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# Economic sensitivity *nexus* and the minerals industry

Leroi Raputsoane\*

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## Abstract

This paper analyses the sensitivity *nexus* between the minerals industry and the aggregate economy to changes in 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 reaction of the minerals industry and the aggregate economy to changes in these macroeconomic indicators. The results provide evidence of a statistically significant higher sensitivity of total output to an unexpected, or surprise, increase in monetary policy interest rate, compared to output of the minerals industry. The results further show a lower sensitivity of total output to an unexpected, or surprise, increase in government expenditure, commodity prices, foreign exchange rate, foreign direct investment, financial market, business confidence, business confidence and market uncertainty, compared to output of the minerals industry. The results finally show mixed sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in geopolitical risk and external, or foreign, demand, compared to output of the minerals industry. The fluctuations in various macroeconomic indicators are important for aggregate economic activity, hence policymakers should monitor developments in macroeconomic events to support economic growth and the minerals industry.

**JEL Classification:** C10, E10, E30, L72

**Keywords:** Economic sensitivity, Minerals industry, Economic cycles

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## Introduction

Economic sensitivity, which refers to the propensity for economic outcomes to vary in response to changes in the underlying assumptions, or conditions, is central to understand the impact of different factors on the economy. Economic sensitivity analysis involves observing the impact of systematically varying key assumptions, such as structural specifications, variables or parameter values on economic results, or outcomes. Consequently, according to Leamer (1985), Canova (1995) and Taylor (2009), sensitivity analysis, as relates to the economy, assists in evaluation of the reliability of conclusions in various contexts and can facilitate the consideration of generalisability of outcomes to various settings, or scenarios. The assumptions in economic sensitivity analysis are made to best approximate the phenomenon that the economic behaviour and hypotheses attempts to capture. In particular, economic sensitivity can be broken down into two distinct, but related concepts, "what-if" analysis and simulation analysis, according to Golfarelli et al. (2006), Rizzi (2009) and Morgan (2014), where "what-if" analysis, on the one hand, focuses on evaluating the impact of specific changes in variables of a system, while simulation analysis, on the other hand, uses models to mimic the behaviour of a system over time.

Analysing the factors that have the greatest impact on predicted economic outcomes is a long tradition in economics, with significant contributions that include Leamer (1985), Harrison and Vinod (1992), Levine and Renelt (1992), Canova (1994), Hansen and Sargent (2008), Canova (1995), Aruoba et al. (2006), Harenberg et al. (2019) and Chan et al. (2009). A case in point is the widely accepted phenomenon 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, hence the

industry is, thus, perceived not to be affected by the fluctuations in economic stabilisation policies, such as financial, monetary and fiscal policies. 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. Output of the mining and quarrying has stagnated in real terms, while it has declined progressively as a percentage of Gross Domestic product (GDP). Paradoxically, the aggregate economy has grown at annual rates of about 4 percent between 2000 and 2010 and at rates of below 2 percent, on average, since then.

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.

Short term, or transitory, economic fluctuations emanate from changes in monetary, financial and fiscal policies as well as other factors that include consumer and business confidence, foreign flow financial assets as well as goods and services 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 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 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 sensitivity *nexus* between the minerals industry and the aggregate economy to changes in 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 reaction of the minerals industry and the aggregate economy to the changes in these macroeconomic indicators. Understanding the sensitivity *nexus* between the minerals industry and the aggregate economy to changes in macroeconomic indicators is important to mining authorities and policymakers alike. 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 mining companies are key players in the global industry. As discussed, the observed trend break, as well as the protracted underperformance of South Africa’s minerals industry, relative to the total economy, since the 1970s could have been a problem of structural misalignments, hence the sector cannot be affected by changes in some economic policies and events. Economic sensitivity will, consequently, reveal the economic impact of specific changes in selected indicators.

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

Monthly data spanning the period January 2000 to December 2023 is used to analyse the sensitivity *nexus* between the minerals industry and the aggregate economy to changes in selected macroeconomic indicators. The variables comprise mining and quarrying output, 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. Inflation rate, or the annual change in Consumer Price Index (CPI), is the headline consumer price inflation. Total output is Gross Value Added (GVA) of 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 spending that includes government consumption, investment and transfer payments. Commodity prices is Commodity Price Index, or 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 amount 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](http://matteoiacoviello.com).

The descriptions and denotations of the variables are presented in Table 1. Mining 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 *GPRIidx* 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 deceleration in output of the minerals industry in 2020 was due to the COVID-19 pandemic, while it mostly moderated 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 subsequently decreased, on average,

