Economic causation nexus and the minerals industry

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Abstract

This paper analyses the causality *nexus* between the minerals industry and selected macroeconomic indicators in South Africa. This is achieved by augmenting a Taylor (1993) rule type central bank monetary policy reaction function with selected macroeconomic indicators and comparing the causality between the minerals industry and these macroeconomic indicators. The results provide evidence of a statistically significant unidirectional causality from commodity prices, foreign exchange rate and geopolitical risk to output of the minerals industry. The results have also shown a unidirectional causality from output of the minerals industry and government expenditure, or fiscal policy stance. The results further show a bidirectional causality between output of the minerals industry and monetary policy interest rate, foreign direct investment, financial market, business confidence, market uncertainty as well as external, or foreign, demand. The results, however, do not show the absence of causality, or causation, between output of the minerals industry and the selected macroeconomic indicators. Macroeconomic indicators are important for economic activity, hence policymakers should monitor developments in macroeconomic events to support economic growth as well as the minerals industry.

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Introduction

Economic causation, or causality, a principle commonly used to analyse the intertemporal flow of effects between two economic episodes, is the hypothesis that an economic event, referred to as the cause, is responsible for, or produces, the occurrence of another economic event, referred to as the effect. Econometrics theory postulates that a variable causes another variable if information about the past of the first variable helps predict the future of the second variable better than using only the past information of the first variable, following Granger (1969). According to Leamer (1985), Diebold (2007) and Granger and Newbold (2014), Granger causality, however, does not establish a true causal relationship, but only indicates that one variable's past information is useful in predicting another, while it doesn't rule out the possibility of other factors or feedback loops. Causality can either be unidirectional, referred to as one way, or bidirectional, referred to as two way, and often involves feedback loops, where the effects of one variable can reinforce or alter the original cause, leading to dynamic relationships where changes in one variable can have cascading effects on other variables.

A widely accepted phenomenon is that the trend break, as well as the protracted underperformance, of the minerals industry relative to total economy since the 1970s was a problem of structural misalignments. The industry is, thus, perceived not to be affected by the fluctuations in economic indicators, such as monetary, financial and fiscal policies and other factors that include foreign flow goods and services, financial assets and geopolitical events. South Africa's mining sector was the second most important industry in the 1970s and 1980s, with more than 20 percent contribution to the Gross Domestic Product (GDP). Meanwhile, the sector currently accounts for single digit figure to the economy. The 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 been growing at rates of about 4 percent between 2000 and 2010 as well as at rates of below 2 percent, on average, since then. According to government Communication and Information System (GCIS), South Africa is known for its abundance of mineral resources and is estimated to have the world's fifth largest mining sector, while its companies are major players in the global industry.

Conventional macroeconomic models distinguish between alternative "anchors" to stabilise the cyclical behavior of economic activity. Macroeconomics literature further highlights the importance of the different shocks, that include the demand and supply side shocks, market rigidities as well as investor and consumer sentiments, 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) and 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. For instance, whereas monetary and fiscal policies are typical demand side management anchors, fiscal policy can also be a supply side management anchor, while the changes in indicators, such as consumer and geopolitical risk, technological advancement, privatisation and deregulation, also demonstrate this demand and supply side disturbances to the economy. Consequently, Diebold and Rudebusch (1970) and Romer (1993) 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.

The short term, or transitory, economic fluctuations emanate from changes in monetary, financial and fiscal policies as well as consumer and geopolitical risk, according to Blanchard et al. (1986), Shapiro (1987), Blanchard and Quah (1988), Shapiro and Watson (1988), Quah (1988) and Gali (1992). 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 and structural changes are primarily driven by supply side factors, such as technological advancements, labor productivity and availability of resources. Demand side and supply side economic management paradigm suggest the need to decompose the macroecomomic indicators into their transitory and permanent components. A detailed literature on the isolation of macroeconomic 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 approaches.

This paper analyses the causality *nexus* between the minerals industry and selected macroeconomic indicators in South Africa. This is achieved by augmenting a Taylor (1993) rule type central bank monetary policy reaction function with selected macroeconomic indicators and comparing the causality *nexus* between the minerals industry and these macroeconomic indicators. Understanding the causality *nexus* between the minerals industry and these macroeconomic indicators is important to mining authorities and policymakers alike. The observed trend break, as well as the protracted underperformance, of the minerals industry relative to the total economy since the 1970s could be a problem of structural misalignmentsnd not the fluctuations in economic indicators, as discussed. For instance, the comovement, or divergence, in the fluctuations of different economic sectors and industries, as with the minerals industry, could be because they behave differently to the common endogenous and exogenous shocks. As opposed to the macroeconomics literature, according to the European Central Bank (ECB) (2012) and Morgan Stanley Capital International (MSCI) (2014), 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.

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

Data

This paper analyses the causality *nexus* between the minerals industry and selected macroeconomic indicators. The variables comprise mining and quarrying and total output, inflation rate, monetary policy interest rate, government expenditure, Commodity prices, Foreign exchange rate, Foreign direct investment, Business confidence, Market uncertainty, External demand and geopolitical risk. Mining and quarrying output is Gross Value Added (GVA) of the minerals industry. Total output is Gross

Value Added (GVA) of x economy wide, output. Inflation rate, or annual change in Consumer Price Index (CPI), is the headline consumer price inflation. Monetary policy interest rate is the short term central bank interest rate, or repurchase rate, and is the rate at which private sector banks borrow from the central bank. Government expenditure is general government spending that includes government consumption, investment and transfer payments. Commodity prices is the All Commodity Price Index, which includes the prices of energy, metals and minerals, agriculture and other commodities. Foreign exchange rate is the South African rand to U.S. dollar spot exchange rate. Foreign direct investment is the value of cross border direct investment transactions received during a given period of time.

Business confidence is the OECD harmonised Business Confidence Index (BCI) and is based on opinion surveys on developments in production, new orders and stocks, or inventory, of goods in the manufacturing sector. Market uncertainty index is the Chicago Board Options Exchange's (CBOE's) measure of stock market volatility, or uncertainty, based on S&P 500 options, often called the fear index. External demand is OECD industrial production, or the overall state of willingness and ability to purchase goods and services across the world. Geopolitical risk is the potential instability and disruption emanating from a nation's involvement in international affairs. Data on total, or economy wide, output and mining and quarrying output and inflation rate was sourced from Statistics South Africa. Data on monetary policy interest rate, government expenditure, foreign exchange rate as well as foreign direct investment was sourced from the South African Reserve Bank. Data on commodity prices was sourced from World Bank (WB) Commodity Price Data, or the Pink Sheet, data on business confidence and External demand was sourced from OECD Data Explorer, data on market uncertainty was sourced from Chicago Board Options Exchange (CBOE), while data on geopolitical risk index, an index of risk constructed by Caldara and Iacoviello (2022), was sourced from matteoiacoviello.com.

The descriptions and denotations of the variables are presented in Table 1. Mining and quarrying output is denoted $GVAMng$ total, or economy wide, output, is denoted $GVAAll$, inflation rate, is denoted $CPIRate$, central bank monetary policy interest rate is denoted $CBRate$, government expenditure is denoted $GOVExp$, commodity prices is denoted $COMPrice$, foreign exchange rate is denoted $FXRate$, foreign direct investment is denoted $FDInv$, business confidence is denoted $BCISA$, market uncertainty is denoted $VIXAll$, external demand is denoted $PDNWld$ and $GPRIdx$ denotes geopolitical risk. The evolution of the variables are depicted in Figure 1. Output of mining and quarrying was range bound between 2000 and 2002, increased between 2003 and 2007, where it reached a peak, and decreased significantly in 2008 and 2009. The decrease in output of 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 mining and quarrying in 2020 was connected to COVID 19 pandemic, while it generally decreased during the sample period.

The movements in output of mining and quarrying were closely mirrored by the movements in total, or economy wide, output, albeit, total, or economy wide, output was generally on an upward trend during the sample period. Although it was also affected by the onset of the Global financial crisis in late 2008 and the COVID-19 pandemic in early 2020, total, or economy wide, output was on upward trend during the sample period between 2000 and 2023, contrary to output of the minerals industry. The central bank monetary policy interest rate, which is the rate at which private sector banks borrow from the central bank, was relatively unchanged from 2000 to mid 2001, from where it decreased and bottomed out at the end of 2001. The interest rate increased from early 2002 and peaked in early 2003 before decreasing notably and bottoming out in mid 2006. However, the interest rate was generally in a downward trend between 2000 and 2023 with notable spikes and peaks in 2003, 2008, 2016 and 2023, while the opposite is true in 2005, 2013 as well as in 2021. The central bank interest rate increased substantially in 2003, 2008, 2016 and 2023 to counteract the rising consumer price inflation pressure in the same period, while it decreased in 2005, 2013 and 2021 to support the economic conditions.

