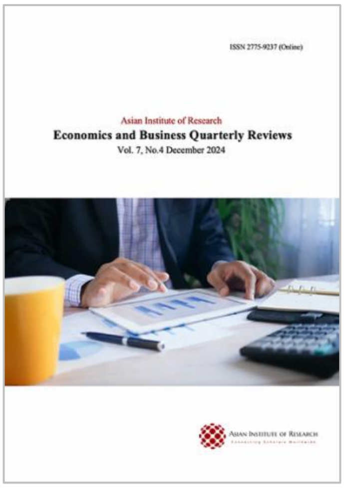

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The Effects of Commodity Prices on Namibia's Business Cycles

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Abstract

The study examined the effects of price shocks in the price of mineral commodities (copper and uranium) on Namibia's business cycles (real GDP) from 1980 – 2018. To estimate the impact of positive and negative changes in commodity prices on business cycles, the study adopted a stepwise least square, Nonlinear Autoregressive Distributed Lag (NARDL) model, and Wald tests to determine cointegration and the presence of asymmetric effects. The findings reveal a long-run cointegration among business cycle (real GDP), commodity (copper and uranium) prices, investment, and export shares of GDP. Moreover, the study unveiled that copper and uranium prices have an asymmetric impact on Namibia's business cycle. Specifically, positive changes (appreciations) for copper and uranium prices significantly impact real GDP more than negative changes (depreciations). Overall, this study supports the Prebisch-Singer Hypothesis, which underscores the importance of industrialisation.

Keywords: GDP, NARDL, Commodity Prices, Copper Prices, Uranium Prices, Business Cycles

1. Introduction

This study examined the effects of commodity price (copper and uranium) shocks on Namibia's business cycles (real GDP). The commodity price-business cycle nexus is among the vital macroeconomic shocks impacting largely commodity-rich countries such as Namibia. Commodity prices in mineral-rich countries play a significant role in the business cycles of those economies. This is considering the considerable impact commodity prices exert on the real GDP growth of mineral and resource-rich economies. Thus, the commodity prices-business cycle nexus is essential to economic agents, macroeconomists, policymakers, and scholars, especially for policy, planning, and decision-making. Therefore, understanding the commodity prices–business cycle nexus for Namibia, a commodity-rich country, is a highly relevant aspect of overall macroeconomic policy. Namibia derives a significant share of its revenue from mineral exports, i.e., diamonds, uranium, gold, copper, etc., to finance its national budget and development. However, the Namibian economy is poorly diversified, relying heavily on the extractive sector (mining) for export earnings and fiscal revenue, and is thus exposed to large and unpredictable fluctuations in commodity prices (AfDB and OECD, 2007).

The impacts of commodity prices on business cycles for different economies have been established in the literature. Yet, the debate about the direction of the effects of commodity prices on business cycles remains lively. Hamilton (1983) documented a significant negative relationship between commodity prices (oil price increases) and economic activity. Specifically, oil shocks contributed to at least some U.S. recessions before 1972. This has been supported by Burbidge and Harrison (1984), Gisser and Goodwin (1986), Bjørnland (2000), Hamilton (2009, 2011), and Stock and Watson, 2012), given different countries.

Regarding commodity price shocks, world price shocks account for a significant fraction of business cycle variability in developing countries (Kose, 2002). Similarly, Houssa, Mohimont, and Otrok (2015) established that commodity shocks are essential in Ghana's and South Africa's business cycles. Jégourel (2018) maintained that cyclicality is one of the critical properties of commodity prices, regardless of their type, and commodity cycles vary in duration and amplitude and are often asymmetrical. Herein, commodity prices are both a cause and a consequence of business cycles, depending on the country, and thus require dedicated measures to ensure that public investment in exporting countries can be sustained. Recently, Mohtadi and Castells-Quintana (2021) asserted that for every country, the extent of a commodity shock depends on the array of commodities exported and the share of each commodity in the country’s total exports.

Academic discourse still rages on whether the impact of commodity prices on business cycles is either linear or nonlinear. For seven South American economies[1], Camacho and Perez-Quiros (2014) proffered evidence on the nonlinear responses of output growth to commodity prices and that their effects on output growth are contingent on the state of the economy, the size of the shock and the sign of the shock. Fossati (2014) documented evidence of a positive and linear relationship between real GDP growth and the growth rate of commodity prices for selected Latin American countries. On the contrary, Liu and Serletis (2022) argued that a common belief postulates a close link between commodity prices and economic growth. Yet, it needs to be clarified whether nonlinear and tail dependence exists in that relation.

Literature has established the commodity prices-business cycle nexus to be more of a short-run phenomenon than a long-run one. Herein, Bjornland (2004) postulated that an oil price shock stimulates the economy temporarily. However, it has no significant long-run impact in Norway. Issa et al. (2008) asserted that the long-run economic growth of commodity-rich countries does not correlate with commodity prices, but short-run economic growth does. Similarly, as Alberola et al. (2017) advanced. Generally, booms in commodity prices tend to raise real GDP in the short term by increasing the value and production of a critical production factor in the economy (natural resources) and lifting the demand for ancillary goods and services.

Even with the numerous works on the commodity price-business cycles nexus, changes in macroeconomic policies have had a significant bearing on the effects of commodity price shocks in some economies. To this end, De Gregorio and Labbé (2011) contended that Chile has become increasingly resilient to copper price shocks (the impact of copper prices on the business cycle has been declining) to macroeconomic policies (a flexible exchange rate, a rule-based fiscal policy, and a flexible inflation targeting regime).

