africa and South African Reserve Bank. Output of mining and quarrying is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $FXRate$ denotes foreign exchange rate.

Figure 1: Plots of the variables

between 2012 and 2023, peaking in 2016 and 2020 aas well as in 2023. The fluctuations in foreign exchange rate were erratic and inconsistent, indicating volatile demand and supply conditions in foreign exchange markets. Since 2000, the south African rand consistently depreciated against the U.S. dollar. The peaks in fluctuations of the rand coincide with some adverse events for the exchange value of the rand, including the U.S. terrorist attacks in 2001, the Global Financial Crisis in 2008, the investor confidence jitters of 2015, the 2020 Covid 19 pandemic as well as the Russia-Ukraine war in 2022.

The variables were transformed to the deviation from their Hodrick and Prescott (1997) trends. 24 months were forecasted at the end of each variable series to correct the Hodrick and Prescott (1997) trend end point problem following Ravn and Uhlig (2002) and Mise et al. (2005). Dating the phases of the economic time series as well as decomposing the economic time series into its short run and long run components are discussed in Burns and Mitchell (1946), Friedman et al. (1963), Romer (1986), Gordon (2007), Kydland and Prescott (1990), Romer (1993) and Stock and Watson (1999), while Hodrick and Prescott (1997), Christiano and Fitzgerald (2003) as well as Baxter and King (1999) provide the methodological aspects of decomposing the economic time series into its components. Decomposing the economic time series into its unobserved short term, also called cyclical, as well as long term, also called permanent or trend, components, will facilitate the analysis of the reaction of mining and quarrying, or the minerals industry, to foreign exchange *developments* over the economic cycle.

Methodology

A Vector Autoregression (VAR) model is estimated to capture the relationship between the minerals industry and foreign exchange developments. The specified Vector Autoregression (VAR) model follows Stock and Watson (2001) and Kadiyala and Karlsson (1997). Vector Autoregression (VAR) models were introduced in applied macroeconomic research by Sims (1980), while the early contributions to their Bayesian equivalents include Litterman (1984). According to Stock and Watson (2001) and Rudebusch (1998), a Vector Autoregression (VAR) is a system of linear equations, one for each variable in the system. In reduced form, each equation in a Vector Autoregression (VAR) model specifies one of the variables as a linear function of its own lagged values as well as the lagged values of other variables being considered in the system and a serially uncorrelated error term. In general, for a VAR(p) model, the first p lags of each variable in the system are used as the regression predictors for each variable.

Vector Autoregression (VAR) models have become standard tools in macroeconomics structural analysis and forecasting, as argue Giannone et al. (2010), Koop and Korobilis (2010) and Koop (2013). According to Del Negro and Schorfheide (2011), these models can capture the important stylised facts about the economic time series despite their simple formulation. These include the decaying pattern in the values of the autocorrelations as the lag order increases and the dynamic linear interdependencies between the model variables. A Vector Autoregression (VAR) model is specified as follows

$$Y_t = \delta + \theta_1 Y_{t-1} + ... + \theta_p Y_{t-p} + \epsilon_t \tag{1}$$

where $Y_t = (Y_{1,t}, ..., Y_{n,t})$ is the $n * 1$ is vector of random variables observed at time t. $\delta = (\delta_1, ..., \delta_n)$ is the $n * 1$ vector of constants or intercept terms, $\theta_1, ..., \theta_p$ are $n * n$ matrices of coefficients, p is the number of lags of each of the n variables and $\epsilon_t = (\epsilon_{1,t}, ..., \epsilon_{n,t})$ is the $n * 1$ dimensional vector of white noise error terms denoted

$$\epsilon_t \sim N(0, \Sigma) \tag{2}$$

where Σ is the $n * n$ variance covariance matrix. Evans and Kuttner (1998), Rudebusch (1998) and Stock and Watson (2001) argue that the error terms are the unanticipated policy shocks, or surprise movements, after taking the Vector Autoregression (VAR) model's past values, or lags, into account.