Government expenditure, or the Fiscal policy stance, maintained an upward trend between 2000 and 2023, or throughout the sample period. Although it was increasing since 2000, government expenditure accelerated notably from around 2008 and peaked in 2023, where its fluctuations were subtle indicating a stable and consistent increase throughout the sample period. Commodity prices maintained an upward trend, on average, between 2000 and 2023, albeit volatile. Although commodity prices were increasing since 2000, they accelerated notably from 2002, peaking in 2008. The decrease in 2009 was followed by another significant increase in 2010 and 2011 they subseqently decreased, on average, from 2012 and bottomed out in 2016 and 2020. Another increase was realised from 2021 with a peak in 2022, before they decreased again in 2023. Business confidence maintained an upward trend, on

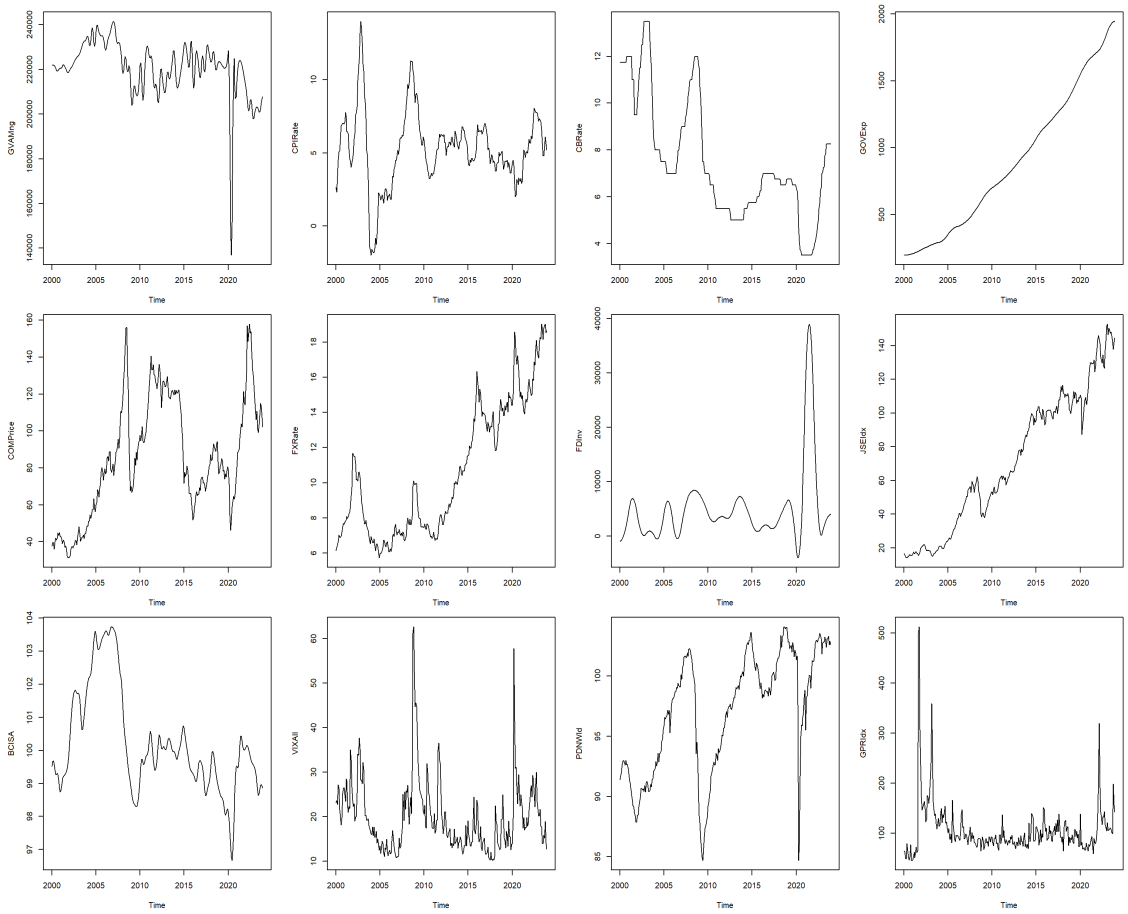
Variable	Denotation	Description
Mining output	GVAMng	Gross Value Added (GVA) of the mining and quarrying, or minerals, industry
Inflation rate	CPIRate	Inflation rate, or annual Consumer Price Index (CPI), is the annual headline consumer price inflation
Interest rate	CBRate	Central bank policy rate and is the rate at which private sector banks borrow from the central bank
Government expenditure	GOVExp	Government spending, or expenditure, includes government consumption, investment and transfer payments
Commodity prices	COMPrice	All Commodity Price Index, includes energy, metals and minerals, agriculture and prices of other commodities
Foreign exchange rate	FXRate	South African rand (ZAR) to U.S. dollar (USD) spot exchange rate
Direct investment	FDInv	Value of cross border direct investment transactions received by South Africa, or the reporting country
Financial market	JSEIdx	South African multi asset class stock exchange that offers listings, clearing, settlement as well as issuer services
Business confidence	BCISA	OECD harmonised Business Confidence Index (BCI) based on opinion surveys in the manufacturing sector
Market uncertainty	VIXAll	Chicago Board Options Exchange's (CBOE's) stock market volatility index based on the S&P 500 index
External demand	PDNWld	OECD industrial production, or the willingness and ability to purchase goods and services across the world.
Geopolitical risk	GPRIdx	Economic, political and social instability and disruption due to a nation's involvement in international affairs

Notes: Data sourced from Statistics South Africa, South African Reserve Bank, the World Bank, Chicago Board Options Exchange (CBOE), Organisation for Economic Co-operation and Development (OECD) Data Explorer and matteoiacoviello.com. Total, or economy wide, output, is denoted $GVAAll$, minerals industry output is denoted $GVAMng$, inflation rate, is denoted $CPIRate$, monetary policy interest rate is denoted $CBRate$, government expenditure, or the fiscal policy stance, is denoted $GOVExp$, commodity prices is $COMPrice$, foreign exchange rate is denoted $FXRate$, foreign direct investment is denoted $FDInv$, financial market is denoted $JSEIdx$, business confidence is denoted $BCISA$, market uncertainty is denoted $VIXAll$, external demand is denoted $PDNWld$ and $GPRIdx$ denotes geopolitical risk.

Table 1: Description of variables

average, between 2000 and 2006, albeit volatile. Although it decreased in 2000 and 2001, business confidence accelerated notably from 2002, peaking in 2006 before it decreased sharply between 2007 and 2009, followed by another increase and a peak in 2010. it subsequently decreased consistently, on average, from 2011 to 2018 before it decreased sharply and bottomed out in 2020. Another increase was realised from 2021 with a peak in 2022, before business confidence decelerated again in 2023.

Foreign exchange rate maintained an upward trend, on average, between 2000 and 2023, or throughout the sample period, albeit volatile. It 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 between 2012 and 2023, peaking in 2016 and 2020 as well as in 2023. Foreign direct investment inflows increased from 2000 and peaked in 2001, following which the indicator decreased and bottomed out in 2004. Foreign direct investment inflows increased again from 2005 and reached a peak in 2008. This was followed by a decrease between 2009 and 2012, where another peak in foreign direct investment inflows was realised in 2013. The inflows were low between 2014 and 2020, the indicator bottomed out in 2015 before recovering slowly between 2016 and 2020, while they increased substatially in 2021 and peaked before falling back to the long term avarage in 2022 and 2023. The financial market index remained muted from 2000, peaking in 2002, while it accelerated sharply between 2003 and 2008. The increase witnessed from 2003 was sustained until the indicator reached a peak in 2008. The index decreased significantly in 2009 and bottomed out in the same period, while it accelerated consistently between 2010 and 2023, peaked out in 2018, bottomed out in 2020 as well as reached another peak in 2023.



