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Economics of HIV Prevention: Understanding the Empirical Intersection between Commodity Price Shocks, Health Spending and HIV Infections in Developing Countries

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Abstract: Background: This study seeks to understand the empirical nature of macro-financial factors associated with the worsening of HIV infections and the risks that need to be carefully monitored for a sustainable improvement in HIV outcomes as developing countries seek to achieve the United Nations 95-95-95 targets. Methods: The author used a panel VAR model to study the long-term endogenous relationships between percentage changes in the annual spot price of the most traded commodities, GDP per capita, health spending, and the HIV infection rate of developing countries. Results: The author discovered that shocks of global commodity prices negatively impact GDP per capita, real government health spending, and real private health spending. These shocks have adverse spillover effects characterized by worsening HIV infections. The reactions from price shocks suggest that GDP per capita contract immediately when a commodity price shock hits developing economies. Real government health spending and real private health spending also contract instantly. HIV infections begin worsening three years after the shock in the energy and precious metal blocks of countries. HIV infections also begin to worsen two years after shocks in the agricultural block of counties. These impacts are statistically significant and can potentially reverse the positive HIV infection gains achieved in the previous years. Emergency funds, insurance schemes, and international aid for HIV need to discharge more funds to counter these shocks. Conclusions: There is a significant risk of reversing HIV infection outcomes arising from commodity price shocks. Funding agencies must protect HIV prevention services from global macro-economic shocks as countries move closer to the United Nations 95-95-95 targets.

Keywords: economic shocks; HIV infections; health spending

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1. Introduction

Since the world adopted the sustainable development goals (SDGs) in 2015, global health spending has increased, reaching $7.9 trillion in 2017, and is expected to increase to $11·0 trillion by 2030 [1]. Spending on HIV programs has also increased. For example, in 2017, developing countries' spending on HIV/AIDS was $20·2 billion [1]. This figure increased beyond $30 billion in 2019, driven by the generosity of international funding agencies.

Although global health spending has increased across HIV/AIDS programs since 2015, limited studies have been conducted to estimate these funds' efficacies in maximizing improvements in HIV outcomes [2]. Furthermore, few studies examine the intersection between economic shocks, health spending, and HIV outcomes—especially in developing countries [3].

Globally, it is a documented fact that an increase in commodity prices causes an improvement in government revenue, which boosts the economy of commodity-dependent countries [4]. The high-commodity price supports government spending. In contrast, a decline in commodity prices negatively affects economic performance and government spending [5]. Most scholars argue that commodity price shocks have significant impacts

on commodity-dependent countries, triggering downward spending from government programs [4–6]. However, these scholars have not been able to provide a unanimous position about the groups of commodities that produce the largest shocks and how such shocks affect spending on government programs. Such a gap is of high priority in developing countries, considering that most of these countries depend on commodity prices for economic growth and government spending on national-priority programs [7].

Hence, there is an extensive demand for studies examining the dynamics of commodity price shocks in different countries and how such shocks affect economic development (GDP per capita), health spending, and HIV infection rates, since HIV programs remain a top priority in many developing countries.

So far, there is evidence that economic growth and a high GDP per capita drive improvement in health spending in developing countries [8]. Such health spending improves HIV outcomes [9], especially with today's advanced technologies like the HIV self-test [10]. However, it remains to be seen if economic shocks negatively impact health spending and if such shocks cause worsening HIV outcomes in developing countries.

Currently, there is limited evidence on how economic shocks worsen HIV outcomes globally [11]. In the few studies reported so far, declining healthcare budgets were associated with increased HIV deaths and new cases of HIV infections [12]. There is, however, scope to improve the literature, especially for developing countries given the diverging contexts of the 20th century and these countries' reliance on raw commodities for economic growth, development, and government spending [7,13,14].