A general matrix notation of a Vector Autoregression (VAR) model with p number of lags, or VAR(p), and no deterministic regressors, can be written as

$$\begin{bmatrix} Y_{1,t} \\ Y_{2,t} \\ \vdots \\ Y_{n,t} \end{bmatrix} = \begin{bmatrix} \delta_1 \\ \delta_2 \\ \vdots \\ \delta_n \end{bmatrix} + \begin{bmatrix} \theta_{1,1} & \theta_{1,2} & \cdots & \theta_{1,n} \\ \theta_{2,1} & \theta_{2,2} & \cdots & \theta_{2,n} \\ \vdots & \vdots & \ddots & \vdots \\ \theta_{n,1} & \theta_{n,2} & \cdots & \theta_{n,n} \end{bmatrix} \begin{bmatrix} Y_{1,t-1} \\ Y_{2,t-1} \\ \vdots \\ Y_{n,t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_{1,t} \\ \epsilon_{2,t} \\ \vdots \\ \epsilon_{n,t} \end{bmatrix} \tag{3}$$

where in this instance, p, or the number of lags, is equal to 1 for each of the n variables. A detailed discussion on Vector Autoregression (VAR) models can be found in Hamilton (1994), while the recent contributions include Lütkepohl (2005), Koop and Korobilis (2010) as well as Giannone et al. (2015).

A Vector Autoregression (VAR) model is estimated using Bayesian methods. A Minnesota prior is specified and a Gibbs style sampler is used in estimation following Kadiyala and Karlsson (1997). At the heart of Bayesian analysis is the Bayes theorem and it is specified as

$$P(\theta_i, \Sigma \mid Y_t, M_i) \, P(Y_t \mid \Sigma, M_i) = P(Y_t \mid \theta_i, \Sigma, M_i) \, P(\theta_i, \Sigma \mid M_i) \tag{4}$$

where M_i is an arbitrary model among a general class of models, θ_i is the parameter vector described above, $p(\theta_i \mid Y_t, M_i)$ is the posterior model probability, $p(Y_t \mid \theta_i, M_i)$ is the marginal likelihood of the model, $p(\theta_i \mid M_i)$ is the prior model probability and $p(Y_t \mid M_i)$ is the constant integrated likelihood over all models. The details on a Bayesian Vector Autoregression (BVAR) model estimation with Minnesota prior, first introduced by Litterman (1979), Litterman (1980) and Litterman (1984) and developed by Sims (1989), is used in this paper, while a brief introduction to Bayesian econometrics and Bayesian Vector Autoregression models, can be found in O'Hara (2015). A more general treatment of Vector Autoregression (VAR) models, including Bayesian estimation with the different types of model priors, can be found in Koop and Korobilis (2010), Canova (2011) as well as Giannone et al. (2015).

According to Rudebusch (1998), the appeal of using Vector Autoregression (VAR) models for analysing policy reaction functions is that they have the ability to identify the effects of shocks without a need to specify a complete structural model of the economy. Giannone et al. (2010) contend that Vector Autoregression (VAR) models have become popular among empirical macroeconomists because they facilitate insight into the dynamic relationships between the economic variables in a relatively unconstrained manner. Koop and Korobilis (2010) and Koop (2013) further argue that the Bayesian methods have become an increasingly popular way of dealing with the problem of over parameterisation of economic models given the limited length of standard macroeconomic datasets. Vector Autoregression (VAR) models can be used successfully in macroeconomic forecasting with a large number of variables when coupled with Bayesian estimation, as argue Sims and Uhlig (1991), due to the flexibility provided by the application of the Bayesian parameter shrinkage. Sims and Uhlig (1991) further argue that Bayesian versions of these models can incorporate unit root nonstationary variables with no disadvantageous consequences on the inference of the parameters of the model.