Notes: Data sourced from Statistics South Africa, South African Reserve Bank, the World Bank, Chicago Board Options Exchange (CBOE), Organisation for Economic Co-operation and Development (OECD) Data Explorer and matteoiacoviello.com. Total, or economy wide, output, is denoted $GVAAll$, output of mining and quarrying is denoted $GVAMng$, central bank monetary policy interest rate is denoted $CBRate$, government expenditure, or the fiscal policy stance, is denoted $GOVExp$, commodity prices is $COMPrice$, foreign exchange rate is denoted $FXRate$, foreign direct investment is denoted $FDInv$, financial market is denoted $JSEIdx$, business confidence index is denoted $BCISA$, market uncertainty is denoted $VIXAll$, external demand conditions is denoted $PDNWld$ and $GPRIdx$ denotes geopolitical risk.

Figure 1: Plots of the variables

Market uncertainty was somewhat elevated from 2001, peaking in 2003, while it accelerated sharply between 2007 and 2009. Market uncertainty then remained relatively elevated between 2010 and 2012, while it subsequently decreased until 2019, albeit a brief increase in 2016. Another sharp acceleration in market uncertainty was realised in 2020, while it increased in 2020. The market uncertainty index was muted between 2004 and 2006, from 2013 to 2015 and from 2018 and 2019 as well as in 2023. External demand, which is the Organisation for Economic Cooperation and Development (OECD) industrial production, decreased in 2000 and bottomed out in 2001, increased again from 2002 and peaked in 2007, decelerated sharply in 2008 and bottomed out in 2009. It decreased significantly from 2019 and bottomed out in 2020. The indicator quickly recovered and increased steeply peaking in 2022, where it remained range bound until 2023. Geopolitical risk was low between 2000 and late 2001. The indicator accelerated significantly, peaking in late 2001, decreased and bottomed out around mid 2002, increased from mid 2002, peaked in early 2003 and subsequently decreased and bottomed out mid 2005, where it remained low and somewhat range bound between from mid 2005 and early 2020. Geopolitical risk decreased slightly between early 2020 and mid 2021, where it spiked and peaked in early 2022, while it decreased and bottomed out in mid 2023, before it accelerated again peaking out in late 2023.

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 *developments* in geopolitical risk over the economic cycle.

Methodology

A Vector Autoregression (VAR) model is estimated to analyse the causality *nexus* between the minerals industry and selected macroeconomic indicators. Examination of the Impulse Response Functions (IRFs) from a Vector Autoregression (VAR) model are analysed understand the reaction of the minerals industry and geopolitical risk. 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 are used as the regression predictors for all variable in the system.

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 the surprise movements, after taking into account the past values of the Vector Autoregression (VAR) model.

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 recent contributions include Lütkepohl (2005), Koop and Korobilis (2010) and 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, $p\left(\theta_i \mid Y_t, M_i\right)$ is the posterior model probability, $p\left(Y_t \mid \theta_i, M_i\right)$ is the marginal likelihood of the model, $p\left(\theta_i \mid M_i\right)$ is the prior model probability and $p\left(Y_t \mid M_i\right)$ 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 negligible disadvantageous influence on the inference of the parameters of the model.

Results

Bayesian Vector Autoregression (BVAR) model was estimated to capture the causality *nexus* between the minerals industry and selected macroeconomic indicators, as discussed. The estimated Bayesian Vector Autoregression (BVAR) specifies a Litterman (1979) and Sims (1989) proposed Minnesota prior and uses a Gibbs style sampler following Stock and Watson (2001) and O'Hara (2015). A 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, as discussed in Giannone et al. (2015). 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, as an alternative to drawing samples from a 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 consumer, business and investor sentiments. A Taylor (1993) rule type central bank monetary policy reaction function with the output of mining and quarrying industry is, thus, augmented with geopolitical risk as follows

$$i_t = \rho + \theta_\pi(\pi_t - \pi_t^*) + \theta_Y(Y_t - \bar{Y_t}) + \theta_M(M_t - \bar{M_t}) + \epsilon_t \tag{5}$$

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, M_t denotes the macroeconomic indicators, while $\bar{M_t}$ is the natural rate of the macroeconomic indicators. θ_π, θ_Y and θ_M 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 the macroeconomic indicators from their natural rates, respectively. ϵ_t is the error, or disturbance, term and the subscript t denotes the time period. As discussed above, the macroeconomic indicators include government expenditure, or the fiscal policy stance, commodity prices, foreign exchange rate, foreign direct investment, business confidence, market uncertainty, external demand and geopolitical risk.

The central bank monetary policy reaction function captures the process through which monetary policy decisions affect consumer price inflation in particular and the aggregate economy in general.

The specified central bank monetary policy reaction function ensures market clearing condition, in that when output equals its steady state level, inflation is the same as its target rate and the macroeconomic indicators equal their steady state levels, 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 macroeconomic indicators, denoted $MACInd_t$. Y_t in Equation 1 can, therefore, be rewritten as

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

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 changes the equations, coefficients and the residuals of the Vector Autoregression (VAR).

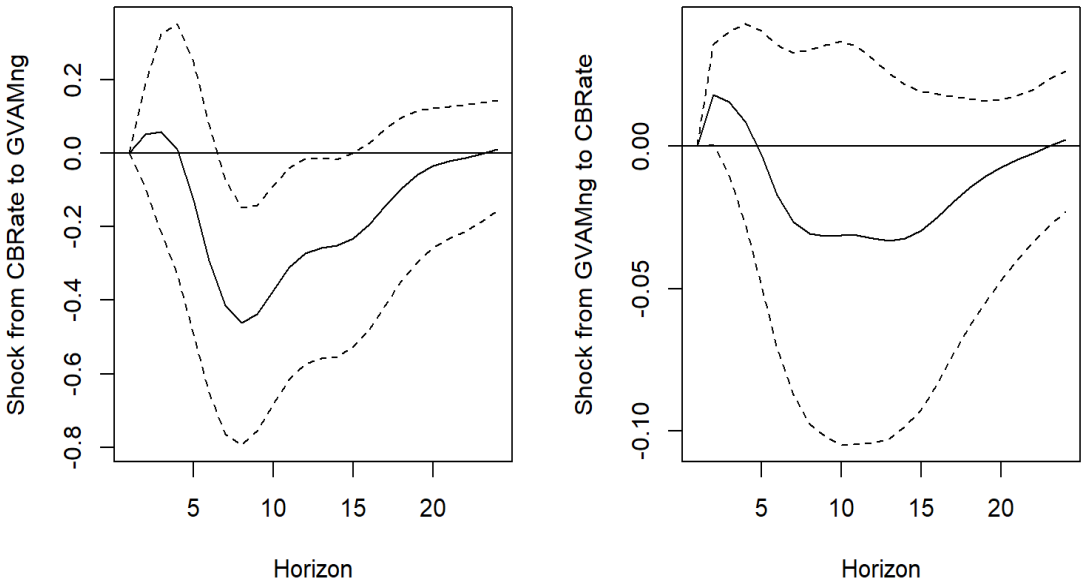
According to Stock and Watson (2001), the standard practice in Vector Autoregression (VAR) model analysis is to report the results from Impulse Response Functions (IRFs) and Forecast Error Variance Decompositions (FEVDs). The reason is that these statistics are more informative than the estimated Vector 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 all other variables 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 aim is to analyse the reaction of the minerals industry output to the developments in geopolitical risk.

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.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in the central bank monetary policy interest rate, vice versa, are depicted in Figure 2, together with their 95 percent confidence intervals, or bands. According to the results, following an unexpected, or surprise, 1 percentage point increase in monetary policy interest rate, minerals industry output initially increases slightly and peaks at 0.06 percent after 3 months, followed by a decrease where mining and quarrying output bottoms out at -0.47 percentage points after 8 months. The effect of the surprise increase in monetary policy interest rate is only statistically significant between 6 months and 15 months, following which mining and quarrying output gradually tends towards its equillibrium, or steady state, level. Following an unexpected, or surprise, 1 percentage point increase in mining and quarrying output, monetary policy interest rate initially increases slightly and peaks at 0.02 percent after 2 months, followed by a decrease where minerals industry output bottoms out at -0.03 percentage points after 13 months, following which monetary policy interest rate tends towards its equillibrium, or steady state, level. The impact of a surprise increase in monetary policy interest rate is scarcely statistically significant up to 2 months.

The results show a weak two way causality between output of mining and quarrying and monetary policy interest rate, where the direction of causality from monetary policy interest rate to output of mining and quarrying industry dominates. A well documented phenomenon, according to Bernanke and Gertler (1995), Svensson (1997), Christiano et al. (1999), Clarida et al. (1999), Clarida et al.