There is a plethora of research works on the effects of commodity price shocks (Blanchard and Galí, 2010; Gubler and Hertweck, 2011; Inoue and Okimoto, 2017; Garcia and Escobar, 2018; Roch, 2019) on macroeconomic variables. However, research on commodity prices-business cycles nexus is scant, especially in sub-Saharan Africa. This is even though economies within sub-Saharan Africa are richly endowed with mineral commodities, which significantly affect these economies’ business cycles. For Namibia, a few macroeconomic models have been developed, i.e., Tjipe et al. (2004), Eita (2011), and Sunde (2015). However, a comprehensive econometric analysis of the effects of commodity price-business cycle nexus has not yet been performed. This study seeks to fill this literature gap, contribute to the commodity price-business cycle discourse for Namibia and sub-Saharan Africa, and inform macroeconomic policy by recommending policy prescriptions for adoption.

The Namibian economy can be disaggregated into three industries: primary, secondary, and tertiary (services). The mining sector, one of the primary industries, is the most significant contributor to the country’s GDP, with an average contribution of 13.1% from 1980 to 2020, while the diamond mining subsector single-handedly averaged 7.0% (or 53.5% of total mining contribution) over the same period (Namibia Statistics Agency, 2021). Moreover,

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[1] Argentina, Brazil, Colombia, Chile, Mexico, Peru and Venezuela.

the mining sector has remained an important foreign exchange earner, as evidenced by the Chamber of Mines' data's revelation that minerals, as a percentage of total exports, averaged 53.0% during the same period. However, the mining sector's importance in exports and foreign exchange earnings indicates that the country is exposed to external shocks in the form of mineral commodity prices inherently determined by international markets. Yet, during the same period, the mining sector registered a decline of 0.2% in average real growth, with fluctuations evident in the sector's growth pattern (Namibia Statistics Agency, 2020). These fluctuations indicate the heightened impact of commodity prices on Namibia's business cycles and external shocks to the overall performance of the mining sector. However, no study has empirically estimated the impact of commodity price shocks on business cycles for the Namibian economy, hence an area warranting comprehensive examination. This is the paper's novelty.

Diamond is the most significant GDP contributor in Namibia's mining sector; however, its price is unavailable; hence, copper and uranium were chosen to capture commodity price shocks owing to their availability. This estimation was made using the nonlinear Autoregressive Distributed Lag (NARDL) as advanced by Greenwood-nimmo (2013) and Shin et al. (2014).

The rest of the paper is structured as follows: Section 2 presents the overview of commodity prices-business cycle nexus; Section 3 discusses the literature review, while the data and methodology are in Section 4; the results and discussion are discussed in Section 5. The conclusions are presented in the last section.

2. Overview of Commodity Price – Business Cycles Nexus

2.1 International commodity price dynamics

Volatility in commodity prices causes instability in exchange rates and fluctuations in growth for developing countries. Commodity price instabilities make commodity-dependent economies, mainly in Africa, more vulnerable to commodity price shocks (UNDP, 2010). One central tenet of these economies, although richly endowed with mineral resources, is that they generally have narrow and limited manufacturing bases and, as such, export commodities in raw form with very limited or no value addition (NPC, 2020). Generally, two strands of literature on drivers of commodity price fluctuations exist amidst others. The first strand argues that oscillations in commodity prices can be attributed to changes in external global demand (Deaton &d Laroque, 1996; Osborn &d Vehbi, 2015; Stuermer, 2018, among others).

The second strand attributes commodity price variations to be driven by global supply factors, including unpredictable and adverse weather conditions (Hamilton, 2008; Cafiero et al., 2011; Kamber, McDonald & Price, 2013). *Table 1* shows selected nominal international commodity prices from which it is evident that all except uranium prices were trending upward from the 1980s to 2018, on average. Moreover, the period from 2010 to 2015 is characterized by a commodity price boom where most prices surged upward. This echoes the commodities boom in the 2000s (or the commodities super cycle experienced from 2000 to 2014), during which rising export earnings contributed to high GDP growth rates and favorable macroeconomic indicators (UNCTAD and FAO, 2017).

Table 1: Selected Commodity Prices (US$ / Unit), average

Commodity	**1980-1985**	**1986-1991**	**1992-1997**	**1998-2003**	**2004-2009**	**2010-2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Copper+	1,632	2,268	2,335	1,660	5,415	7,339	4,868	6,170	6,530	6,010	6,174
Crude oil	31	18	18	23	64	90	43	53	68	61	41
Gold+	424	396	365	299	667	1,384	1,249	1,258	1,269	1,393	1,770
Uranium	22	13	11	10	51	43	26	22	25	26	29
Zinc+	804	8,810	1,095	954	2,079	2,051	2,090	2,891	2,922	2,550	2,266

Source:

+Copper (US$/ metric tonne), Gold (US$/ troy ounce) and Zinc (US$/ troy ounce) prices – the World Bank Pink sheet

*Crude oil (US$/barrel) and Uranium ((US$/pound) prices – IMF World Economic Outlook Database, April2021

2.2 Mining sector developments

Namibia's mining sector has always been the economy's backbone, evidenced by its multi-fold increase in contribution to GDP, economic growth driver, and source of government revenue, amongst others. Moreover, the sector contributed significantly to overall economic development by creating jobs, housing, and poverty reduction. The GDP of the mining sector increased multi-fold from N$ 8.1 billion to N$ 27.0 billion between 2009 and 2018. National accounts data (NSA, 2018) reflect Diamond as the single most significant contributor to GDP, with a contribution of 3.5% and 9.5% in 2009 and 2018, respectively. This was followed by Uranium, which contributed 4.3% and 1.5% in 2009 and 2018.

Namibia is a small, open economy whose openness is evidenced by its openness (trade as % of GDP) indicator, which averaged 97.4% between 1993 and 2018. This implies that it trades significantly with the rest of the world. Data from various annual reviews of the Chamber of Mines (CoM) reflect that since 1993, diamonds have consistently been the most significant mineral commodity export. Furthermore, data from CoM and NSA reveal that between 2010 and 2018, mining exports averaged 43.0% of total exports of goods and services. Of these, exports (as % of total exports of goods and services) of diamonds, uranium, zinc refined, and copper averaged 17.1%, 9.5%, 4.9%, and 4.5%, in that order.