Results

A Bayesian Vector Autoregression (BVAR) model was estimated to capture the relationships between the minerals industry and foreign exchange developments, as discussed. The estimated Bayesian Vector Autoregression (BVAR) specifies a Minnesota prior and uses a Gibbs style sampler following Stock and Watson (2001) and O'Hara (2015). The 0.05 prior was set on all coefficients except the own first lags which were set to 0.95 to account for persistence in the variables. The number of lags to include of each variable was set to 4 following the Schwarz (1978) Bayesian information criterion. The integer value for the horizon of the Impulse Response Functions (IRFs) was set to 24, corresponding to 2 years, given that monthly data is used in estimation. 10000 is the number of Gibbs sampler replications to keep from the sampling run, while 1000 is the sampling burn in length for the Gibbs sampler. Gibbs sampling, or Gibbs sampler, is a Markov Chain Monte Carlo (MCMC) technique used to sample from probability distributions, where the Gibbs sampler draws iteratively from the posterior conditional probability distributions, in contrast to sampling from the joint posterior probability distribution.

As discussed, conventional macroeconomic models distinguish between alternative "anchors" to stabilise the cyclical behavior of economic activity. Macroeconomics literature further highlights the importance of demand side and supply side shocks, market rigidities as well as investor and consumer sentiments. Moreover, the exchange rate disconnect puzzle, as discussed in Meese and Rogoff (1983a) and Meese and Rogoff (1983b) as well as the Dominant Currency Pricing (DCP), as discussed in Goldberg and Tille (2008) and Gopinath (2015), among others, suggest a negligible effect of the exchange rate on macroeconomic fluctuations, ceteris paribus, and hence on output of mining and quarrying. A Taylor (1993) rule type central bank monetary policy reaction function with the output of mining and quarrying industry is, thus, augmented with foreign exchange rare as follows

$$i_t = \rho + \theta_\pi(\pi_t - \pi_t^*) + \theta_Y(Y_t - \bar{Y}_t) + \theta_C(E_t - \bar{E}_t) + \epsilon_t \tag{5}$$

where i_t is the nominal interest rate, ρ is the natural rate of interest, π_t is the inflation rate, π_t^* is the central bank target for inflation, Y_t is output, $\bar{Y}_t$ is the natural rate of output, E_t denotes foreign exchange rate, while $\bar{G}_t$ is the natural rate of . θ_π, θ_Y and θ_C are the responsiveness of the nominal interest rate to the deviations of inflation from the central bank inflation target, the deviations of output from its natural rate and the deviations of from its natural rate, respectively. ϵ_t is the error term and the subscript t denotes the time period. The central bank monetary policy reaction function captures the process through which the monetary policy decisions affect the consumer price inflation in particular and the aggregate economy in general. The specified central bank monetary policy reaction function ensures market clearing, or equillibrium, condition, in that whenever output is equal to its steady state level, consumer price inflation is the same as its target rate and foreign exchange fate equals its steady state level, hence the nominal interest rate is also equivalent to its natural rate.

The variables in the specified central bank monetary policy reaction function comprise output of mining and quarrying, denoted $GVAMng_t$, inflation, denoted CPI_t, interest rate, denoted $CBRate_t$ and foreign exchange rate, denoted $FXRate_t$. Y_t in Equation 1 can, thus, be rewritten as

$$Y_t = (GVAMng_t, CPI_t, CBRate_t, FXRate_t) \tag{6}$$

where Y_t is the vector of random variables observed at time t. Stock and Watson (2001) argue that a reduced form Vector Autoregression (VAR), on the one hand, expresses each variable as a linear function of its own past values, the past values of all other variables being considered and a serially uncorrelated error term. On the other hand, a recursive Vector Autoregression (VAR) constructs the error terms in each regression equation to be uncorrelated with the error in the preceding equations by including contemporaneous values as regressors. Consequently, the results of a recursive Vector Autoregression (VAR) depend on the order of the variables where changing the order of the model variables also changes the equations, coefficients and residuals of the Vector Autoregression (VAR).