(2000), Christiano et al. (2005), Woodford and Walsh (2005), Walsh (2010) and Svensson (2010), is that central banks understand how their actions impact the economy and make informed decisions about how to achieve their goals of price stability and economic growth. According to Bernanke and Mishkin (2007), Svensson and Woodford (2004), Woodford (2007) and Adrian (2018), monetary policy forecast targeting, which is a framework where central banks use future economic projections to guide their monetary policy decisions suggests causation, or a direct influence where one event, the cause, directly results in another event, the effect, monetary policy decision making. The results are, thus, consistent with inflation forecast targeting, where current monetary policy actions are expected to influence future economic variables, such that the monetary authorities place a greater emphasis on the future path of inflation and total, or economy wide, output, hence on minerals industry output.



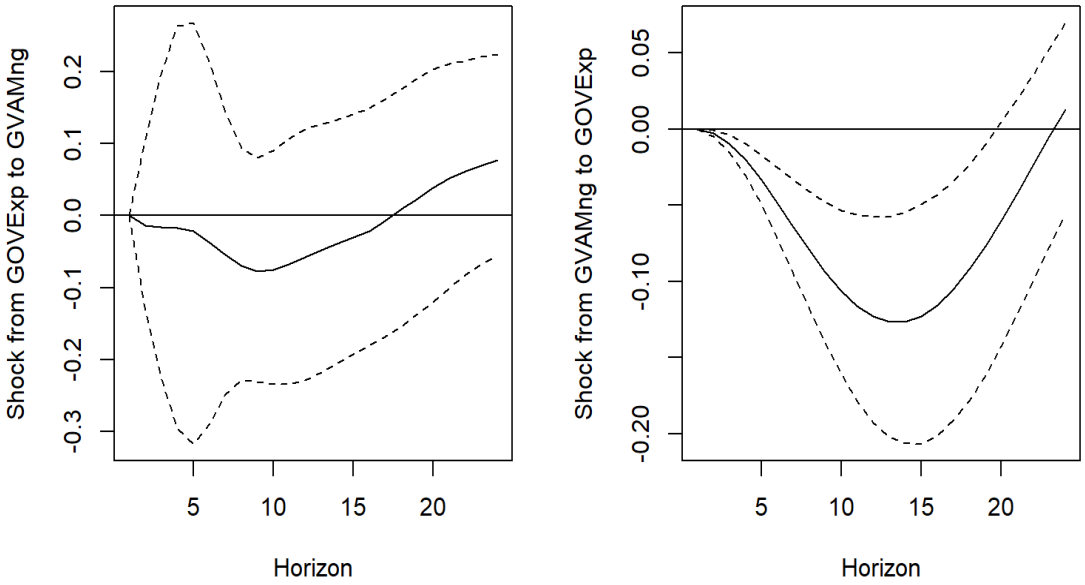
Notes: Data sourced from Statistics South Africa, South African Reserve Bank. Mining and quarrying output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI and $CBRate$ denotes central bank monetary policy interest rate. The x axis depicts the horizon of the Impulse Response Functions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

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

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in government expenditure, or the fiscal policy stance, vice versa, are depicted in Figure 3, together with their 95 percent confidence intervals, or bands. According to the results, following an unexpected 1 percentage point increase in government expenditure, output of the minerals industry decreases slightly and bottoms out at -0.08 percentage points after 9 months, followed by a stable increase, and gradually tendency towards equilibrium, or steady state, level after 17 periods. The effect of the surprise increase in government spending on output of the mining industry is statistically insignificant in all periods. Following an unexpected, or surprise, 1 percentage point increase in output of the minerals industry, government expenditure initially decreases and bottoms out at -0.13 percentage points after 13 months, subsequently recovers and increases after 23 months before it progressively progressively, tends towards and fluctuates around, its equilibrium, or steady state, level. The effect of the unexpected, or surprise, increase in output of the minerals industry on government expenditure becomes statistically significant immediately, while it remains statistically significant up to 19 months, consistent with the countercyclical fiscal policy.

The results show a unidirectional causality between output of mining and quarrying and government expenditure, where the direction of causality is predominantly from Government expenditure to output of mining and quarrying industry dominates. The reaction of the minerals industry output to fiscal policy developments, though statistically insignificant, as well as the reaction of fiscal policy developments to the minerals industry output show evidence of a countercyclical government spending. Keynesian economics hypothesise that, higher government spending or lower taxes during a recession may help economic recovery, according to Christiano et al. (1999), Abel and Bernanke (2001), Atkin-

son and Hamilton (2003) and Christiano et al. (2011). In this manner, fiscal policy is referred to as countercyclical, such that discretionary spending cuts and tax increases during economic booms are compensated for by government spending increases and tax cuts during recessions, while the opposite policy stance by government is refereed to as Procyclical. Blanchard and Perotti (2002), Hemming et al. (2002) and Woodford (2011) argue that the multipliers for spending and tax shocks are typically small, while they also present evidence that positive government spending shocks have a positive effect on output, implying procyclical fiscal policy, whereas the positive tax shocks have a negative effect.



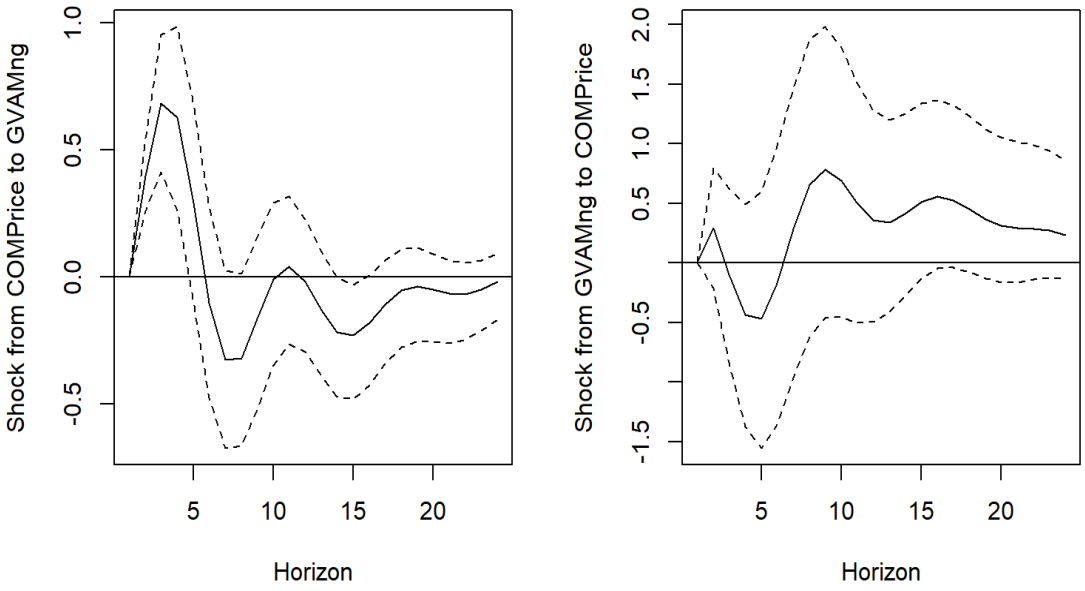
Notes: Data sourced from Statistics South Africa, South African Reserve Bank and the World Bank. Mining and quarrying output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $GOVExp$ denotes government expenditure. 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

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in commodity prices, vice versa, are depicted in Figure 4, together with their 95 percent confidence intervals, or bands. Following an unexpected 1 percentage point increase in commodity prices, output of the minerals industry initially increases and peaks at 0.69 percentage points after 3 months, followed by the decrease and where output of the minerals industry bottoms out at -0.33 percentage points after 7 months, subsequently followed by a stable fluctuation and gradual increase of output of the minerals industry towards its equilibrium, or steady state, level after 24 months. The effect of a surprise increase in commodity prices on output of mining and quarrying is statistically significant up to 5 months. Following an unexpected, or surprise, 1 percentage point increase in output of the minerals industry, commodity prices initially increase slightly and then decrease and bottom out at -0.47 percentage points after 5 months, subsequently recover and peak at 0.76 percentage points after 9 months before it progressively, tends towards and fluctuates around, its equilibrium, or steady state, level. The effect of the unexpected increase in output of mining and quarrying on commodity prices is, however, statistically insignificant in all periods.