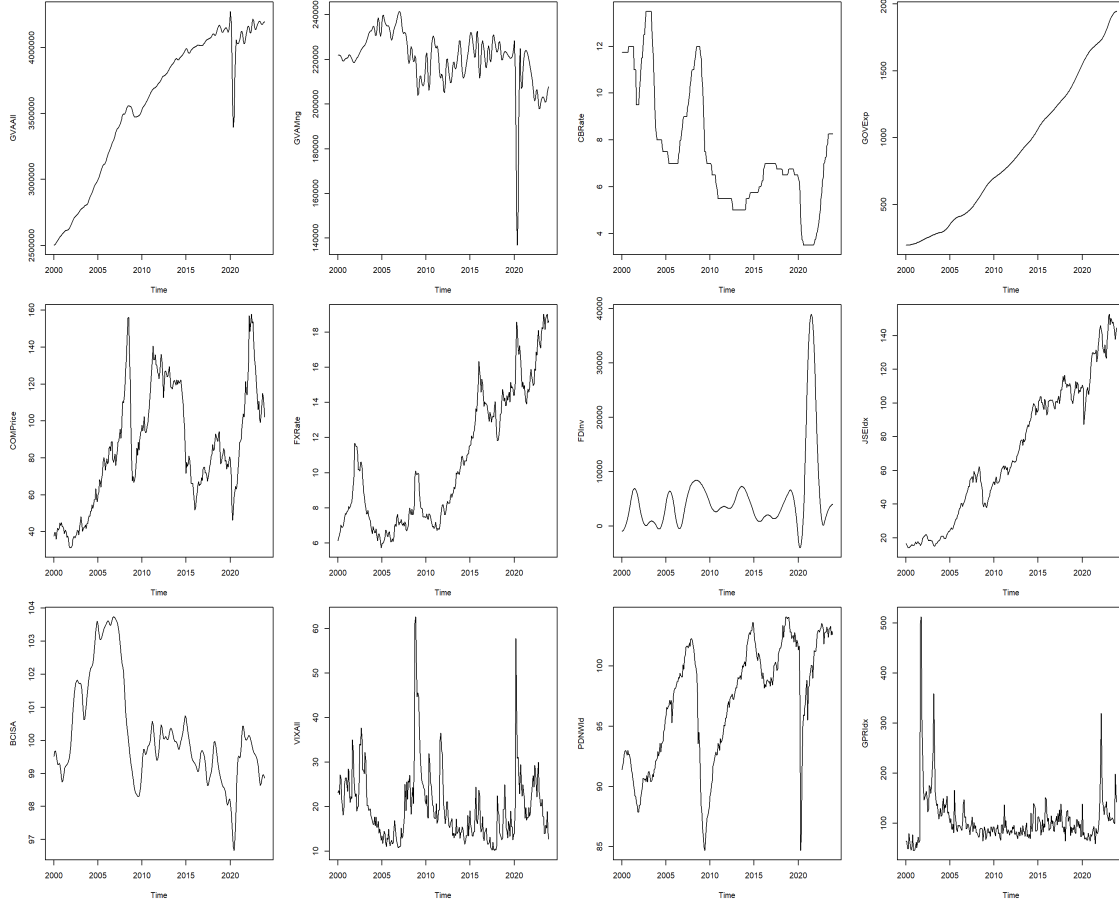
Variable	Denotation	Description
Mining output	GVAMng	Gross Value Added (GVA) of the mining and quarrying, or minerals, industry
Total output	GVAAll	Gross Value Added (GVA) of total economy, or economy wide output
Inflation rate	CPIRate	Inflation rate, or annual Consumer Price Index (CPI), is the annual 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 matteoia-coviello.com. Total, or economy wide, output, is denoted *GVAAll*, output of mining and quarrying is denoted *GVAMng*, 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*, financial market is denoted *JSEIdx*, business confidence index is denoted *BCISA*, market uncertainty is denoted *VIXAll*, external demand is denoted *PDNWld* and *GPRIdx* denotes geopolitical risk.

Table 1: Description of variables

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 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 substantially in 2021 and peaked before falling back to the long term average in 2022 and 2023. The financial market index remained



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 matteoia-coviello.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 denoted *COMPrice*, foreign exchange rate is denoted *FXRate*, foreign direct investment is denoted *FDInv*, financial market index is denoted *JSEIdx*, business confidence index is denoted *BCISA*, market uncertainty is denoted *VIXAll*, external demand is denoted *PDNWld* and *GPRIdx* denotes geopolitical risk.

Figure 1: Plots of the variables

mutated 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.

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 sensitivity *nexus* between the minerals industry and the aggregate economy to changes in 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 include Lütkepohl (1991), Hamilton (1994) and Watson (1994) and their Bayesian equivalents include Litterman (1984). According to Rudebusch (1998) and Stock and Watson (2001), 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

$$Y_t = \delta + \theta_1 Y_{t-1} + \dots + \theta_p Y_{t-p} + \epsilon_t \quad (1)$$

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

$$\epsilon_t \sim N(0, \Sigma) \quad (2)$$

where  $\Sigma$  is the  $n \times n$  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

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

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 Lütkepohl (1991) and Hamilton (1994), while recent contributions include 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

$$P(\theta_i, \Sigma | Y_t, M_i) P(Y_t | \Sigma, M_i) = P(Y_t | \theta_i, \Sigma, M_i) P(\theta_i, \Sigma | M_i) \quad (4)$$

where  $M_i$  is an arbitrary model among a general class of models,  $\theta_i$  is the parameter vector described above,  $p(\theta_i | Y_t, M_i)$  is the posterior model probability,  $p(Y_t | \theta_i, M_i)$  is the marginal likelihood of the model,  $p(\theta_i | M_i)$  is the prior model probability and  $p(Y_t | M_i)$  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 negligible disadvantageous influence on the inference of the parameters of the model.

## Results

Bayesian Vector Autoregression (BVAR) model was estimated to the sensitivity *nexus* between the minerals industry and the aggregate economy to changes in 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. 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

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

where  $i_t$  is the nominal interest rate,  $\rho$  is the natural rate of interest,  $\pi_t$  is the inflation rate,  $\pi_t^*$  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.  $\theta_\pi$ ,  $\theta_Y$  and  $\theta_M$  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 its natural rates, respectively.  $\epsilon_t$  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 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 macroeconomic indicators, denoted  $MACInd_t$ .  $Y_t$  in Equation 1 can, therefore, be rewritten as