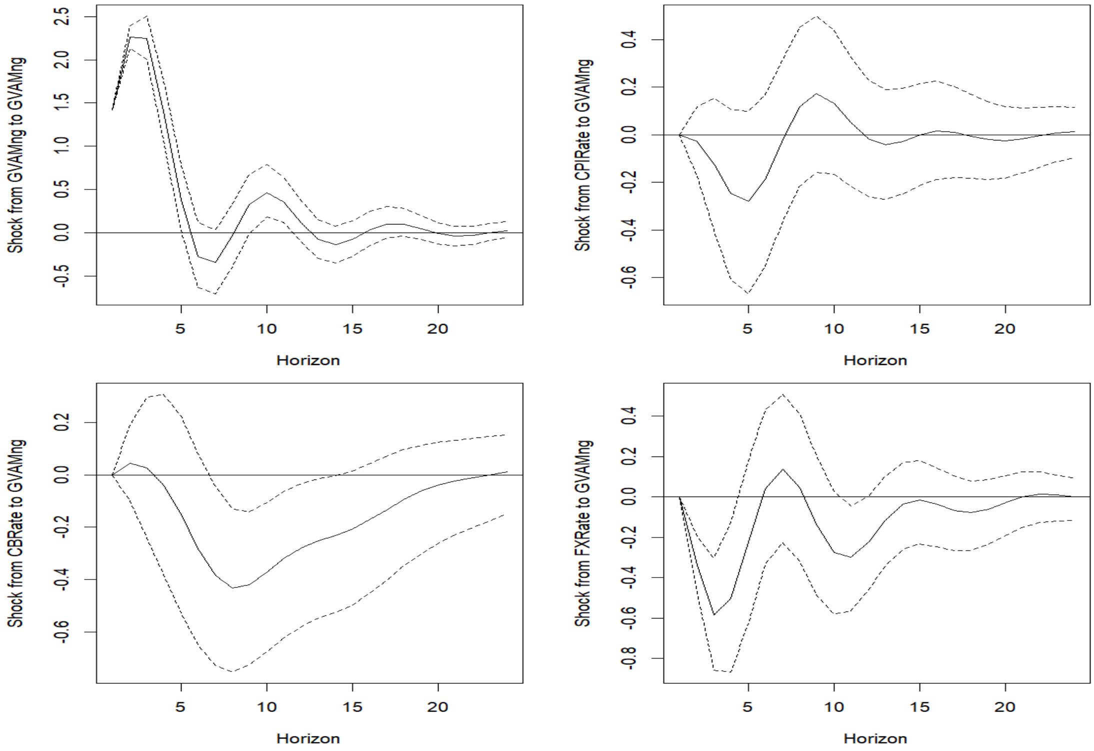
According to Stock and Watson (2001), the standard practice in Vector Autoregression (VAR) model analysis is to report the results from Impulse Response Functions (IRFs) and Forecast Error Variance Decompositions (FEVDs). The reason is that these statistics are more informative than the estimated Vector Autoregression (VAR) regression coefficients. Rudebusch (1998) further argues that most Vector Autoregression (VAR) model equations do not have a clear structural interpretation. Vector Autoregression (VAR) models are also atheoretical, that is, they are not built on some economic theory, hence a theoretical structure is not imposed on the equations. Every variable is assumed to influence every other variable in the system, which makes a direct interpretation of the estimated coefficients difficult, according to Hyndman and Athanasopoulos (2018). Therefore, in this paper, the Impulse Response Functions (IRFs) are the only model statistics that are reported given that the interest is to analyse the reaction of the minerals industry to foreign exchange rate developments.

The variables were transformed to stationarity in that they were decomposed into deviations from their long term trends. The detrending is useful conceptually because it eliminates the common steering force that time may have on each variable series and hence induces stationarity. As such, the variables are mean reverting, thus, the Bayesian Vector Autoregression (BVAR) model is assumed to be covariance stationary. As discussed above, Rudebusch (1998) and Stock and Watson (2001) argue that the residuals of the Vector Autoregression (VAR) model are unanticipated shocks, or surprise movements in the variables. According to Stock and Watson (2001), the Impulse Response Functions (IRFs) trace out the response of current and future values of each of the variables to a unit increase in the current value of one of the Vector Autoregression (VAR) errors. This error is assumed to return to zero in subsequent periods and that all other errors are equal to zero. Consequently, the Impulse Response Functions (IRFs) show the impact, or effect, of a unit, or 1 percentage point, change in the variable under consideration on the rest of the other Vector Autoregression (VAR) model variables.