The results show a weak one way causality between output of mining and quarrying and commodity prices, where the direction of causality from commodity prices to output of mining and quarrying dominates. The boom and bust cycles in prices of commodities, as discussed, have had important implications for global macroeconomics fluctuations, affecting everything from the goods and services markets to financial markets, as evidenced in Labys et al. (1999), Labys and Maizels (1993), Frankel (2008) and Blanchard and Gali (2007). The results are consistent with the hypothesis that the prices of Commodities and economic growth co move in the short run, while large and persistent long run movements in commodity prices exhibit no such large persistent changes in economic growth, particularly in most resource rich countries. Economies, particularly those that are abundantly endowed with natural resources and hence are dependent on commodity exports, have a long history of volatile and

disruptive economic cycles, as summarised in Auty (2002), Frankel (2010), Frankel (2012) and Jacks (2013). The results have also shown that the minerals industry lacks the market share to influence the market price of commodities and hence it must accept prevailing prices in commodities markets.

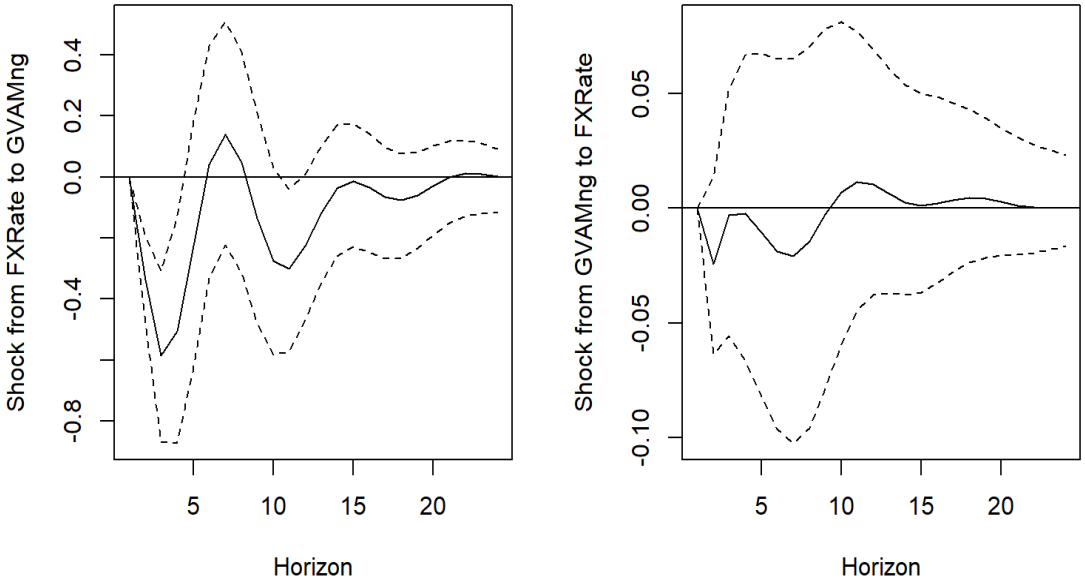


Notes: Data sourced from Statistics South Africa, South African Reserve Bank and the World Bank. Mining and quarrying output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $COMPrice$ denotes commodity prices. The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

Figure 4: Impulse Response Functions (IRFs) with shocks from output of the minerals industry

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in foreign exchange rate, vice versa, are depicted in Figure 5, together with their 95 percent confidence intervals, or bands. 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, followed by an increase and peak at 0.13 percentage points after 7 months, a decrease and subsequent fluctuation and gradual increase 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. 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, followed by another decrease where foreign exchange rate bottoms out at -0.02 after 7 months, subsequently recovers and peaks at 0.01 percentage points after 11 months before it progressively tends towards, its equilibrium level. The effect of the unexpected increase in mining and quarrying industry output on foreign exchange rate is statistically insignificant in all time periods.

The results show a unidirectional causality between output of mining and quarrying and foreign exchange rate, where the direction of causality from foreign exchange rate to output of mining and quarrying industry dominates, which is consistent with a relatively insignificant output of the minerals industry in global context. 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 and Rogoff (1996) and Obstfeld (2001). The empirical results are, however, consistent with the Dominant Currency Pricing (DCP) that the dollar appreciation against emerging market currencies predicts a decline in the volume of trade between these countries, as discussed in Goldberg and Tille (2008), Gopinath (2015), Devereux et al. (2017), citeGopinathStein2021, Gopinath et al. (2022). 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.



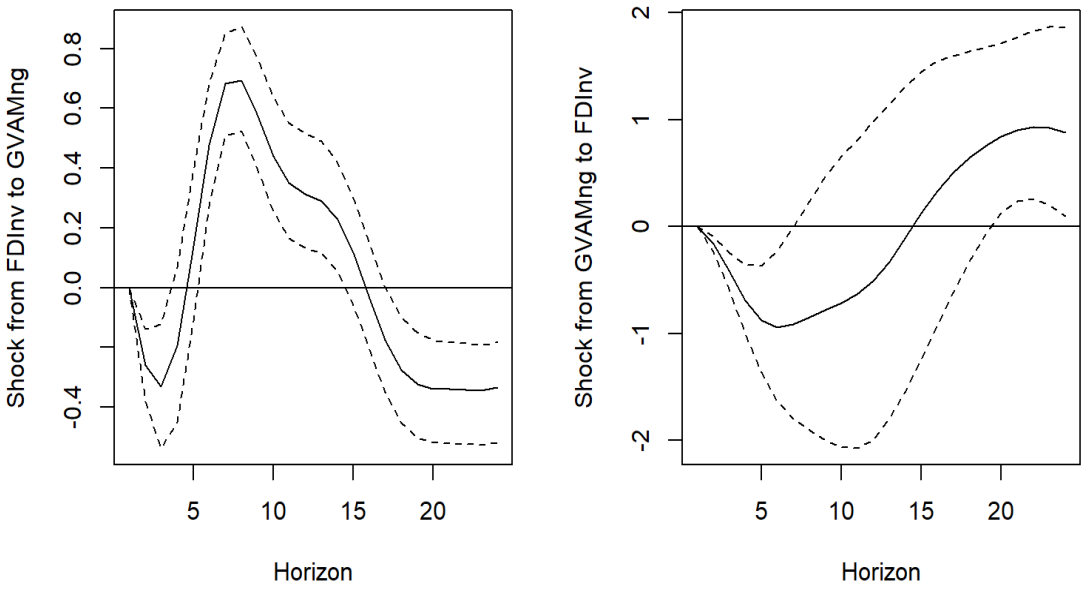
Notes: Data sourced from Statistics South Africa, South African Reserve Bank and the World Bank. Mining and quarrying output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $FXRate$ denotes foreign exchange rate.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

Figure 5: Impulse Response Functions (IRFs) with shocks from output of the minerals industry

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in foreign direct investment, vice versa, are depicted in Figure 6, together with their 95 percent confidence intervals, or bands. Following an unexpected, or surprise, 1 percentage point increase in foreign direct investment, output of the minerals industry decreases and bottoms out at -0.33 percentage points after 3 months, followed by an increase and peak out at 0.70 percentage points after 8 months, followed by another decrease and bottom out at -0.34 percentage points after 23 months, before a subsequent fluctuation and gradual move towards its equilibrium level. The effect of the surprise increase in foreign direct investment is statistically significant between 2 and 3 months, 6 and 14 months as well as from 18 months onwards. Following an unexpected 1 percentage point increase in output of the minerals industry, foreign direct investment decreases and bottoms out at -0.94 percentage points after 6 months, followed by a sustained increase and a peak at 0.93 percentage points after 22 months, before it fluctuates and progressively tends towards, its steady state level. The effect a surprise increase in output of the minerals industry on foreign direct investment is statistically significant up to 8 months and from 20 months onwards.