Mekasha et al., 2022 [15] argued that the earnings from commodity sectors drive economic development and health outcomes in developing countries. Hence, by analyzing commodity price shocks, one can likely understand the potential failure in improving HIV outcomes from this specific type of economic fluctuation. Such risks need to be carefully monitored by policymakers in order for HIV programs to continue to deliver sustainable improvement outcomes [16].

In Greece, the recent economic shocks worsened HIV infections [17] and the declining GDP worsened HIV infections. Other papers cite the declining affordability, health spending, and access to healthcare as responsible for worsening health outcomes [18].

Building on the Greek literature, this paper explores how global commodity price shocks affect economic development, health spending, and HIV infections in developing countries. This set of indicators has the potential to offer a comprehensive guide to the macro-financial risks of HIV infections in developing countries.

The current study contributes to the mainstream literature in two ways. Firstly, this empirical analysis informs the ongoing health spending and HIV prevention efforts about the lessons from the previous economic shock episode on how it had affected HIV infection outcomes. Secondly, this study also enlightens developing countries about the financial restraints of the recent COVID-19 economic shocks and how such activities may affect the UN's goals of averting HIV infections.

This paper seeks to answer the following questions: (1) How do commodity price shocks affect economic development, health spending, and HIV infections in developing countries, and (2) what factor(s) determine the resilience of a health system towards averting HIV infections during commodity price shocks (fall in prices).

2. Material and Methods

2.1. Data

For country selection, the author initially considered all developing countries relying on commodities as primary source of income from 1995 to 2019. The author opted to analyze 1995–2019 to capture both the boom and bust of commodity prices.

The eligibility criteria for choosing the listed developing countries included in this paper were influenced by three factors:

1. The country must be considered a commodity-dependent country—exporting commodities in one of the three commodity-export sectors (agricultural products, precious

metals, and energy commodities) as defined by the United Nations Conference on Trade and Development (UNCTAD) (See Table 1).
2. According to the International Monetary Fund (IMF), UNCTAD, or Morgan Stanley Capital International (MSCI) classification, the country must be considered a developing country.
3. Without gaps, the country must have at least 30 years of consecutive annual data for macro-economic variables presented in World Bank or IMF databases.

Table 1. Countries considered for the analysis.

Metal Block	Energy Block	Agricultural Block
Brazil (Tin and iron ore)	Gabon (Crude oil)	Honduras (Coffee)
Jamaica (Alumina)	Egypt (Crude oil)	Kenya (Tea)
Peru (Copper)	Indonesia (Crude oil)	Mali (Cotton)
Ukraine (Coal)	Malaysia (Natural gas)	Paraguay (Sugar)
Zambia (Copper)	Nigeria (Crude oil)	Sri Lanka (Cocoa)
Zimbabwe (Platinum)	Russia (Natural gas)	Uruguay (Soyabeans)

Ultimately, 18 countries satisfied the screening criteria to be included in this study (See Table 1). After that, the author categorized the countries based on the commodity sector dependence as presented by UNCTAD [19]. The author then created panels comprising six agriculture-export-dependent countries, six precious-metal-dependent countries, and six energy-dependent countries.

Considering that the theoretical model was created to examine the fluctuations in price movements, the author had to transform the data by taking log values and detrending them using the Hamilton filter [20] to obtain the cyclical components of the data. Sources for the datasets are presented in Table 2.

Table 2. Data source.

Variable	Data Source
Commodity prices	World Bank & Bloomberg
GDP per capita	World Bank & Bloomberg
Real government health spending (RGH)	World Health Organization & Business Monitor International
Real private health spending (RPH)	World Health Organization & Business Monitor International
HIV infections	Institute of Health Metrics and Evaluation

The author then adopted analyzing the impact of these prices on health spending and HIV infections, using a panel analysis recommended by the World Health Organization [21] and recent studies [22,23].