The Impulse Response Functions (IRFs) of a Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in the other variables are depicted in Figure 2, together with their 95 percent confidence intervals, or bands. According to the results, following an unexpected 1 percentage point increase in output of the minerals industry, minerals industry output initially increases and peaks at 2.25 percentage points after 3 months. The increase is followed by a rapid decrease where the minerals industry output bottoms out at -0.36 percentage points after 7 months. The initial increase in minerals industry output remains statistically significant for about 12 months following which its potency begins to progressively wane, or dissipate. Output of the minerals industry, thereafter, rapidly moves towards its steady state level in about 20 months. Following an unexpected 1 percentage point increase in consumer price inflation, output of the minerals industry initially decreases and bottoms out at -0.28 percentage points after 5 months. Output of the minerals industry then increases, peaking at 0.17 percentage points after 9 months. Output of the Minerals industry then fluctuates and progressively tends towards, its natural rate. The effect of the unexpected, surprise, increase in consumer price inflation is statistically insignificant during all the time periods.

Following an unexpected 1 percentage point increase in monetary policy interest rate, output of the minerals industry increases slightly and peaks after 2 months. The initial increase in output of the minerals industry is followed by a decrease where the minerals industry output bottoms out at -0.43 percentage points after 8 months. The effect of the surprise increase in monetary policy interest rate is, however, statistically significant between 6 and 14 periods, following which it begins to progressively discipate and hence the minerals industry output gradually tends towards its steady state level. Following an unexpected, or surprise, 1 percentage point increase in foreign exchange rate, output of the minerals industry decreases and bottoms out at -0.59 percentage points after 3 months. The initial increase is followed by an increase where output of the minerals industry peaks at 0.13 percentage points after 7 months. The increase in output of the minerals industry is followed a decrease and subsequent fluctuation and gradual increase of output of the minerals industry towards its equilibrium, or steady state, level after 21 months. The effect of an unexpected, or surprise, increase in foreign exchange rate on output of minerals industry is statistically significant up to 5 months.

The Impulse Response Functions (IRFs) of a Vector Autoregression (VAR) model with innovations, or shocks, in the minerals industry output are depicted in Figure 3, together with their 95 percent confidence intervals, or bands. The results of the reaction of the minerals industry output to its own innovations, or to an unexpected 1 percentage point increase in minerals industry output, are reported above, that output of the minerals industry initially increases and peaks at 2.25 percentage points after 3 months and that the effect remains statistically significant for about 12 months. Following an unexpected 1 percentage point increase in output of the minerals industry, consumer price inflation decreases and bottoms out at -0.03 percentage points after 5 months. The initial decrease is followed by an increase where consumer price inflation peaks at 0.02 percentage points after 9 months. Consumer price inflation subsequently decreases and progressively, tends towards and fluctuates around,