$$Y_t = (GVAMng_t, CPI_t, CBRate_t, MACInd_t) \quad (6)$$

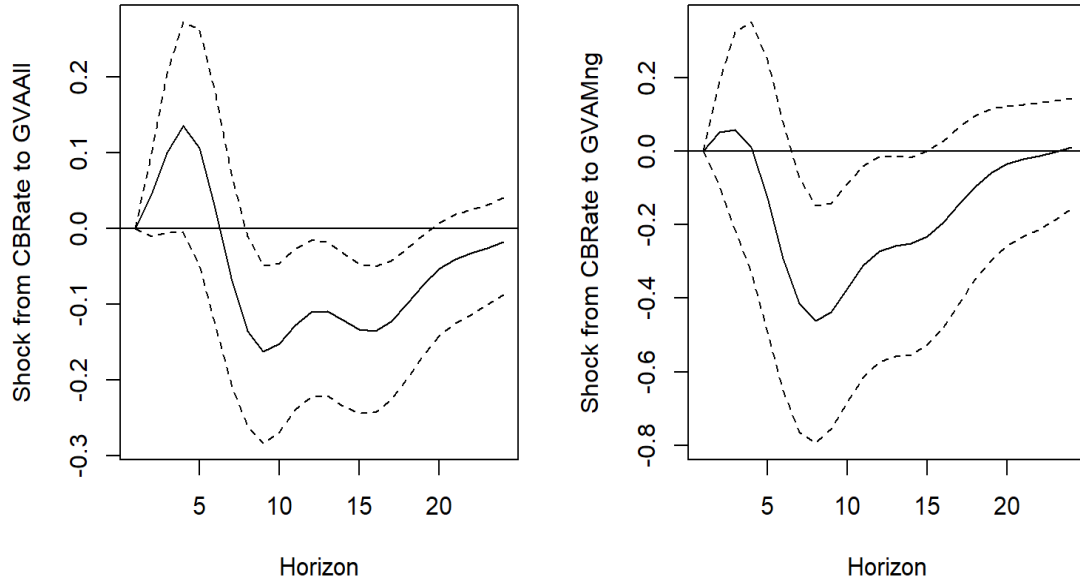
where  $Y_t$  is the vector of random variables observed at time  $t$ . Stock and Watson (2001) argue that a reduced form Vector Autoregression (VAR), on the one hand, expresses each variable as a linear function of its own past values, the past values of all other variables being considered and a serially 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, total, or economy wide, output initially increases slightly and peaks at 0.13 percent after 4 months, followed by a decrease and a bottom out at -0.16 percentage points after 9 months. The effect of an increase in the interest rate is only statistically significant between 7 and 20 months, following which total output gradually tends towards its equilibrium level. 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 minerals industry output bottoms out at -0.47 percentage points after 8 months. The effect of the surprise increase in the interest rate is only statistically significant between 6 and 15 months, following which output of minerals industry gradually moves towards its equilibrium, or steady state, level.

The results show higher sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in monetary policy interest rate, compared to output of the minerals industry. A well documented phenomenon in monetary economics, 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 make informed decisions about how to achieve their goals of price stability and economic growth. 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, according to Bernanke and Mishkin (2007), Svensson and Woodford (2004), Woodford (2007) and Adrian (2018). 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.



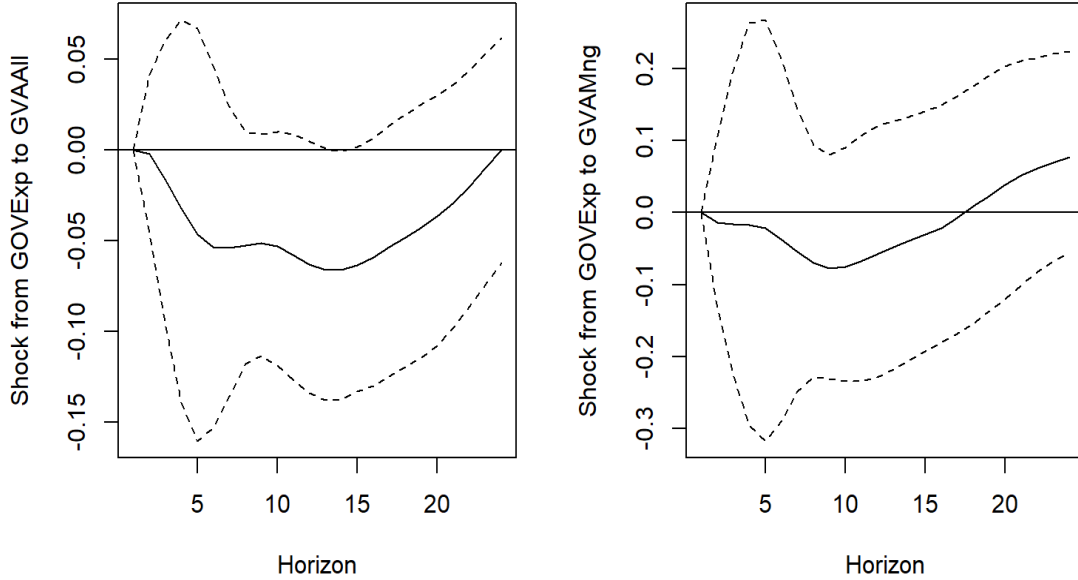
Notes: Data sourced from Statistics South Africa and South African Reserve Bank. Mining and quarrying output is denoted *GVAMng*, total, or economy wide, output, is denoted *GVAAll* and *CBRate* denotes central bank monetary policy interest rate. The x axis depicts the horizon of the Impulse Response 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 total, or economy wide, output, and output of the minerals industry to innovations, or shocks, in government expenditure, or fiscal policy stance, are depicted in Figure 3, together with their 95 percent confidence intervals, or bands. According to the results, following an unexpected, or surprise, 1 percentage point increase in government expenditure, total, or economy wide, output decreases and bottoms out at -0.07 percentage points after 14 months, following which it gradually recovers and progressively tends towards and fluctuates around, its equilibrium, or steady state, level. The effect of the unexpected increase in government expenditure is statistically insignificant in all periods, consistent with the countercyclical fiscal policy. following an unexpected, or surprise, 1 percentage point increase in government expenditure, output of the minerals industry decreases slightly and bottoms out at -0.06 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.

The results show lower, but persistent, sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in government expenditure, or fiscal policy stance, compared to output of the minerals industry. The reaction of total, or economy wide, output and minerals industry output to fiscal policy developments, though statistically insignificant, show 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), Atkinson 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 higher government spending and tax cuts during recessions, while the opposite policy stance by government is referred 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.