Literature established varying primary commodity export thresholds as a percentage of total exports indicative of a resource-rich country. To this end, Auty (1993) and IMF (2012) postulate a primary commodity export threshold value of at least 40% and 20%, respectively. Similarly, Namibia is classified among other resource-intensive countries (for which non-renewable natural resources represent 25% or more of total exports) within sub-Saharan Africa, according to the IMF (2022). Consequently, according to the established thresholds, Namibia can thus be regarded as a resource-rich country. However, this commodity dependence exposes the Namibian economy to global commodity price dynamics. This view is supported by Acemoglu and Zilibotti (1997), Lederman and Porto (2016), and McIntyre et al. (2018), who proclaimed that the main side effect of commodity dependence is the exposure to sector-specific shocks that trickle down across the economy, increasing their macroeconomic vulnerability and impairing long-term growth.

Some of the Namibian mining sector's stylized facts globally, include being recognised among the top producers of different minerals and among the earliest countries where minerals were discovered. Accordingly, diamonds were first found in Namibia in 1908. In terms of volume and value, Namibia is recognised as the 4th among the leading diamond producing countries within southern Africa, following Botswana, South Africa and Angola, respectively (McKechnie, 2019). Similarly, uranium mining in Namibia dates back to pre-1980, when the first commercial uranium mine began operating as early as 1976. Yet, Namibia has significant uranium mines capable of providing 10% of world mining output (World Nuclear Association, undated). Namibia ranks as the 4th largest producer of uranium after Kazakhstan, Canada, and Australia, according to World Nuclear Association uranium production figures 2011-2020 (World Nuclear Association, undated). From 2011 to 2020, Namibia was the largest uranium producer in SSA, with an average production of 7.6% of the total global total. Its production figures have increasingly been rising significantly above SSA peers.

Namibia is also among the vital copper-producing countries, although more of a significant producer than it is of uranium. According to Copper Development Association Inc. (2021), Namibia's production figures are significantly lower than others; it is the 4th largest in Africa after Zambia, Congo, and South Africa, respectively. Data from the Chamber divulge that the mining revenue (as % of government revenue) averaged 7.2% between 1999/00 and 2018/19.

A narrow manufacturing base and dominant mining sector mineral-rich characterise Namibia. Being a small, open, and commodity-based economy, Namibia is susceptible to global economic outturns (booms and recessions) owing to volatile commodity prices. Thus, the dependency on the mining sector has concerned policymakers, considering that minerals are exported in their raw form without any value addition. Yet, as outlined in NPC (2021), only a few minerals have value addition, i.e., Gold (gold bars), Diamonds (diamond polishing and processing), Copper (copper smelting – copper cathodes), and Zinc (Zinc processing leading to 99.99995% pure zinc).

This slow structural transformation is even though the country's long-term aspirations, as articulated in Vision 2030 (Republic of Namibia, 2004) are to become a prosperous and industrialised. At the core of the vision is industrialisation, which would ultimately lead to the country's structural transformation. Consequently, various policies, i.e., National Development Plans, Industrialization Policy, and Growth at Home strategy, were adopted to transform the status quo. These policies advocated for increased manufacturing (value addition), of which primary industries (extractive sectors, agriculture, and mining) were to play a significant role in the transformation trajectory.

The Joint Value Addition Committee was established in 2013, after which an in-depth analysis of the beneficiation possibilities for Namibia's essential mineral commodities and opportunities for value addition was done (Mines and Energy, 2013). Moreover, the government introduced an export levy to incentivise value addition. However, as Hausmann et al. (2022) established, Namibia's economy is comparatively less complex, and attractive opportunities to diversify tend to be more distant when assessed within the lenses of economic complexity (a measure of knowhow agglomeration vis-à-vis its peers). Yet, the researchers identified 97 products with potential for diversification, which were grouped into five diversification schemes: (i) Chemicals & Basic materials, (ii) Food industry, (iii) Machinery and electronics, (iv) Metals, mining, & adjacent industries, and (v) Transportation & logistics.

Namibia Statistics Agency's data shows that average manufacturing contribution to GDP was stagnant (below 20.0%) between 1980 and 2018. This is notwithstanding the noble policies aimed at ensuring the achievement of industrialisation. The structural transformation has not matched expectations. The commodity boom experienced from 2001 to 2007 spurred the mining sector's average 11.7% growth, more than double the average real GDP growth of 5.4%. Yet, Namibia's mining sector growth has been characterised by volatility.

3. Literature Review on Commodity Prices and Business Cycles

3.1 Theoretical foundations of Business Cycles and Commodity Prices

Burns and Mitchell (1946) postulate that business cycles are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; in duration, business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar characteristics with amplitudes approximating their own.

The Prebisch-Singer Hypothesis (PSH) claims that the terms of trade of economies dependent on primary commodities tend to worsen in the long run because of the secular decline of primary commodity prices relative to the prices of manufactured goods (Singer, 1950; Prebisch, 1950).

The Real Business Cycle (RBC) is the natural and efficient response of the economy to changes in the existing production technology. The RBC argues that recessions and booms efficiently respond to exogenous changes in the natural economic environment. It assumes that there are large random fluctuations in the rate of technological change. Individuals rationally adjust their labour supply and consumption levels in reaction to these fluctuations (Mankiw, 1989).

According to the Keynesian Business Cycle Theory, the economy is inherently unstable, given that economic activity overshoots and undershoots the growth path (Cloete, 1990). The Keynesian school points out that the existence of a business cycle is evidence of the failure of the price mechanism to coordinate demand and supply in the markets for goods and services and factors of production (Cloete, 1990). It argues that prices respond with a time lag to changes in demand. This results in a level of economic activity that tends to be continually above or below its equilibrium level.