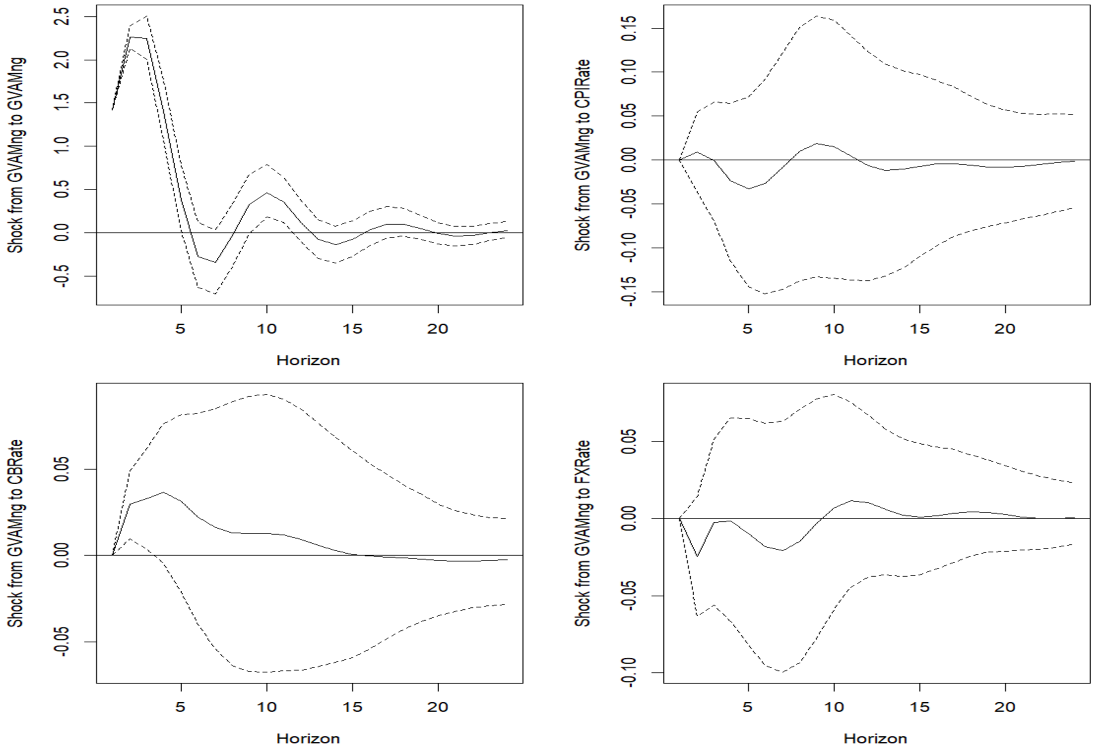
Notes: Data sourced from Statistics South Africa and South African Reserve Bank. Mining output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $FXRate$ denotes foreign exchange rate. The x axis depicts the horizon of the Impulse Response Functions (IRFs).

Figure 2: Impulse Response Functions (IRFs) with shocks to output of the minerals industry

its equilibrium, or steady state, level in about 19 months. The effect of the surprise increase in output of the minerals industry on consumer price inflation is statistically insignificant in all time periods.

Following an unexpected 1 percentage point increase in output of the minerals industry, the central bank monetary policy interest rate initially increases and peaks at 0.03 percentage points after 4 months. The central bank monetary policy interest rate subsequently decreases progressively, tends towards and fluctuates around, its equilibrium, or steady state, level. The effect of the surprise increase in output of the minerals industry on the central bank monetary policy interest rate is, however, statistically significant up to 3 months. Following an unexpected, or surprise, 1 percentage point increase in output of the minerals industry, foreign exchange rate initially decrease slightly and bottom out at -0.02 percentage points after 2 months. The initial decrease is followed by another decrease where foreign exchange rate bottoms out at -0.02 after 7 months. Foreign exchange rate subsequently recovers and peak at 0.01 percentage points after 11 months before it progressively fluctuates around and tends towards, its equilibrium, or steady state, level. The effect of the unexpected increase in minerals industry output on foreign exchange rate is statistically insignificant in all time periods.

Macroeconomic theory postulate that foreign exchange rates are determined by the interaction of supply and demand in foreign exchange markets, according to the Mundell-Flemming model by Fleming (1962) and Mundell (1963), implying the role of macroeconomic fundamentals, under a freely floating exchange rate regime, as discussed in Dornbusch (1976), Obstfeld (1996) and Obstfeld (2001). Conventional macroeconomics, therefore, suggests that a country's balance of trade is affected by the exchange rate where the exchange rate depreciation, or devaluation, can lead to an improvement in the balance of trade, while the opposite is true for the exchange rate appreciation, or revaluation. Empirical macroeconomics, however, find an apparent weak linkage between nominal exchange rates and macroeconomic fundamentals, also known as the exchange rate disconnect puzzle, as established by Meese and Rogoff (1983a), Meese and Rogoff (1983b) and discussed in Meese and Rogoff (1988), Froot and Rogoff (1995), Taylor (1995), Frankel and Rose (1995) as well as Chen and Rogoff (2003), among others. According to Obstfeld (2000), Cheung et al. (2005) and Engel and West (2005),the apparent weak relationship between foreign exchange rates and macroeconomic fundamentals is that exchange



Notes: Data sourced from Statistics South Africa and South African Reserve Bank. Mining output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $FXRate$ denotes foreign exchange rate. The x axis depicts the horizon of the Impulse Response Functions (IRFs).