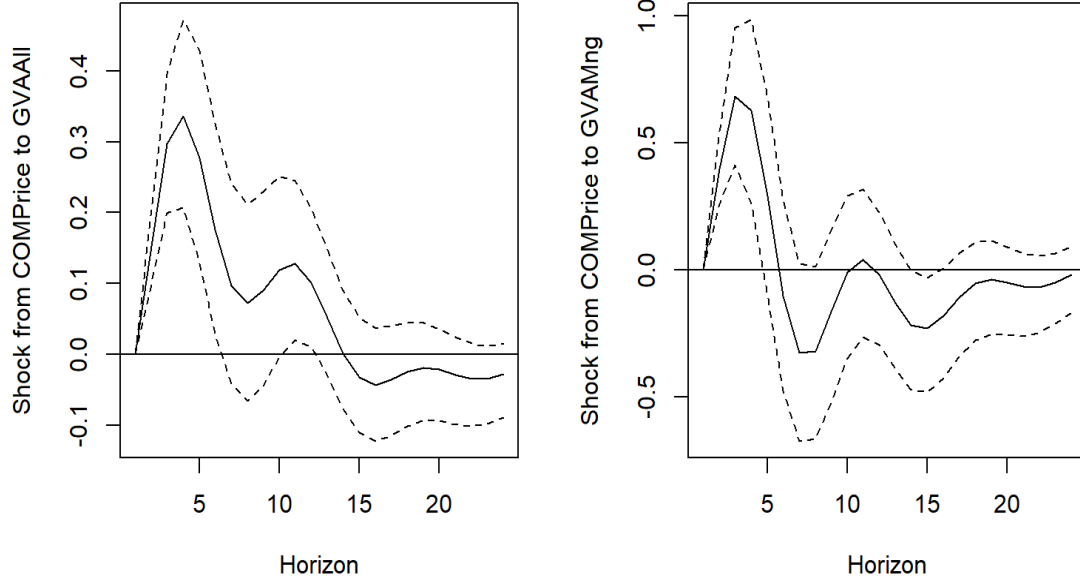
Notes: Data sourced from Statistics South Africa and South African Reserve Bank. Mining and quarrying output is denoted *GVAMng*, total, or economy wide, output, is denoted *GVAAll* and *GOVExp* denotes Government expenditure. The x axis depicts the horizon of the Impulse Response Functions (IRFs).

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 total, or economy wide, output, and output of the minerals industry to innovations, or shocks, in commodity prices are depicted in Figure 4, together with their 95 percent confidence intervals, or bands. Following an unexpected, or surprise, 1 percentage point increase in commodity prices, total, or economy wide, output increases and peaks out at 0.34 percentage points after 4 months, following which it decreases and bottoms out at -0.04 percentage points after 16 months before it progressively, tends towards and fluctuates around, its equilibrium, or steady state, level. The effect of the unexpected increase in commodity prices on total, or economy wide, output is statistically insignificant up to 7 months. 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, and subsequently 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 the prices of commodities on output of mining and quarrying is statistically significant up to 5 months.

The results show lower, but persistent, sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in commodity prices, compared to output of the minerals industry. The boom and bust cycles in prices of commodities 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), Blanchard and Perotti (2002), Frankel (2010), Frankel (2012) and Jacks (2013). The results have also shown that the mining and quarrying industry lacks market share to influence the commodities market price, hence, it accepts prevailing prices in commodities markets.



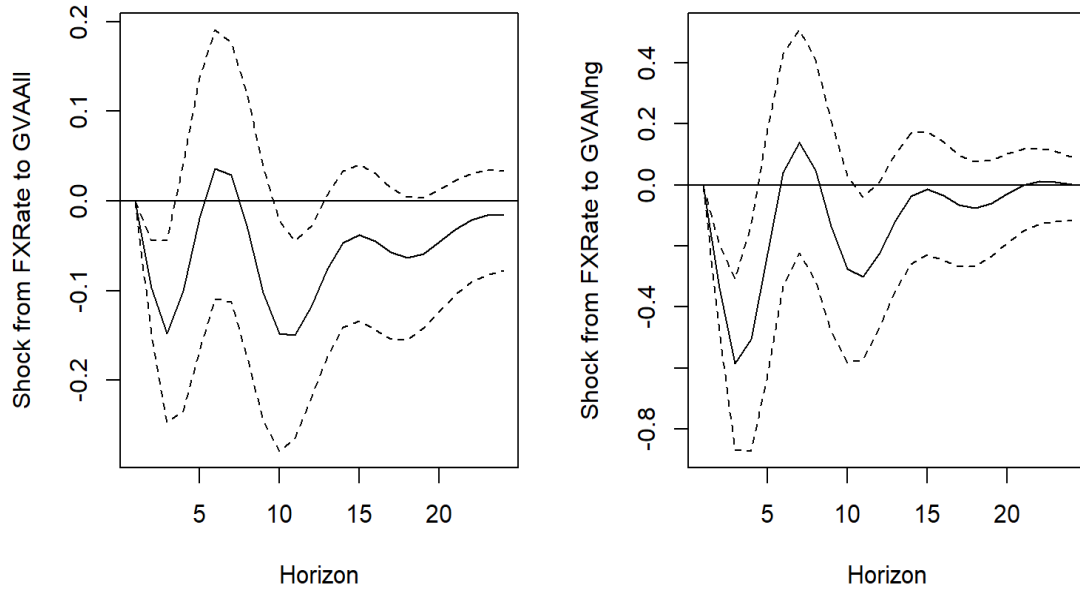
Notes: Data sourced from Statistics South Africa, South African Reserve Bank and the World Bank. Mining and quarrying output is denoted *GVAMng*, total, or economy wide, output, is denoted *GVAAll* and *COMPrice* denotes Commodity prices. The x axis depicts the horizon of the Impulse Response Functions (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 total, or economy wide, output, and output of the minerals industry to innovations, or shocks, in foreign exchange rate 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, total, or economy wide, output decreases and bottoms out at -0.15 percentage points after 3 months, followed by an increase and peak out at 0.039 after 6 months and another bottom out at -0.15 after 11 months, before it progressively tends towards its equilibrium level. The effect of the unexpected increase in foreign exchange rate on total output is statistically significant up to 3 months and between 10 and 12 months. Following an surprise 1 percentage point increase in foreign exchange rate, minerals industry output 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, and subsequent fluctuation and gradual increase towards its steady state level after 21 months. The effect of an unexpected, or surprise, increase in foreign exchange rate on output of mining and quarrying is statistically significant up to 5 months.