3.2 Empirical works on the effects of Commodity Prices on Business Cycles

The commodity price-business cycle nexus for different regions and economies has been established in the literature. Researchers who pursued single-country studies include Medina and Soto (2007), who adopted a DSGE for Chile and found that if the fiscal policy is conducted using a structural balance fiscal rule, such that the government saves most of the extra revenues from the higher copper price, then a copper price shock of 10% would increase output only by 0.05%. There would be a slight decrease in inflation. On the flip side, however, scholars posit that when fiscal policy is highly expansive, the same copper price increase implies an output growth of up to 0.7%, while inflation will also increase. Fuentes and García (2016) implement the same econometric approach for Chile and establish that a rise of 1% in the copper price leads to a 0.16% increase in GDP over five years. For Spain, Cantavella (2020) adopted the NARDL approach and observed that an increase (decrease) in accurate oil prices has a negative (positive) impact on real per capita GDP. The negative effect (oil price decrease) affects real per capita GDP more than the positive effect (oil price increase).

Some researchers undertook multi-country analyses to unravel the impacts on different regions. Interestingly, the findings remain polarised for Emerging Markets and Developing Economies (EMDEs) in the other areas. Following this, Elafif et al. (2017) adopted a NARDL technique for Turkey (Emerging and Developing Europe) and Saudi Arabia (Middle East) and revealed contrasting findings. First, an increase (decrease) in the oil price causes a rise (fall) in the real GDP of Saudi Arabia. However, the positive effect (oil price increase) has a more significant effect than the negative effect (oil price decrease). Moreover, an increase (decrease) in the oil price causes Turkey's real GDP to fall (rise). Yet, the negative effect (oil price decrease) has a greater effect than the positive effect (oil price increase).

Ogundipe (2020) conducted a multi-country study on fifty-three African commodity-dependent countries through a System of Generalized Method of Moments (SGMM) and established that about 3.8% variation in real GDP was induced by a 1% change in commodity price volatility. Furthermore, it finds a negative contemporaneous relationship between commodity price volatility and growth. Consequently, confirms the prominent Prebisch-Singer hypothesis that commodity-dependent exporting countries tend to experience worsening macroeconomic conditions in the long run.

World Bank (2021) asserted that in copper EMDE exporters, economic activity increased statistically significantly after a copper price increase. They also establish asymmetric responses in copper exporters; copper price jumps increased output in copper exporting EMDEs by 0.07% after two years, but then the effect dissipated. Conversely, a copper price collapse, on the other hand, lowered output by more than three times as much (0.22%) two years after the shock, and the effect remained significant for three years. However, compared to copper, aluminium price shocks were not followed by statistically substantial output changes. These differences reflect the lower reliance on aluminium exports for aluminium exporters than the copper reliance for copper exporters. Literature on single-country studies globally (including SSA) in support of the commodity price–business cycle nexus remains scanty. Also, to the researcher’s knowledge, no empirical study has been undertaken to quantify these effects for Namibia.

4. Data and Methodology

4.1 Data, Description and Source

This study adopted an annual time series spanning 1980 to 2018, which covers Namibia’s pre- (prior to 1990) and post-independence (1990-2018) periods. This has rich endowments of several events impacting the commodity price-business cycle nexus. These include the Iran–Iraq war of 1980-1981; the U.S. recession of 1990-1991; the Asian Financial Crisis of 1998-2000; the commodities boom in the 2000s (or the commodities super cycle experienced from 2000 to 2014); the Global financial crisis of 2008-2009; among others.

The study adopted a five-variable model reflecting two international commodity prices (copper and uranium prices expressed in real US$ per metric tonne and real US$ per pound, respectively), one business cycle variable (real GDP reflected in US$) and two control variables [investment and exports shares of GDP, expressed as a percentage (%)]. In the analysis, asymmetric copper and uranium price changes were used. To this end, positive copper price changes (CP^{+}) and positive uranium price effects (UP^{+}) are distinguished from negative copper price changes (CP^{-}) and negative uranium price changes (UP^{-}), correspondingly. The data were derived from the World Bank's World Development Indicators, World Bank's Commodity Price Data (the Pink Sheet), IMF World Economic Outlook, and Namibia Statistics Agency.

On the choice of business cycle indicator, Teräsvirta and Anderson (1992) they are cautioned that it is convenient to select one that shows as much cyclical variation as possible whenever the non-linearity of business cycles is studied. In reinforcing this, Botha (2004), Aigheyisi (2018), and Yan and Huang (2020) adopted the real GDP growth (year-over-year), fluctuations, or volatility as the representative or proxy variable for the business cycle. Based on these studies, real GDP is chosen as the business cycle indicator in this study.

Deaton (1999); Dehn (2000); Collier and Goderis (2012); and Gruss (2014) established the impact of commodity price shocks on business cycles or business cycle indicators i.e. GDP. Most studies on commodity prices-business cycle nexus adopted quarterly data. However, this study adopted a low-frequency annual time series due to the unavailability of high-frequency data (i.e., quarterly).

4.2 Model Specification and Estimation Approach

Greenwood-nimmo (2013) and Shin et al. (2014) advanced the well-known Autoregressive Distributed Lag (ARDL) model of Pesaran and Shin (1999) and Pesaran, Shin, and Smith (2001) to the nonlinear ARDL cointegration approach (NARDL) which has nonlinearity properties to detect asymmetries in both short-run and long-run among the variables. Also, the NARDL technique is superior to standard cointegration (i.e. Engle-Granger and Johansen) as it permits simultaneously modeling asymmetric nonlinearity and cointegration among underlying variables in a single equation context. Botha (2004) advanced that non-linear models learn over time and adjust to the new levels of peaks and troughs and can, therefore, predict turning points more accurately.