Figure 3: Impulse Response Functions (IRFs) with shocks from output of the minerals industry

rates are extremely volatile relative to the models of the underlying macroeconomic fundamentals.

The results provide evidence of a statistically significant effect of an unexpected, or surprise, increase in foreign exchange rate on output of the minerals industry, which decreases and bottoms out at -0.59 percentage points after 3 months. The results further show that the effect of an unexpected, or surprise, increase in foreign exchange rate on output of the mining industry is statistically significant up to 5 months. Although the results support the Fleming (1962) and Mundell (1963) model that a country's balance of trade is affected by the exchange rate, they are at odds with the hypothesis that the exchange rate depreciation, or devaluation, can lead to an improvement in the balance of trade, while the opposite is true for the exchange rate appreciation, or revaluation. Most transactions in international trade are invoiced in a few currencies, according to Gopinath et al. (2020), Gopinath and Stein (2021) and Gopinath et al. (2022), the U.S. dollar being the most dominant. This paradigm is called the Dominant Currency Pricing (DCP), as discussed in Goldberg and Tille (2008), Gopinath (2015), Devereux et al. (2017), Gopinath et al. (2022). The movements in the exchange value of the dollar, thus, explain the direction of emerging markets exchange rates, hence the dollar appreciation against the other currencies predicts a decline in the volume of trade between these countries. The empirical results are, therefore, consistent with the Dominant Currency Pricing (DCP) paradigm.

Conclusion

This paper analysed the reaction of the minerals industry to foreign exchange *developments* in South Africa. This was achieved by augmenting a Taylor (1993) rule type central bank monetary policy reaction function with the foreign exchange rate. The results provide evidence that, following an unexpected, or surprise, increase in foreign exchange rate, output of the minerals industry initially decreases and bottoms out at -0.59 percentage points after 3 months. The results further show that the effect of an unexpected increase in foreign exchange rate on output of minerals industry is statistically significant up to 5 months. Although the results support the conventional macroeconomic theory that a country's balance of trade is affected by the exchange rate, they are at odds with the hypothesis that the exchange rate depreciation, or devaluation, can lead to an improvement in the balance of trade, while the opposite is true for the exchange rate appreciation, or revaluation. The results are consistent with the Dominant Currency Pricing (DCP) paradigm that most transactions in international trade are invoiced in a few currencies, the U.S. dollar being the most dominant, hence appreciation of the dollar against other currencies predicts a decline in the volume of trade between these countries.

Most countries follow a freely floating exchange rate regime since the Bretton Woods system collapsed in the 1970s, where the value of their currencies are determined by the forces of supply and demand in the foreign exchange market. Since the collapse of the Bretton Woods system, most currencies, including the rand, are freely floating with little direct or indirect intervention through, among others, the sale of foreign exchange in the market for the purpose of influencing their exchange rates. As a result, exporters and importers could use the available financial strategies and instruments, including hedging and Pricing to Market (PTM), to manage the exchange rate risk and to minimise adverse movements in prices of international trade transactions. As discussed, however, renouncing the Dominant Currency Pricing (DCP) paradigm and adopting the Producer Currency Pricing (PCP) or Local Currency Pricing (LCP), could introduce severe risks to international trade transactions. Several economic indicators, such as the monetary policy interest rates, Government expenditure and taxation, prices of financial assets and commodities, affect economic activity, at least theoretically, and as a result, it is important for future research to analyse their impact on the minerals industry.