The results show a bidirectional, or two way, causality between output of mining and quarrying and foreign direct investment, where the direction of causality from foreign direct investment to output of the minerals industry dominates. Foreign direct investment inflows, as discussed, are cross border direct investment transactions, according to the Organisation for Economic Cooperation and Development (OECD) (2025). International Monetary Fund (IMF) (1994) and European Central Bank (ECB) (2016) advocate the free flow of capital across borders given that it allows such investment flows to seek the highest returns, while they contribute to fixed capital formation and economic growth. Bosworth et al. (1999), Feldstein (2000) and Loungani and Razin (2001) contend that, the resilience of foreign direct investment during financial crises has lead many emerging and developing countries to consider them as the private capital inflow of preference. According to Bacchetta (2000), Calvo and Mendoza (2000), Claessens (2000) and Cavallo (2019), countries have liberalised their policies to establish a hospitable regulatory framework for foreign direct investment by relaxing the regulations on market entry and foreign ownership, harmonising governance structures and promoting well functioning of markets.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in the financial market, vice versa, are depicted in Figure 7, together with their 95 percent confidence intervals, or bands. According to the results, following an unexpected, or surprise, 1 percentage point increase in the financial market, output of



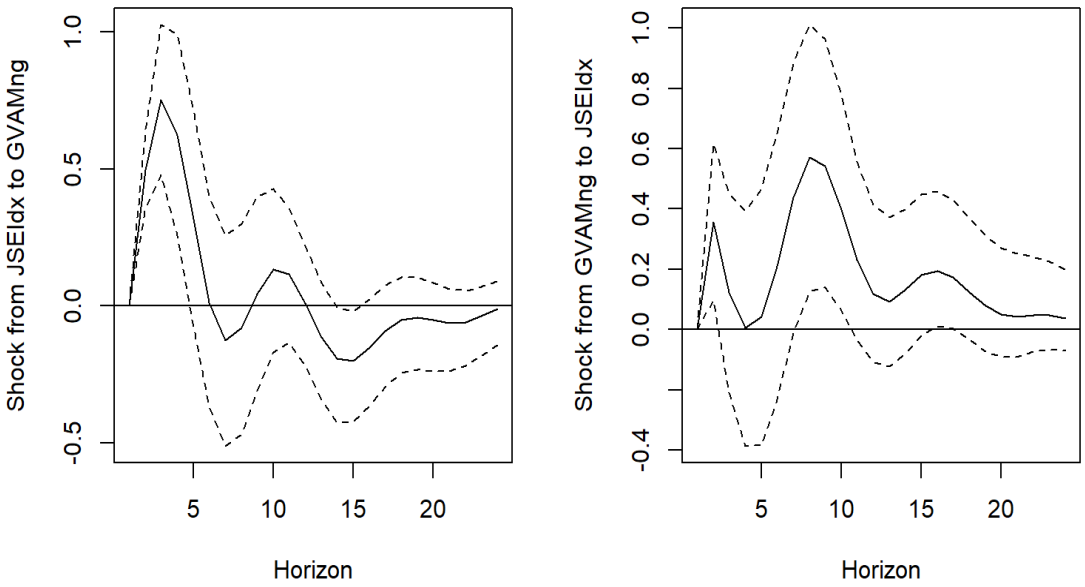
Notes: Data sourced from Statistics South Africa, South African Reserve Bank and the World Bank. Mining and quarrying output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $FDInv$ denotes foreign direct investment.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

Figure 6: Impulse Response Functions (IRFs) with shocks from output of the minerals industry

the minerals industry increases and peaks out at 0.76 percentage points after 3 months, followed by a decrease and bottoming out at -0.19 percentage points after 15 months, followed an increase, subsequent fluctuation and gradual movement towards its equilibrium, or steady state, level after 23 months. The effect of an unexpected increase in the financial market is statistically significant up to 5 months. Following a surprise 1 percentage point increase in output of the minerals industry, the financial market initially increase slightly and peaks at 0.36 percentage points after 2 months, followed by a slowdown and another increase and a peak at 0.57 percentage points after 8 months, subsequently decreases and progressively tends towards its steady state level. The effect of unexpected increase in minerals industry output is statistically significant up to 2 months and between 8 and 10 months.

The results show a moderate bidirectional causality between output of mining and quarrying and the financial market, where the direction of causality from the financial market to output of mining and quarrying industry is more pronounced. Evidence strongly supports the view that a well functioning and effectively regulated financial market, which according to Hayes (2024) generally refers to a market where securities trading occurs, including the stock market, bond market, foreign exchange market and derivatives market, boosts, or at least precedes, economic growth. According to Grossman and Miller (1988) and Levine (1996), well functioning and regulated financial markets foster business and economic confidence, hence they support consumption and investment decisions by economic agents, which drives economic growth and, ceteris paribus, on output of the minerals industry, as also discussed in Levine (1996), Miller (1998) as well as Levine and Zervos (1998). According to Hall (2024), as the financial market rises and falls, so too, does economic sentiment hence consumption and investment decisions by economic agents, which drives economic growth, while Goldsmith (1959) and Gurley and Shaw (1967) also discuss the existence of a causal relationship from economic growth to the financial markets.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in business confidence, vice versa, are depicted in Figure 8, together with their 95 percent confidence intervals, or bands. Following an unexpected 1 percentage point increase in business confidence, output of the minerals industry initially increases and peaks at 0.59 percentage points after 5 months, followed by the decrease and bottoming out at -0.03 percentage points after 17 months, followed by a stable fluctuation and gradual increase of output of the minerals industry towards its equilibrium, or steady state, level after 24 months. The effect of an unexpected, or surprise, increase in business confidence on mining and quarrying output is statistically significant up to 7 months. Following a surprise 1 percentage point increase in output of the minerals



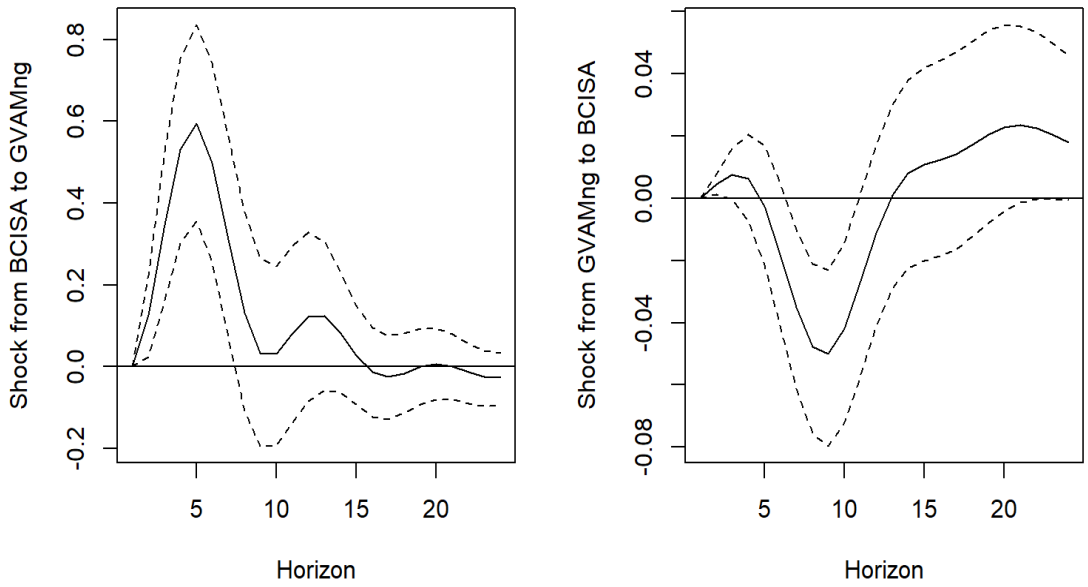
Notes: Data sourced from Statistics South Africa, South African Reserve Bank and the World Bank. Mining and quarrying output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $JSEIdx$ denotes the financial market. The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

Figure 7: Impulse Response Functions (IRFs) with shocks from output of the minerals industry

industry, business confidence initially increase slightly and then decrease rapidly, bottoming out at -0.05 percentage points after 9 months, subsequently recovers and peaks at 0.02 percentage points after 20 months before it progressively, tends towards and fluctuates around its equilibrium level. The effect of the surprise increase in output of the minerals industry on thre indicator of business confidence is, however, only statistically significant between 1 and 2 months as well as between 7 and 10 months.

The results show a bidirectional causality between output of mining and quarrying and business confidence, where the direction of causality from business confidence to output of mining and quarrying industry, vice versa, tend to have a balanced effect. Changes in business confidence have important implications for macroeconomics fluctuations, affecting the economic agents' decision making on investment, employment and business expansion plans. Such decision making is premised on rational expectations hypothesis, first introduced by Muth (1961) and developed by Lucas (1972) and Sargent and Wallace (1976), adaptive expectations hypothesis, introduced by Fisher (1911) and discussed in Cagan (1956), Friedman (1957) and Mishkin (2021) and self fulfilling animal spirits hypothesis, first introduced by Keynes (1936) and discussed in Farmer (1999, 2012, 2013) and Blanchard et al. (2013). In particular, the Rational Expectations Theory (RET) hypothesises that economic agents, such as consumers and businesses, make decisions based on all available information, past experiences and rational thinking in forward looking manner without making systematic errors. Business confidence, according to Blanchard et al. (2013), is important to comprehend current and future economic performance.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in market uncertainty, vice versa, are depicted in Figure 9, together with their 95 percent confidence intervals, or bands. Following an unexpected, or surprise, 1 percentage point increase in market uncertainty, output of the minerals industry decreases and bottoms out at -0.96 percentage points after 3 months, followed by an increase where output of the minerals industry peaks out at 0.37 percentage points after 8 months, followed a decrease and subsequent fluctuation and gradual movement of output of the minerals industry towards its equilibrium, or steady state, level after 18 months. The effect of an unexpected, or surprise, increase in market uncertainty is statistically significant up to 5 months. Following an unexpected 1 percentage point increase in output of the minerals industry, market uncertainty index initially decrease and bottoms out at -0.30 percentage points after 2 months, followed by a sustained increase where market uncertainty index fluctuates and steadily tends towards, its equilibrium, or steady state, level. The effect of the increase in output of mining and quarrying is statistically significant up to 2 months.