Camacho and Perez-Quiros (2014) asserted that examining the effects of commodity price shocks on output growth, which is crucial in designing counter-cyclical stabilization policies in the Latin American region, is essentially nonlinear and multivariate. Also, a long-term relationship between output and commodity prices has not been detected for selected Latin American countries. Despite the numerous works on business cycles, Kamber *et al*. (2016) cautioned that no model could include all the factors that might be relevant for understanding the business cycle. Following empirical literature review, the economic models with respect to copper and uranium prices are written as follows:

$$GDP_t = f(CP_t, INV_t, MXP_t) \tag{1.1}$$

$$GDP_t = f(UP_t, INV_t, MXP_t) \tag{1.2}$$

Where:
GDP_t = Gross Domestic Product (reflected as the business cycle variable);
CP_t = copper price;
UP_t = uranium price;
INV_t = investment share of GDP (%)
MXP_t = exports (% of GDP).

Next, equations 1.1 and 1.2 are log-transformed into natural logs reflecting the two commodity prices of interest:

$$LNGDP_t = \beta_0 + \beta_1 LNCP_t + \beta_2 LNINV_t + \beta_3 LNMXP_t + e_t \tag{1.3}$$

$$LNGDP_t = \alpha_0 + \alpha_1 LNUP_t + \alpha_2 LNINV_t + \alpha_3 LNMXP_t + \pi_t \tag{1.4}$$

Where e_t and π_t residuals that are assumed to be white noise are represented β_0, β_1, β_2, β_3 and α_0, α_1, α_2, α_3 are the vectors of long-run coefficients; all other variables are as previously defined.

According to economic theory, when commodity prices (for copper and uranium in this case) rise, it increases exports earnings and value for those minerals in commodity exporters (Collier & Goderis, 2012; Cavalcanti, Mohaddes & Raissi, 2012). This will improve the country's net export position, positively impacting output. Therefore, the effect of an increase in commodity prices on output is expected to be positive. Also, upsurges in investment and exports positively impact GDP according to the Keynesian theory.

Following Shin, Yu and Green-wood-Nimmo (2014), the nonlinear ARDL technique was implemented. The commodity prices can be decomposed into negative and positive partial sums. To this end, the asymmetric impact of commodity prices (copper and uranium prices) is accounted for by including their positive changes ($LNCP_t^+$and $LNUP_t^+$) and negative changes ($LNCP_t^-$ and $LNUP_t^-$). These reflect the partial sums of positive and negative commodity prices. Specifically, the partial sums for copper prices are as follows:

$$the\ \Delta CP_t^+ = \sum_{i=1}^{t} \Delta CP_i^+ = \sum_{i=1}^{t} \max\,(\Delta\, CP_i, 0) \text{ and } \Delta CP_t^- = \sum_{i=1}^{t} \Delta CP_i^- = \sum_{i=1}^{t} \min\,(\Delta\, CP_i, 0)$$

Similarly, the partial sums for uranium prices are:

$$\Delta UP_t^+ = \sum_{i=1}^{t} \Delta UP_i^+ = \sum_{i=1}^{t} \max\,(\Delta\, UP_i, 0) \text{ and } \Delta UP_t^- = \sum_{i=1}^{t} \Delta UP_i^- = \sum_{i=1}^{t} \min\,(\Delta\, UP_i, 0)$$

Given the linear specifications of equations (1.3) and (1.4), it is impossible to capture the asymmetric impact of copper and uranium price changes. Thus, there is a need to account for asymmetries in the relationship between copper price and GDP on the one hand and uranium price and GDP on the other. Subsequently, equation (1.3) can be specified in nonlinear form as follows:

$$\begin{aligned}\Delta LNGDP_t = {} & \gamma_0 + \beta_1 LNGDP_{t-1} + \gamma_1^+ LNCP_{t-1}^+ + \gamma_2^- LNCP_{t-1}^- + \beta_4 LNINV_{t-1} + \beta_5 LNMXP_{t-1} \\ & + \sum_{i=1}^{p} \varphi_1\, \Delta LNGDP_{t-i} + \sum_{i=0}^{q} \varepsilon_1^+ \Delta LNCP_{\text{t-i}}^+ \qquad (1.5) \qquad + \sum_{i=0}^{q} \varepsilon_2^- \Delta LNCP_{t-i}^- \\ & + \sum_{i=0}^{q} \varphi_4\, \Delta LNINV_{t-i} + \sum_{i=0}^{q} \varphi_5\, \Delta \mathrm{LNMXP}_{t-i} + e_t\end{aligned}$$

Where Δ is the first difference operator; LN is the natural logarithm of the variables; γ_0 is the drift; e_t is white noise error; p and q are lag orders, $\gamma_i's$ are the short-run asymmetry coefficients while ε_i, the long-run asymmetry coefficients (effect of positive and negative copper price changes on GDP) are calculated as $\beta_2 = \frac{\gamma_1^+}{\beta_1}$ and $\beta_3 = \frac{\gamma_2^-}{\beta_1}$; β_1 and φ_1 are the lagged effects. Also, $\sum_{i=0}^{q} \varepsilon_1^+$ captures the short-run impact of copper price increase on real GDP while $\sum_{i=0}^{r} \varepsilon_2^-$ Captures the short-run impact of a copper price decrease on real GDP. Similarly, equation (1.4) can be specified in nonlinear form as follows:

$$\begin{aligned}\Delta LNGDP_t = {} & \theta_0 + \alpha_1 LNGDP_{t-1} + \delta_1^+ LNUP_{t-1}^+ + \delta_2^- LNUP_{t-1}^- + \alpha_4 LNINV_{t-1} + \alpha_5 LNMXP_{t-1} \\ & + \sum_{i=1}^{p} \vartheta_1\, \Delta LNGDP_{t-i} + \sum_{i=0}^{q} \epsilon_1^+ \Delta LNUP_{t-i}^+ \qquad (1.6) \qquad + \sum_{i=0}^{q} \epsilon_2^- \Delta LNUP_{t-i}^- \\ & + \sum_{i=0}^{q} \vartheta_4\, \Delta \mathrm{LNINV}_{\mathrm{t-i}} + \sum_{i=0}^{q} \vartheta_5\, \Delta \mathrm{LNMXP}_{\mathrm{t-i}} + \pi_t\end{aligned}$$