The results show lower sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in foreign exchange rate, compared to output of the minerals industry. As discussed in Dornbusch (1976), Obstfeld and Rogoff (1996) and Obstfeld (2001), 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. The empirical results for both total output and output of the minerals industry are consistent with the Dominant Currency Pricing (DCP) that the U.S. 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, leads to an improvement in the balance of trade, while the opposite is true for the exchange rate appreciation.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction



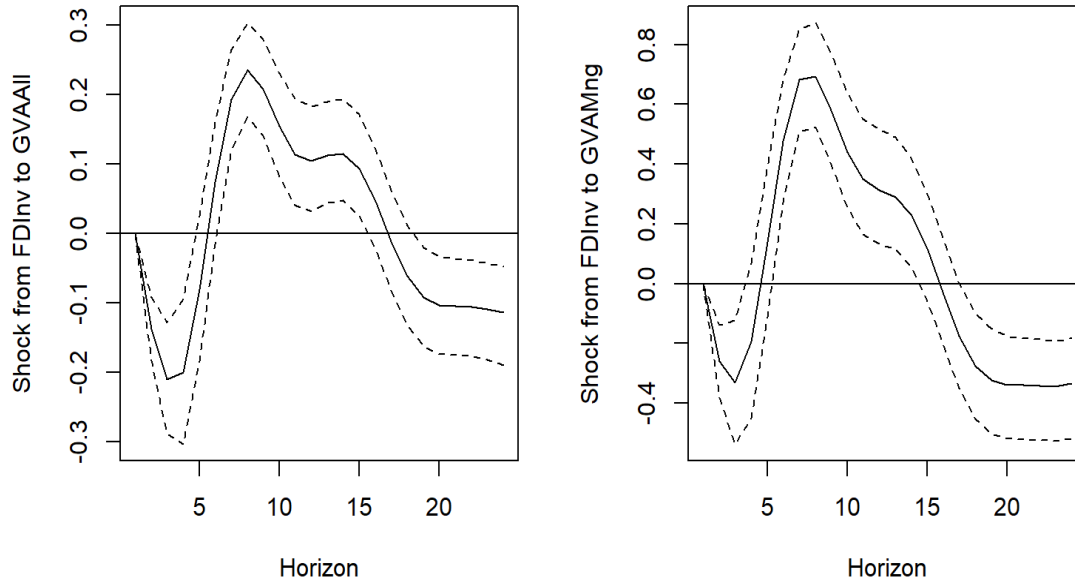
Notes: Data sourced from Statistics South Africa and South African Reserve Bank. Mining and quarrying output is denoted *GVAMng*, total, or economy wide, output, is denoted *GVAAll* and *FXRate* denotes foreign exchange rate. The x axis depicts the horizon of the Impulse Response Functions (IRFs).

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

of total, or economy wide, output, and output of the minerals industry to innovations, or shocks, in foreign direct investment 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, total, or economy wide, output decreases and bottoms out at -0.21 percentage points after 3 months, followed by an increase and peak out at 0.23 percentage points after 8 months, before it subsequently fluctuates and gradually move towards its equilibrium, or steady state, level. The effect of the surprise increase in foreign direct investment is statistically significant up to 4 months, 6 and 14 months and from 16 months to the end of the sample period. 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 and another decrease before it fluctuates and gradually tends towards its steady state level. The effect of a surprise increase in foreign direct investment is statistically significant up to 3 months, between 6 and 14 months as well as from 18 months to the end of the sample period.

The results show lower sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in foreign direct investment, compared to output of the minerals industry. Foreign direct investment inflows are the value of cross border direct investment transactions during given period, 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 national 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 promotion of well functioning of markets.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of total, or economy wide, output, and output of the minerals industry to innovations, or shocks, in financial market 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 financial market, total, or economy wide, increases and peaks out at 0.32 percentage points after



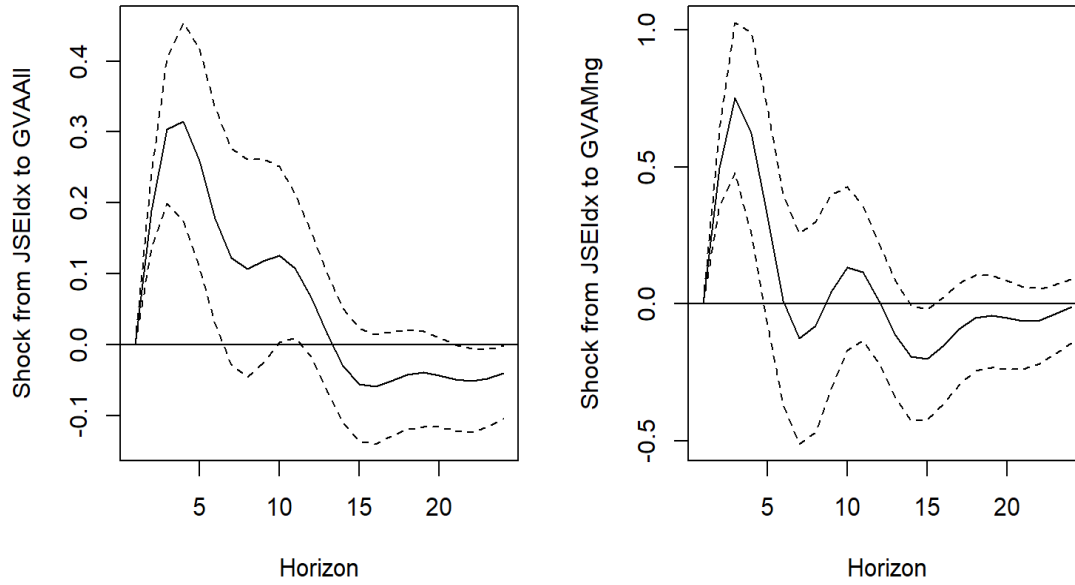
Notes: Data sourced from Statistics South Africa and South African Reserve Bank. Mining and quarrying output is denoted *GVAMng*, total, or economy wide, output, is denoted *GVAAII* and *FDInv* denotes foreign direct investment. The x axis depicts the horizon of the Impulse Response Functions (IRFs).

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

4 months, followed by a decrease and bottoming out at -0.06 percentage points after 16 months, followed an increase, subsequent fluctuation and gradual movement towards its equilibrium, or steady state, level. The effect of an unexpected increase in financial market is statistically significant up to 6 months. Following an unexpected, or surprise, 1 percentage point increase in financial market, output of 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, before it increases, subsequently fluctuates and gradually move towards its equilibrium level after 23 months. The effect of a surprise, or unexpected, increase in financial market is statistically significant up to 5 months.