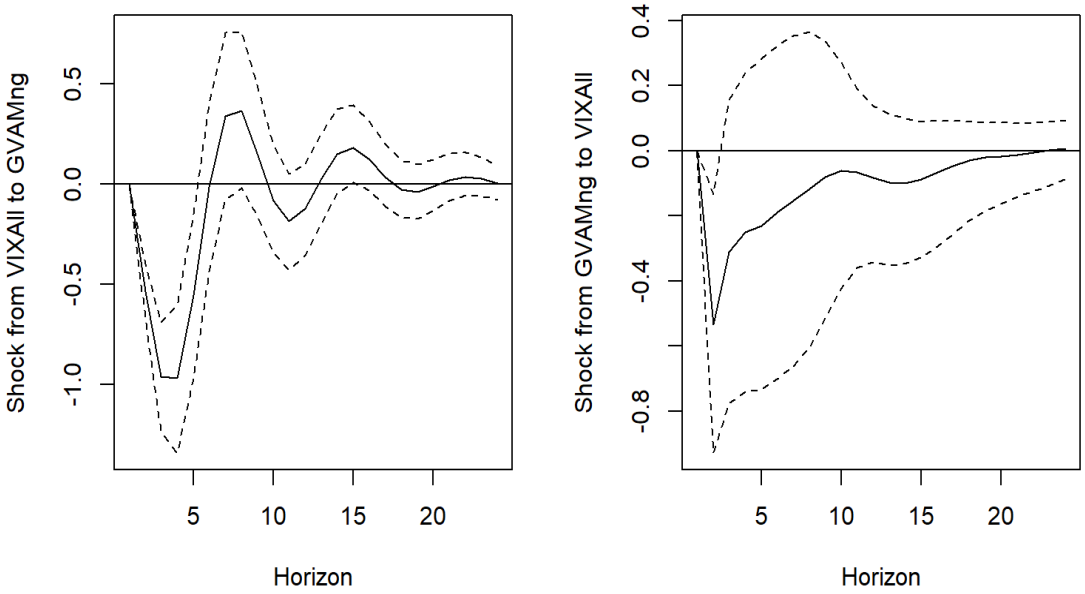
Notes: Data sourced from Statistics South Africa, South African Reserve Bank and the World Bank. Mining and quarrying output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $BCISA$ denotes business confidence. The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

Figure 8: Impulse Response Functions (IRFs) with shocks from output of the minerals industry

The results show indicates a weak bidirectional causality between output of mining and quarrying and market uncertainty, where the direction of causality from market uncertainty to output of mining and quarrying industry is more significant. Market uncertainty, a phenomenon where economic agents cannot contemplate the possible states of events, or characterise their probability distributions, and their outcomes until further information becomes available, has direct implications for economic activity, affecting business investment and household consumption decisions, according to Gilchrist et al. (2014), Kose and Terrones (2015), Bobasu et al. (2020) as well as Gieseck and Rujin (2020). According to Gieseck and Rujin (2020), the theoretical transmission mechanisms, or channels, on the effects of market uncertainty on economic activity include the irreversibility of investment channel, described in Bernanke (1983) and Pindyck (1990), precautionary savings channel, described in Leland (1968), and financial frictions channel, described in Christiano et al. (2014) and Arellano et al. (2019). Market uncertainty about the economy runs contrary to the business cycle, hence, the countercyclical behavior of a cross sectional dispersion of economic variables that reflect fluctuations in market uncertainty.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in external demand conditions, vice versa, are depicted in Figure 10, together with their 95 percent confidence intervals, or bands. Following a surprise, or unexpected, 1 percentage point increase in external demand, output of the minerals industry increases slightly and peaks out at 0.11 percentage points after 2 months, it then decreases bottoming out at -0.67 percentage points after 5 months, followed by an increase and a peak out at 0.23 percentage points after 9 months, subsequently fluctuates and gradually move towards its equilibrium level. The effect of the surprise increase in external demand on mining and quarrying output is only statistically significant between 7 and 10 months. Following an unexpected 1 percentage point increase in output of the minerals industry, external demand increases and peaks out at 0.26 percentage points after 2 months, followed by a rapid decrease where the minerals industry output bottoms out at -0.15 percentage points after 7 months, before it subsequently, fluctuates and gradually moves towards its steady state level. The effect of the increase in output of the minerals industry remains statistically significant for 4 months following which its potency begins to progressively decrease, or dissipate.

The results show a moderate bidirectional, or two way, causality between output of mining and quarrying and external, or foreign, demand conditions, where the direction of causality is from external demand to output of mining and quarrying is balanced. External, or foreign, demand, which refer to the overall state of willingness and ability of consumers, businesses and governments to purchase goods



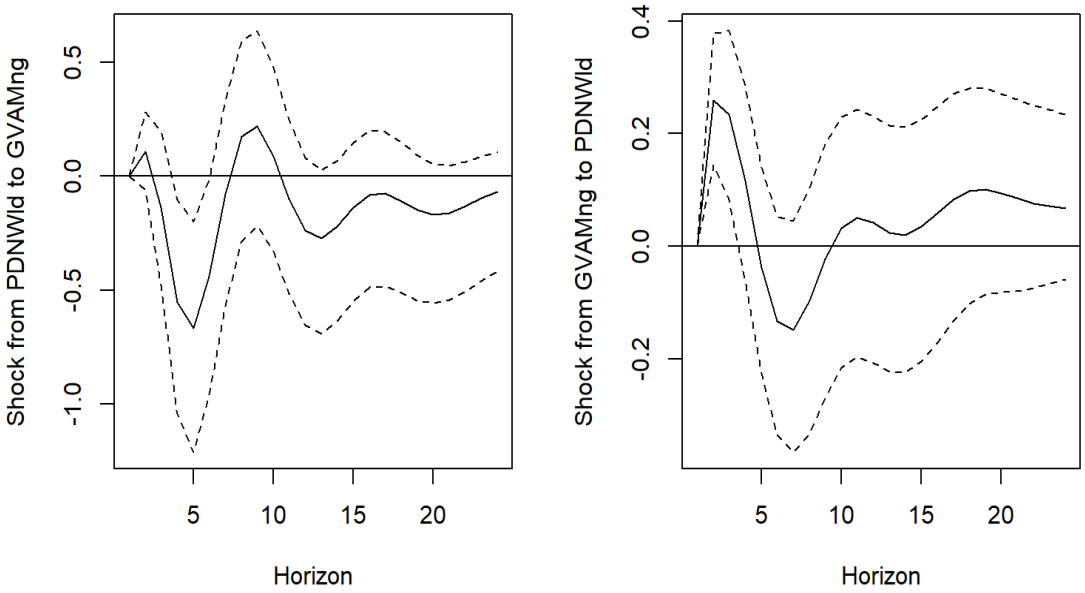
Notes: Data sourced from Statistics South Africa, South African Reserve Bank and the World Bank. Mining and quarrying output is denoted $GVAMng$, consumer price inflation rate, is denoted CPI, central bank monetary policy interest rate, is denoted $CBRate$ and $VIXAll$ denotes market uncertainty. The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

Figure 9: Impulse Response Functions (IRFs) with shocks from output of the minerals industry

and services across the world, play a crucial role in shaping the countries' balance of trade and hence their level of economic growth, according to United Nations Industrial Development Organisation (UNIDO) (2023) and Gill and Kose (2024). Classical theories of international trade, also discussed in Dornbusch (1987), Obstfeld and Rogoff (1996), Uribe and Schmitt-Grohe (2017) and Gill and Kose (2024), in particular, the Heckscher-Ohlin theory, or the factor endowment theory, developed by Eli Heckscher and Bertil Ohlin, postulate that countries should specialise in production and export goods and services that utilize their most abundant factors of production, such as labor, capital, land as well as minerals. Consequently, increased external demand often lead countries towards export orientation strategies, whereas low external demand may encourage reliance on import substitution strategies.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of the minerals industry output to innovations, or shocks, in geopolitical risk, vice versa, are depicted in Figure 11, together with their 95 percent confidence intervals, or bands. According to the results, following a surprise 1 percentage point increase in geopolitical risk, output of the minerals industry initially decreases and bottoms out at -0.35 percentage points after 5 months, followed by some recovery and another decrease and a bottom out at -0.24 percentage points after 13 months, before a stable fluctuation and gradual increase of output of the minerals industry towards its equilibrium level after 23 months. The effect of the unexpected, or surprise, increase in geopolitical risk on output of mining and quarrying is only statistically significant between 12 and 14 months. Following a surprise 1 percentage point increase in output of the minerals industry, geopolitical risk initially increase and peaks out at 0.91 percentage points after 4 months and then decreases progressively, tends towards and fluctuates around, its equilibrium, or steady state, level after 17 months. The effect of a surprise, or unexpected, increase in output of minerals industry is, nonetheless, statistically insignificant in all time periods.