Where Δ is the first difference operator; LN is the natural logarithm of the variables; θ_0 is the drift; π_t is white noise error; p and q are lag orders; $\delta_i's$ are the short-run asymmetry coefficients while ϵ_i, the long-run asymmetry coefficients (effect of positive and negative copper price changes on GDP) are calculated as $\alpha_2 = \frac{\delta_1^+}{\alpha_1}$ and $\alpha_3 = \frac{\delta_2^-}{\alpha_1}$; α_1 and ϑ_1 are the lagged effects. Furthermore, $\sum_{i=0}^{q} \epsilon_1^+$ captures the short-run impact of uranium price increase on real GDP while $\sum_{i=0}^{r} \epsilon_2^-$ Captures the short-run impact of a copper price decrease on real GDP. The dynamic NARDL models computed in equations (1.3) and (1.4) were used to perform the bound-testing procedure proposed by Pesaran et al. (2001) to establish whether variables are cointegrated (i.e., exhibit a long-run relationship). Also, the standard Wald test was applied to uncover the existence of asymmetric relationship as among variables in the long run and in the short n.

4.3 Tests for Unit Root

The Augmented-Dickey Fuller (ADF) and the Phillips-Perron (PP) Tests were applied to test the unit roots. Stationarity of variables must be checked before using the ARDL model to ensure that no series is stationary at I(2); otherwise, the outcomes will be incorrect (Ofori-Abebrese et al., 2017; Wong & Shamsudin, 2017; Khan et al., 2019). Pesaran et al., (2001) proffered that the ARDL method can be applied where the time series is stationary at levels [I(0)] or stationary at first differences or fractionally integrated [I(1)]. Moreover, within the ARDL framework, the series should not be I(2) since this integration order invalidates the F-statistics and all critical values established by Pesaran. Cointegration of the variables is also often empirically established. Herein, Brooks (2008), proffered that in most cases, if two variables that are I(1) are linearly combined, then the combination will also be I(1).

5. Results and Discussion

5.1 Unit root tests

The unit root tests revealed that one variable (LNMXP) is stationary at level I(0), whereas four variables (LNGDP, LNCP, LNUP, and LNINV) are integrated in the first order I(1) (*Table 2)*. The variables are I(0) and I(1), with none is I(2), thereby justifying the appropriateness of the ARDL model for the analysis (Pesaran, Shin, and Smith, 2001).

Table 2: Unit root tests

Variable	**ADF**		**Order of integration**	**PP**		**Order of integration**
	Level	**1st Difference**	**I(1)**	**Level**	**1st Difference**	**I(1)**
LNGDP	-3.048183	-4.372643**	I(1)	-3.091208	-4.224651**	I(1)
LNCP	-2.243143	-5.213096**	I(1)	-2.243143	-5.163415**	I(1)
LNUP	-2.131240	-4.209574**	I(1)	-2.224255	-4.226284**	I(1)
LNINV	-1.938428	-4.913236**	I(1)	-2.295604	-4.910336**	I(1)
LNMXP	-3.544264**		I(0)	-3.613294**		I(0)

Note: ** Implies rejection of the null hypothesis at a 5% significance level.

Source: Author's computation.

5.2 Cointegration Test Results

The study applied Wald F-test statistics to determine whether there is asymmetric cointegration between commodity prices and real output in Namibia. The decision rule is such that if the F-statistic is more significant than their respective Pesaran upper bound critical values at the 5% level of significance, then there is cointegration. This, in other words, implies that there is a long-run relationship among the variables. Yet, there would be no cointegration should the F-statistic fall below the lower bound and undetermined should it have fallen in between the lower and upper bounds. Table 3 presents the cointegration results, which confirm the cointegration for both linear and nonlinear models for the two commodities.

Table 3: Bounds Test for Linear / Non-Linear Cointegration

Model 1 – Copper prices

Model specification	F-statistic	Lower bound I(0) critical value	Upper bound I(1) critical value	Conclusion
Linear	4.854213	2.79	3.67	Cointegration
Nonlinear	3.562881	2.56	3.49	Cointegration
Model 2 – Uranium prices				
Linear	5.335273	2.79	3.67	Cointegration
Nonlinear	6.556687	2.56	3.49	Cointegration

Note: decisions made at a 5% significance level. The optimal lag order was based on AIC.

Source: Author’s calculations.

5.3 NARDL Lon-run and Short-run/ECM Estimation

After confirming nonlinear cointegration, the NARDL long-run parameters for commodity prices (copper and uranium prices) are estimated (Table 4). Results reveal that the decomposed positive effects of copper prices are significant at 1%, while the decomposed adverse effects are not significant even at 10%. The estimated long-run parameters for positive and negative copper price shocks are 0.315 and -0.088, respectively. Thus, a positive copper price shock exerts a more significant impact on real GDP than a negative shock, whose impact on real GDP is negative.

Unlike copper prices, the decomposed positive and negative effects of uranium prices are highly significant at 1%. In that order, the estimated long-run parameters for positive and negative uranium price shocks are 0.139 and -0.185. Like the effects of copper price shocks, this exemplifies that a positive uranium price shock exerts the most significant impact on real GDP (positive effect) compared to adverse shocks, whose impact on real GDP is negative. Overall, the finding that both positive shocks for copper and uranium prices are positive is in line with economic theory and implies that the positive shocks (increase) impact actual economic activity positively.