The results show lower, but more persistent, sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in financial market, compared to output of the minerals industry. According to Hayes (2024), a financial market generally refers to a market where securities trading occurs, including the stock market, bond market, foreign exchange market and derivatives market. Evidence strongly supports the view that a well functioning and effectively regulated financial 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*, the output of the minerals industry, as also discussed in Levine (1996), Miller (1998), Levine and Zervos (1998) as well as Hall (2024). 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 total, or economy wide, output, and output of the minerals industry to innovations, or shocks, in business confidence are depicted in Figure 8, together with their 95 percent confidence intervals, or bands. Following an unexpected 1 percentage point increase in business confidence, total, or economy wide, output increases and peaks at 0.20 percentage points after 5 months, following which total, or economy wide, output decrease and gradually fluctuates towards its equilibrium, or steady state, level. The effect of an unexpected, or surprise, increase in business confidence on total, or economy wide, output is statistically significant up between 3 months and 7 months as well as briefly between 13 months and 14 months. Following an unexpected, or surprise, 1 percentage point increase in business confidence, output of the minerals industry initially increases and peaks at 0.59 percentage points after



Notes: Data sourced from Statistics South Africa and South African Reserve Bank. Mining and quarrying output is denoted *GVAMng*, total, or economy wide, output, is denoted *GVAAll* 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

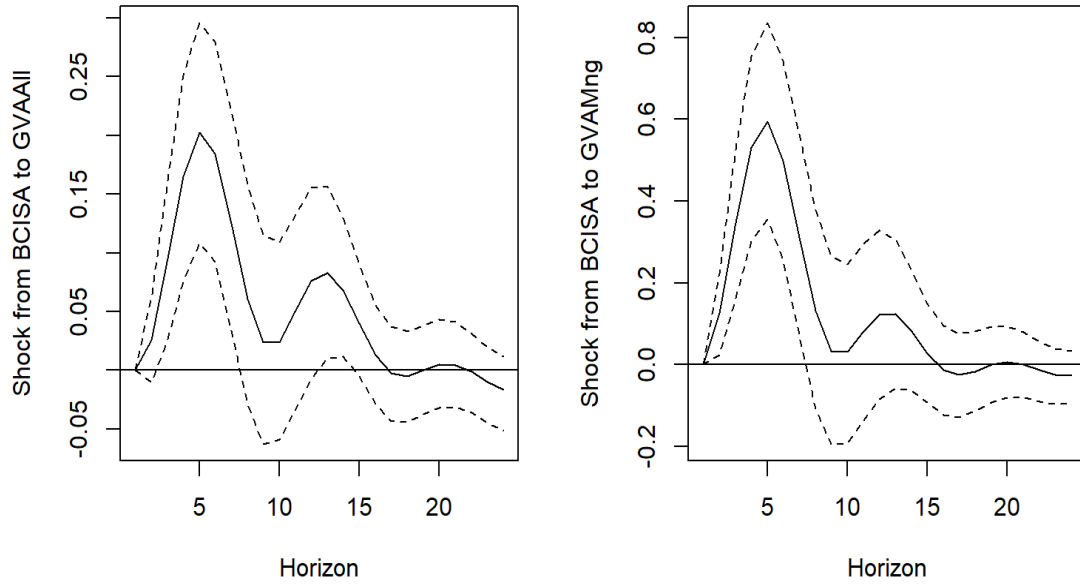
5 months, followed by the decrease and bottoming out at -0.03 percentage points after 17 months, before a gradual increase as well as stable fluctuation of output of the minerals industry towards its equilibrium, or steady state, level after 24 months. The effect of an unexpected, or surprise, increase in business confidence on output of mining and quarrying is statistically significant up to 7 months.

The results show lower sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in business confidence, compared to output of the minerals industry. Changes in business confidence have important implications for macroeconomics fluctuations, affecting the economic agents' decision making on investment, employment and business expansion plans. Such economic agents' 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, thus, predicts economic conditions and can also be used to assess the evolution of business cycles and anticipate cyclical turning points in economic activity.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of total, or economy wide, output, and output of the minerals industry to innovations, or shocks, in market uncertainty 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, total, or economy wide, output decreases and bottoms out at -0.36 percentage points after 4 months, followed by an increase and a peaks out at 0.12 percentage points after 8 months, as well as a decrease and subsequent fluctuation and gradual movement of total output towards its equilibrium, or steady state, level after 18 months. The effect of a surprise increase in market uncertainty is statistically significant up to 5 months. Following an unexpected 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 and a peak out at 0.37 percentage points after 8 months, before output of the minerals industry decreases, fluctuates and gradually tends towards its steady state level after 18 months. The effect of a surprise increase in market uncertainty remains statistically significant up to 5 months.

The results show lower sensitivity of total, or economy wide, output to an unexpected, or surprise,





Notes: Data sourced from Statistics South Africa, South African Reserve Bank and OECD Data Explorer. Mining and quarrying output is denoted *GVAMng*, total, or economy wide, output, is denoted *GVAAll* and *BCISA* denotes business confidence. The x axis depicts the horizon of the Impulse Response Functions (IRFs).

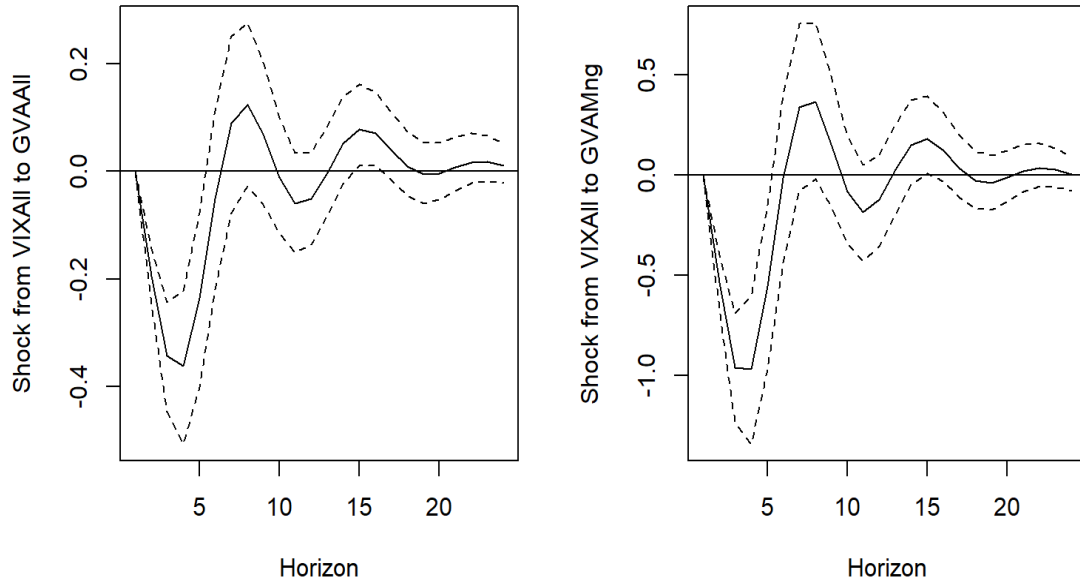
Figure 8: Impulse Response Functions (IRFs) with shocks from output of the minerals industry