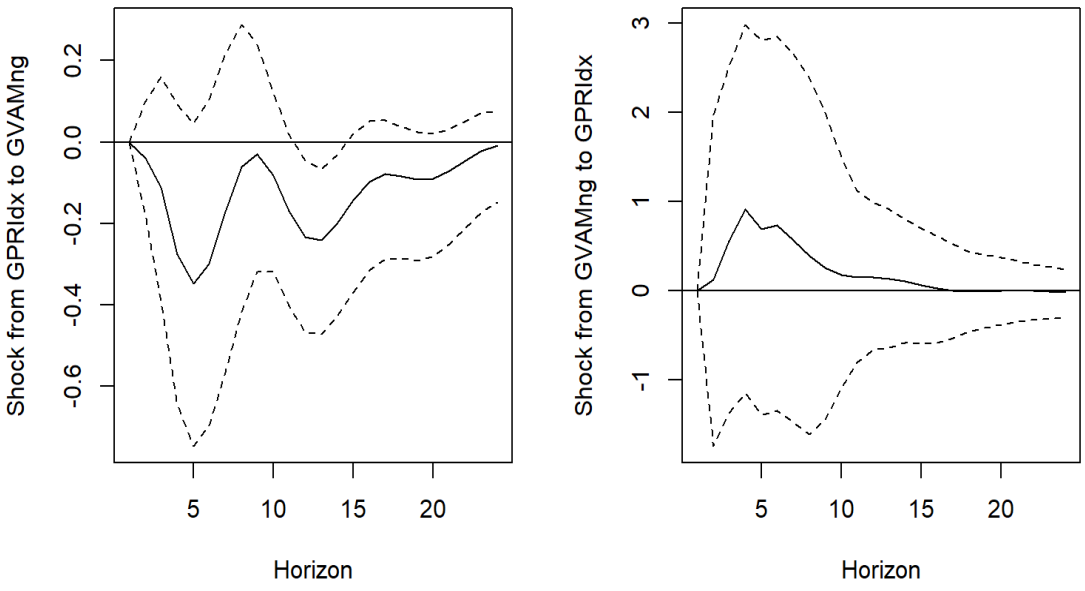
The results imply negligible and delayed unidirectional, or one way, causality between output of mining and quarrying and geopolitical risk, where the direction of causality from geopolitical risk to output of mining and quarrying industry dominates. Geopolitical risk, or instability and disruption from a nation's involvement in international affairs, has had significant implications for macroeconomics fluctuations around the world, fuelling a rise in conflicts, protectionism and cross border restrictions, among others, with adverse consequences on economic fundamentals, decimating cross national consumer, business and investor sentiments, according to Aiyar et al. (2023a) and Alfaro (2023). A detailed discussion on geopolitical risk and geoeconomic fragmentation, defined as a policy driven reversal of global economic integration, can be found in Caldara and Iacoviello (2022), Aiyar et al. (2023b), Aiyar



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

Figure 10: Impulse Response Functions (IRFs) with shocks from output of the minerals industry

and Ilyina (2023), Aiyar et al. (2023a) as well as Caldara et al. (2024). A detailed discussion on the benefits of economic globalisation, in particular, economic liberalisarion, can be found in Dornbusch (1992), Obstfeld (1994), Eichengreen and Irwin (1995) as well as Frankel and Romer (1999). Consequently, the escalation of geopolitical tensions can adversely affect economies, undermining business ventures, which often results in severe losses and even a complete shutdown of business operations.



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

Figure 11: Impulse Response Functions (IRFs) with shocks from output of the minerals industry

Economic causation, or causality, as discussed, is a principle commonly used to analyse the intertemporal flow of effects between two economic incidences, premised on the hypothesis that an economic event, referred to as the cause, is responsible for, or produces, the occurrence of another economic event, referred to as the effect. Economic causation, or causality, is discussed in detail in Granger (1969), Simon (1970), Sims (1972) Granger (1980), Geweke (1982), Leamer (1985), Hamilton (1994), Granger (2004), Heckman (2008), Diebold (2007) as well as Granger and Newbold (2014), together with its alternatives. Selected macroeconomic indicators comprise the central bank monetary policy interest rate, government expenditure, or the Fiscal policy stance, commodity prices, foreign exchange rate, foreign direct investment, financial market, business confidence, market uncertainty, external, or foreign, demand and geopolitical risk. The estimated results to capture the causality *nexus* between the minerals industry and selected macroeconomic indicators have provided evidence of mixed cause and effect relationships. Economic Causality, or causation, as discussed, can be unidirectional or bidirectional, and often involves feedback loops, leading to dynamic relationships between variables.

The results have shown a unidirectional causality from commodity prices, foreign exchange rate and geopolitical risk to output of mining and quarrying. The results have also shown a unidirectional causality from output of mining and quarrying and government expenditure. The results have further shown a bidirectional causality between output of mining and quarrying and monetary policy interest rate, foreign direct investment, financial market, business confidence, market uncertainty as well as external, or foreign, demand. The results have not shown the absence of causality, or causation, between output of mining and quarrying and the selected macroeconomic indicators. Granger causality, a method to analyses the direction and strength of intertemporal relationships between variables, only indicates precedence, or that one variable's past information is useful in predicting another, while it doesn't rule out the possibility of other factors or feedback loops, according to Leamer (1985), Diebold (2007) and Granger and Newbold (2014). Although changes in output of the minerals industry may Granger cause some of the selected macroeconomic indicators, the effect could only be a precedence, and not necessarily a cause, given that the minerals industry is relatively small in a global context.

Conclusion

This paper analyses the causality *nexus* between the minerals industry and selected macroeconomic indicators in South Africa. This is achieved by augmenting a Taylor (1993) rule type central bank monetary policy reaction function with selected macroeconomic indicators and comparing the causality *nexus* between the minerals industry and these macroeconomic indicators. The results have provided evidence of a unidirectional causality from commodity prices, foreign exchange rate and geopolitical risk to output of mining and quarrying. The results have also shown a unidirectional causality from output of mining and quarrying and government expenditure. The results have further shown a bidirectional causality between output of mining and quarrying and monetary policy interest rate, foreign direct investment, financial market, business confidence, market uncertainty and external, or foreign, demand. The results have, however, not shown the absence of causality, or causation, between output of mining and quarrying and the selected macroeconomic indicators. Changes in output of the minerals industry may Granger cause some macroeconomic indicators, hence the effect could only be a precedence, and not necessarily a cause, given that the minerals industry is relatively insignificant in global context.

Economic causation, or causality, as discussed, is a principle that is commonly used to analyse the intertemporal flow of effects between two economic episodes, where the hypothesis is that an economic event, referred to as the cause, is responsible for the occurrence of another economic event, referred to as the effect. A widely accepted phenomenon, as discussed, is that the trend break, as well as the protracted underperformance, of the minerals industry relative to the total economy since the 1970s was a problem of structural misalignments. The results, however, have predominantly shown causality between output of mining and quarrying and some selected macroeconomic indicators, with possibility of feedback loops between these variables. The fluctuations in macroeconomic indicators are important for economic activity, hence policymakers should monitor the developments in macroeconomic events to support economic growth and the minerals industry. Several economic indicators, such as the monetary policy interest rates, government expenditure and taxation, foreign direct investment, prices of commodities and financial assets as well as foreign exchange rate, affect economic activity, at least theoretically, hence it's important for future research to analyse their impact on the minerals industry.

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