Table 4: NARDL long-run parameter estimation (copper and uranium prices)

Model 1 – Copper prices		
Exogenous variables	**Parameters**	**P-values**
LNCP_POS	0.315032	0.0000***
LNCP_NEG	-0.087911	0.1596
LNINV	0.085016	0.2619
LNMXP	-0.311213	0.0702*
C	22.94052	0.0000***
Selected Model: ARDL(4, 3, 3, 0, 3)		
Model 2 – Uranium prices		
Exogenous variables	**Parameters**	**P-values**
LNUP_POS	0.139384	0.0000***
LNUP_NEG	-0.184955	0.0000***
LNINV	0.094579	0.0237**
LNMXP	-0.166965	0.0979*
C	22.21100	0.0000***
Selected Model: ARDL(1, 1, 2, 0, 0)		

Note: *** 1% significance level, ** 5% significance level, * 10% significance level.
Dependent Variable: D(LNGDP).

Source: Author’s calculations.

Next, the study estimates short-run models for copper and uranium prices shown in Table 5. Results reveal that positive shocks (appreciations) are positive and statistically significant at 1%, whereas negative shocks (depreciations) for both commodity prices are not statistically significant even at a 10% significance level. Therefore, the short-run estimated results corroborate those of the long run, specifically given positive shocks. This finding aligns with economic theory and implies that the positive shocks (increase) impact real economic activity positively.

The finding that the positive effects of commodity prices have a positive impact on real GDP corroborates Fuentes and García (2016) and Vallejo (2017). They are also congruent with Deaton and Miller (1995) and Raddatz (2007), in view of Africa and low-income countries, who found that higher commodity prices significantly raise income in the short run. Whereas the resource literature predicts an ambiguous effect of commodity booms on long-run growth, empirical studies by Deaton and Miller (1995) for Africa and Raddatz (2007) for low-income countries established that higher commodity prices significantly raise income in the short run.

The ECT_{t-1} term was negative and statistically significant at 1% for both commodity price models. This is in line with a priori expectation, thus confirming a stable and robust asymmetric long-run relationship between real GDP and the two commodity prices as previously established by the result of the Wald test for cointegration in Table 4. The estimated error correction terms for copper and uranium prices are -0.538 and -0.505, correspondingly. This implies that about 53.8% and 50.5% of the disequilibria in copper and uranium prices are corrected within one year.

The R-squared for the copper and uranium price models are 0.641 and 0.520, respectively. This implies that the regression model explains 64.1% and 52.0% of the variability observed in real GDP for the copper and uranium price models, respectively. Moreover, the Durbin-Watson statistic for both copper and uranium price models is closer to two (2), confirming the absence of autocorrelation.

Table 5: Short-run NARDL estimation (copper and uranium prices)

Model 1 – Copper prices		
Exogenous variables	**Parameters**	**P-values**
Δ(LNGDP(-1))	0.405843	0.0184**
Δ(LNGDP(-2))	-0.238808	0.3118
Δ(LNGDP(-3))	-0.350951	0.1003
Δ(LNCP_POS)	0.153033	0.0011***
Δ(LNCP_POS(-1))	-0.114901	0.0232**
Δ(LNCP_POS(-2))	-0.114632	0.0276**
Δ(LNCP_NEG)	0.097056	0.1278
Δ(LNCP_NEG(-1))	0.114396	0.0803*
Δ(LNCP_NEG(-2))	0.127885	0.0360**
Δ(LNMXP)	0.029138	0.5969
Δ(LNMXP(-1))	0.126408	0.0431**
Δ(LNMXP(-2))	0.079206	0.1397
CointEq(-1)*	-0.538362	0.0001***
R-squared	0.641037	
Durbin-Watson stat	2.289480	
Model 2 – Uranium prices		
Exogenous variables	**Parameters**	**P-values**
Δ(LNUP_POS)	0.133330	0.0000***
Δ(LNUP_NEG)	-0.026718	0.2453
Δ(LNUP_NEG(-1))	0.077310	0.0118**
CointEq(-1)*	-0.505071	0.0000***
R-squared	0.520404	
Durbin-Watson stat	1.811052	

Note: *** 1% significance level, ** 5% significance level, * 10% significance level. Dependent Variable: D(LNGDP). Source: Author's calculations.

5.4 Model Stability

The results of CUSUM and CUSUM of squares tests for copper and uranium price models are presented in Figure 1, confirming that they lie within the 5% band, thereby confirming both models' stability.