increase in market uncertainty, compared to output of the minerals industry. 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 behaviour of a cross sectional dispersion of economic variables that reflect movement in market uncertainty, employment, income, productivity and stock returns.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of total, or economy wide, output, and output of the minerals industry to innovations, or shocks, in external, or foreign, demand 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, total output increases slightly and peaks out at 0.02 percentage points after 2 months, decreases and bottoms out at -0.11 percentage points after 4 months, followed by an increase and a peak out at 0.37 percentage points after 8 months, before it fluctuates and gradually moves towards its equilibrium level. The effect of the surprise increase in external demand on mining and quarrying output is only statistically significant between 7 months and 11 months. Following a surprise 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, and subsequently fluctuates towards its equilibrium level. The effect of the surprise increase in external demand on output of the minerals industry is only statistically significant between 4 and 6 months.

The results show mixed sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in external, or foreign, demand, compared to output of the minerals industry. The sensitivity of total, or economy wide, output is lower and statistically insignificant, compared to output of the minerals industry, up to 6 months, while the opposite is true after 6 months. External, or foreign, demand, which refer to the willingness and ability of consumers, businesses and governments to purchase goods





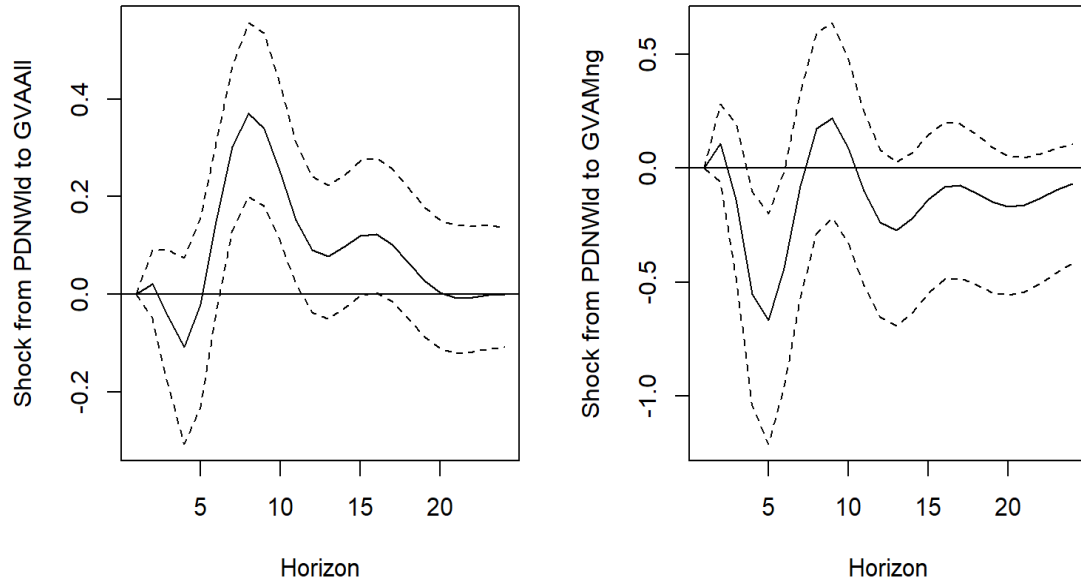
Notes: Data sourced from Statistics South Africa, South African Reserve Bank and Chicago Board Options Exchange (CBOE). Mining and quarrying output is denoted *GVAMng*, total, or economy wide, output, is denoted *GVAAll* and *VIXAll* denotes Market uncertainty. The x axis depicts the horizon of the Impulse 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 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), especially, 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 use their most abundant factors of production, such as labor, capital and natural resources. Consequently, high external, or foreign, demand conditions often lead countries to adopt export orientation strategies.

Impulse Response Functions (IRFs) of the Vector Autoregression (VAR) model for the reaction of total, or economy wide, output, and output of the minerals industry to innovations, or shocks, in geopolitical risk are depicted in Figure 11, together with their 95 percent confidence intervals, or bands. According to the results, following an unexpected, or surprise, 1 percentage point increase in geopolitical risk, total, or economy wide, output decreases and bottoms out at -0.04 percentage points after 5 months, followed by fluctuation, gradual increase and tendency towards its equilibrium, or steady state, level. The effect of an unexpected increase in geopolitical risk on output of mining and quarrying is only statistically significant between 19 months and 22 months. Following an unexpected, or surprise, 1 percentage point increase in geopolitical risk, output of the minerals industry decreases and bottoms out at -0.35 percentage points after 5 months, followed by another decrease and a bottom out at -0.24 percentage points after 13 months, before fluctuation and gradual increase towards its equilibrium, or steady state, level after 23 months. The effect of a surprise increase in geopolitical risk on mining and quarrying output is only statistically significant between 12 months and 14 months.