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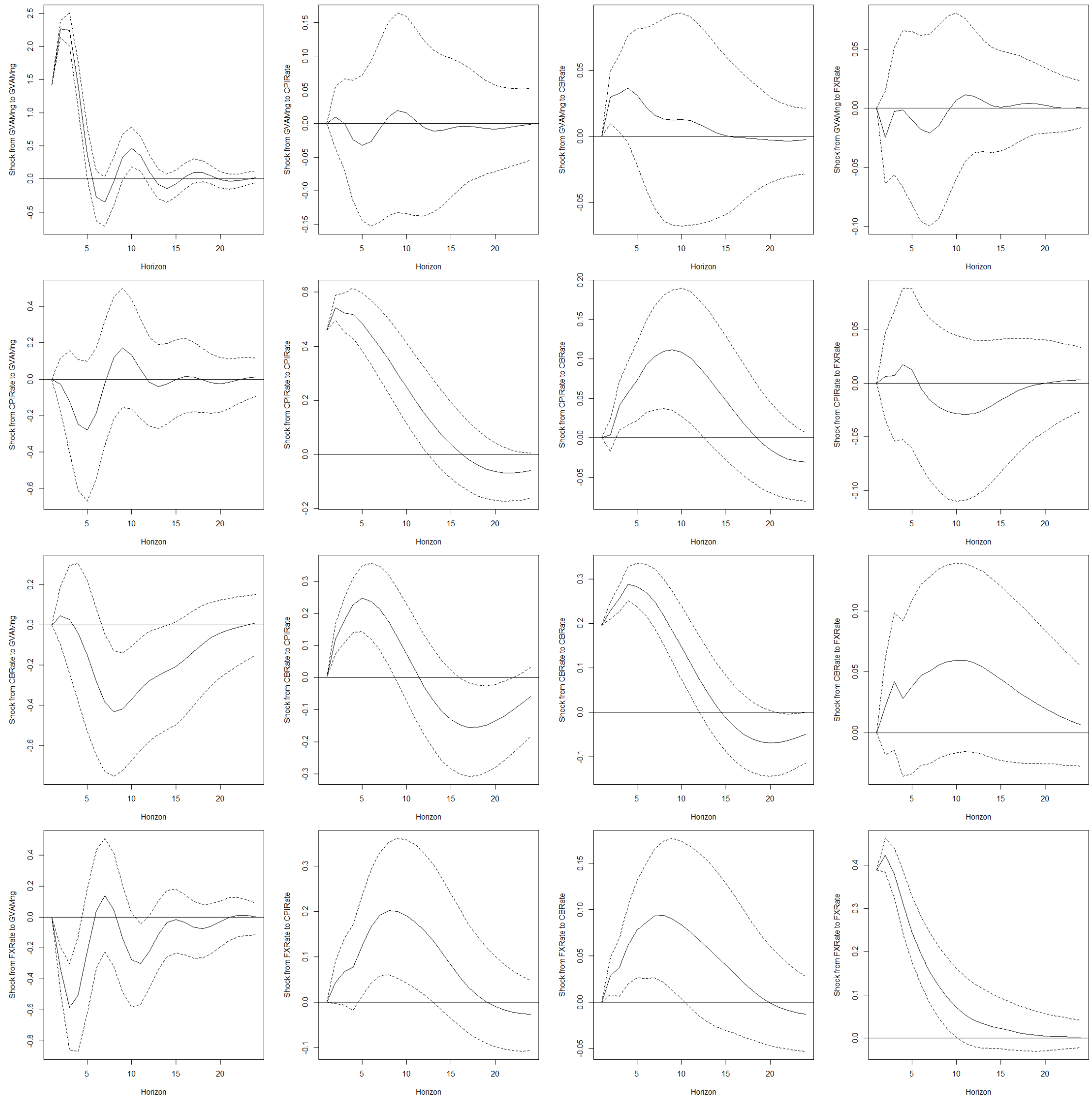
Appendix

Appendix 1. Complete Impulse Response Functions (IRFs)

The complete Impulse Response Functions (IRFs) of a Vector Autoregression (VAR) model with foreign exchange rate are shown in Figure 4. This Figure is not intended to be a part of the paper, but is included to demonstrate the completeness of the analysis.



Notes: Data sourced from Statistics South Africa and South African Reserve Bank. Mining output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $FXRate$ denotes foreign exchange rate. The x axis depicts the horizon of the Impulse Response Functions (IRFs).

Figure 4: Complete Impulse Response Functions (IRFs) with foreign exchange rate