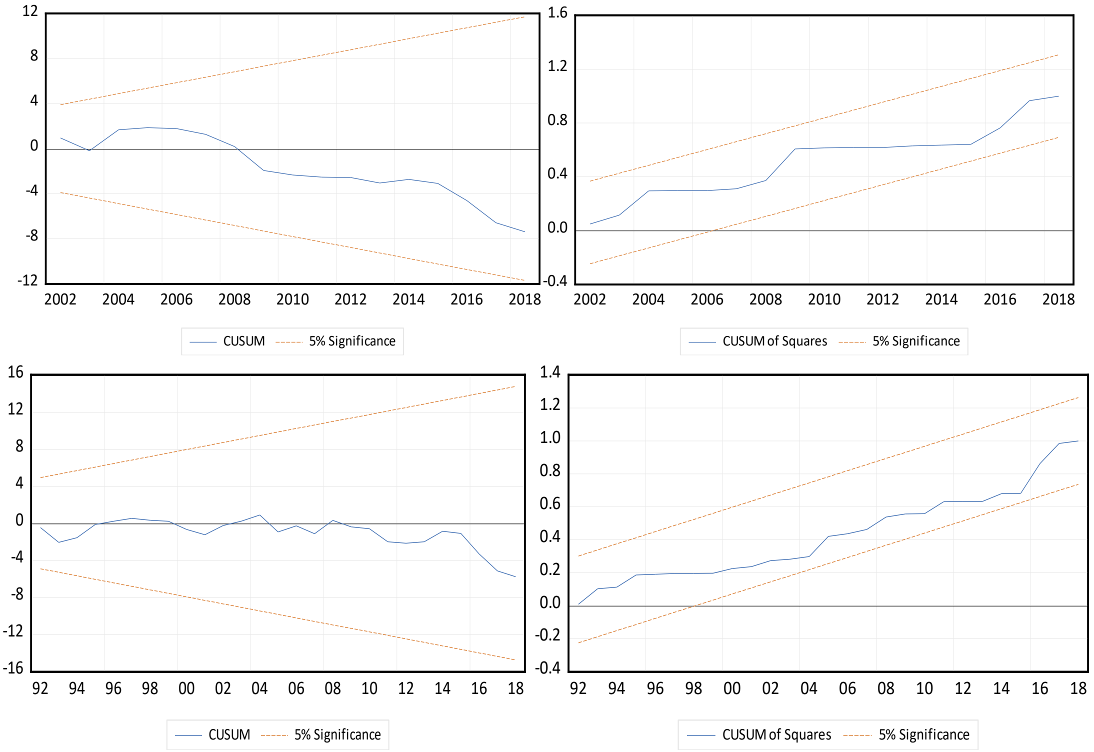

Figure 1: Results of Model Stability (CUSUM and CUSUMSQ) Tests

*Note: Copper prices – the first two horizontal panels; Uranium prices – the bottom two panels

Source: Author's construct using EViews 11.

5.5 Asymmetric Cointegration Test Results

They examined whether the coefficients are symmetrical or asymmetrical in the long run through the Wald Coefficient diagnostic tests. To test for the long-run asymmetry between commodity prices (copper and uranium prices) and the business cycle (GDP) in Namibia, the null hypothesis is H_0: No asymmetry (equality) against the alternative H_1: there is asymmetry. *Table 6* presents the results of the joint asymmetric test whose p-values are less than 0.05 for both the copper and uranium prices models, thereby indicating rejection of the equality null hypothesis at a 5% significance level. This confirms that there is a long-run asymmetric relationship among the variables for both copper and uranium price models.

Table 6: Joint asymmetric test

Model	Asymmetric test	F-statistics	p-value
Copper prices	$\beta_1 = \beta_2 = \beta_3 = \beta_4 = 0$	3.335127	0.0200**
Uranium prices	$\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = 0$	5.452661	0.0024***

Note: *** 1% significance level, ** 5% significance level, * 10% significance level

Source: Author's computation.

Table 7 presents the results of the Wald coefficient long-run asymmetric test. Since the p-values are less than 0.05 for the two models, the null hypotheses are rejected, thus confirming that there is inequality (asymmetry) and that the coefficients for positive and negative effects are not the same in the long run.

Table 7: Wald Coefficient (Long-run) asymmetric test

Model	Asymmetric test	F-statistics	p-value
Copper prices	Long run: $-\gamma_1^+/\beta_1 = -\gamma_2^-/\beta_1$	134.3262	0.0000***
Uranium prices	Long run: $-\delta_1^+/\alpha_1 = -\delta_2^-/\alpha_1$	704.0470	0.0000***

Note: *** 1% significance level. Source: Author's computation.

5.6 Diagnostic Tests

Residual diagnostic tests such as Breusch-Pagan-Godfrey (BPG) for heteroscedasticity, Jarque-Bera for normality, and Breusch-Godfrey Serial Correlation LM were performed to validate the results of the NARDL models. *Table 8* reveals that the optimal models passed all the conventional and stability tests (p-values > 0.05); hence, they are homoscedastic, normally distributed, and free from serial correlation. Additionally, the p-values are more significant than 0.05 for Ramsey's test, confirming that both models are free from specification error (correctly specified).

Table 8: Results of the Residual Diagnostic and Stability Tests

Model 1 – Copper prices		
Test	**Test-Statistic***	**Probability**
BPG for heteroscedasticity	1.698044	0.1424
Jarque-Bera (JB) for normality	0.609021	0.7375
Breusch-Godfrey (BG) Serial Correlation LM	1.644007	0.2225
RESET for model specification	0.304283	0.5888
Model 2 – Uranium prices		
Test	**Test-Statistic***	**Probability**
BPG	1.247434	0.3109
JB	0.918426	0.6318
BG	0.158694	0.8541
RESET	0.350210	0.5591

*Note: F-statistic – BPG, BG and RESET tests; the JB statistic – JB

Source: Author's computation.

6. Conclusions

The study examined the effects of commodity prices on Namibia's business cycles from 1980 to 2018. Herein, commodity prices (copper and uranium prices) and real GDP (a proxy for business cycles) were adopted through the NARDL approach. The outcomes reveal a long-run cointegration among business cycle (real GDP), commodity (copper and uranium) prices, investment, and export shares of GDP. Both copper and uranium prices have unveiled asymmetric impacts on Namibia's business cycle. Herein, positive changes for copper and uranium prices have the most significant impact on real GDP than negative changes.

These underlying results have important policy implications for the mineral resource-rich Namibia. The study recommends the extraction of mineral commodities, especially during commodity booms, to boost economic growth and development. Proceeds and windfall revenues from mineral resources during booms can be saved in the wealth fund to be utilised during periods of depressed commodity prices. Furthermore, diversification of its export basket from predominantly mineral resource exports (as is currently) is strongly emphasised to mitigate the impacts from commodity shocks. Overall, this study supports the Prebisch-Singer Hypothesis, which underscores the importance of industrialisation to realise the advantages of technical progress.

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