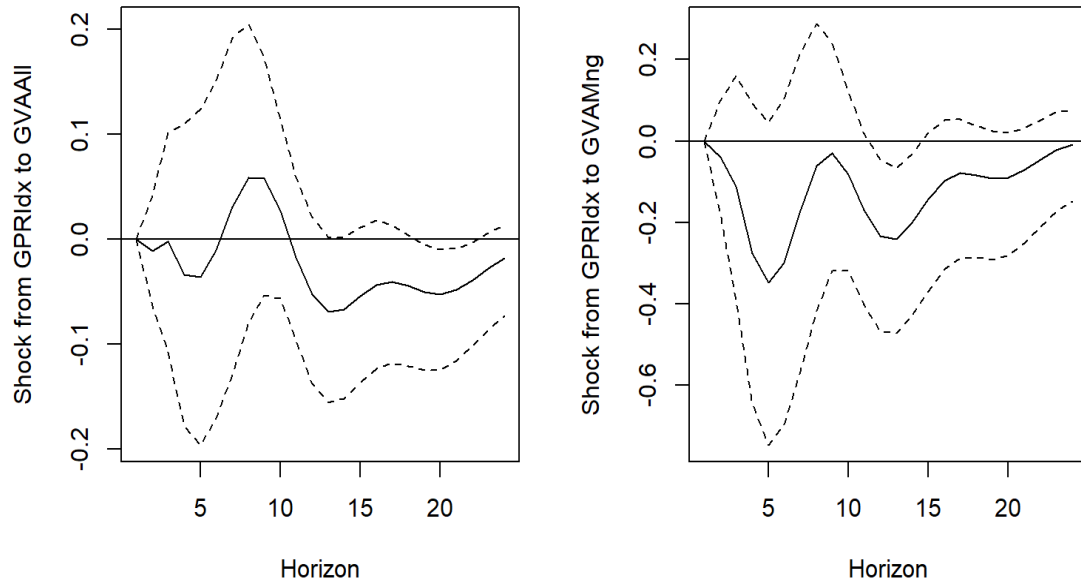
The results show somewhat mixed sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in geopolitical risk, compared to output of the minerals industry. Although the sensitivity of total, or economy wide, output is lower and mostly statistically insignificant, it shows some recovery between 7 months and 10 months, compared to output of the minerals industry, which remain in decline up to 23 months. Geopolitical risk, or instability and disruption from a nation's involvement in international affairs, has had significant implications for macroeconomics fluctuations around the world, according to Aiyar et al. (2023a) and Alfaro (2023). A detailed discussion on geopolitical risk and geoeconomic fragmentation, which is defined as a policy driven reversal of global economic integration, can be found in Caldara and Iacoviello (2022), Aiyar et al. (2023b), Aiyar and Ilyina (2023), Aiyar et al. (2023a) as well as Caldara et al. (2024), while a detailed discussion on the benefits of economic



Notes: Data sourced from Statistics South Africa, South African Reserve Bank and OECD Data Explorer. Mining and quarrying output is denoted *GVAMng*, total, or economy wide, output, is denoted *GVAAll* and *PNDWld* denotes external demand. 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

globalisation, in particular, economic liberalisation, can be found in Dornbusch (1992), Obstfeld (1994), Eichengreen and Irwin (1995) as well as Frankel and Romer (1999). Escalation of geopolitical tensions is often associated with adverse affects economic outcomes, given that it undermines consumer and business confidence, resulting in serious losses or even a complete shutdown of business operations.



Notes: Data sourced from Statistics South Africa, South African Reserve Bank and matteoiacoviello.com. Mining and quarrying output is denoted *GVAMng*, total, or economy wide, output, is denoted *GVAAll* 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

The results provide evidence of a statistically significant higher sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in monetary policy interest rate, compared to

output of the minerals industry. The results also provide evidence of a statistically significant lower sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in government expenditure, commodity prices, foreign exchange rate, foreign direct investment, financial market, business confidence, business confidence and market uncertainty, compared to output of the minerals industry. The results finally provide evidence of a statistically significant mixed sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in geopolitical risk and external, or foreign, demand, compared to output of the minerals industry. The sensitivity of total, or economy wide, output to an unexpected increase in external, or foreign, demand is lower and statistically insignificant, while the opposite is true after this period, compared to output of the minerals industry, up to a period of a year. Although the sensitivity of total, or economy wide, output to a surprise increase in geopolitical risk is generally lower and statistically insignificant, it evidences some recovery for 4 months, compared to output of mining and quarrying that remains in decline up to 2 years.

Economic sensitivity analysis has contributed to the understanding how changes in selected economic indicators affects output of the minerals industry and the aggregate economy, or economy wide output. Examining the relationship between these macroeconomic indicators and economic outcomes assists mining authorities and policymakers to anticipate the impact of policy decisions or external shocks and formulate informed decisions about investment, resource allocation and overall economic performance. The sensitivity *nexus* between the minerals industry and the aggregate economy to changes in macroeconomic indicators is consistent with the hypothesis that 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. consequently, 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 endogenous and exogenous economic fluctuations over the economic cycle.

## Conclusion

This paper analysed the sensitivity *nexus* between the minerals industry and the aggregate economy to changes in macroeconomic indicators in South Africa. This was achieved by augmenting a Taylor (1993) rule type central bank monetary policy reaction function with selected macroeconomic indicators and comparing the reaction of the minerals industry and the aggregate economy to changes in these macroeconomic indicators. The empirical results provide evidence of a statistically significant higher sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in monetary policy interest rate, compared to output of the minerals industry. The results further provide evidence of a statistically significant lower sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in government expenditure, commodity prices, foreign exchange rate, foreign direct investment, financial market, business confidence, business confidence and market uncertainty, compared to output of the minerals industry. The results finally provide evidence of a statistically significant mixed sensitivity of total, or economy wide, output to an unexpected, or surprise, increase in geopolitical risk and external, or foreign, demand, compared to output of the minerals industry.

Economic sensitivity, or the propensity for economic outcomes to vary in response to changes in the underlying assumptions, or conditions, is central to understand the impact of different factors on the economy. It is consistent with the hypothesis that comovement, or divergence, in the fluctuations of different economic sectors and industries, as with the minerals industry, could be that they behave differently to the common endogenous and exogenous shocks. Examining the relationship between these macroeconomic indicators and economic outcomes assists policymakers to anticipate the impact of policy decisions or external shocks and formulate informed decisions about investment, resource allocation and overall economic performance. The fluctuations in macroeconomic indicators are important for aggregate economic performance, 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, prices of commodities and financial assets and foreign exchange rate, affect economic performance, at least theoretically, hence it's important for future research to analyse their impact on the minerals industry.

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