2.2. Panel Unit Root Tests

To inform model specification, the author assessed the level of integration of the variables of interest and found that most series were stationary in level and for some variables after the first differencing (Table 3). The author ran the Fisher–ADF and Fisher–PP tests, which assume individual unit root processes across countries included in the panel. The Fisher–ADF test suggested that all variables were stationary in level except for real private health spending. The stationarity bar was higher on the Fisher–PP test. Such differences pointed to the need to check for cointegration to ensure that the estimated VAR model can be relied upon for inference.

Table 3. Panel unit root tests.

Variable		Fisher-ADF	Fisher-PP
LN commodity price	Level	80.966 ***	47.987
	1st difference	−2.457 ***	66.345 **
GDP per capita	Level	28.612 ***	29.412
	1st difference	−6.171	123.912 ***
Real government health spending	Level	97.123 ***	86.125 ***
	1st difference	99.124 ***	123.543 ***
Real private health spending	Level	30.134	52.345
	1st difference	173.223 ***	110.469 ***
HIV infection rate	Level	150.804 ***	184.231 ***
	1st difference	−10.234 ***	255.814 ***

***, **, denote significant p value at < 0.05 and 0.10.

2.3. Cointegration Tests

The author also conducted cointegration tests on the panel VAR to ensure that inference is based on nonspurious relationships. The cointegration analysis is helpful because the variables included in the VAR panel must have different orders of integration. Johansen's trace and maximum eigenvalue tests confirmed the existence of cointegrating relationships, with the number of cointegrating vectors ranging from 3 to 5. The finding of cointegration in the system enables the author to examine interactions among variables.

2.4. Econometric Estimation

2.4.1. Structural Vector Autoregression

Following the approaches of Drechsel and Tenreyro [24], the authors estimated the evolution of commodity price shocks as presented in Equation (1) using the Structural Vector Autoregression (SVAR) approach:

$$Z_{it} = \sum_{j=0}^{p} A_{ix_{it-j}} + e_{it} \quad (1)$$

where Z_{it} is a vector of dependent variables, A_i is n × n matrix of the parameters on lagged variables, x_{it-j} denotes a vector of the lagged dependent variables, e_{it} is a set of errors with zero expected values and a variance–covariance matrix Σ. Hannan–Quinn (HQIC) information criterion chooses p = 2 as the optimal lag number. To identify the exogenous structural shock effects, the author relied on Cholesky decomposition ordering similar to Fernández, Schmitt-Grohé, and Uribe [25]. Such ordering ensures that the vector of endogenous variables (GDP per capita, health spending, and HIV infections) has no contemporaneous impact on the vector of commodity prices. This is important because it enables one to uniquely identify the shocks from the exogenous prices, ceteris paribus.

The impacts of commodity price on the other variables are obtained by shocking the error term for commodity price and tracing its marginal effects through all equations in the system. As an impulse in one variable is likely to be accompanied by an impulse in another variable, orthogonalized impulses are considered, which were interpreted as a block unit shock for each panel presented in Table 1. This enables the author to simulate the impulse response functions (IRFs)—with commodity prices giving the exogenous impulse shocks and endogenous variables (GDP per capita, health spending, and HIV infections) responding to shocks.

2.4.2. Vector Error Correction Model

With this model the author wanted to analyze whether the main endogenous variables (GDP per capita, health spending, and HIV infections) have a long-run steady state relationship with global commodity price shocks using a Vector Error Correction Model (VECM) [26]. The author opted to estimate the VECM separately for each economic block using Equation (2):

$$\Delta Y_{it} = \varphi_i \langle Y_{i,t} - \theta_i x_{it} \rangle + \sum_{j=1}^{n-1} \omega_{ij}^{*} Y_{i,t-1} + \sum_{j=0}^{q-1} \mathfrak{H}_{ij}^{*} \Delta x_{i,t-1} + _i \quad (2)$$

where $\varphi_i = -(1 - \sum_{j=1}^{n} \omega_{ij})$, $\theta_i = \sum_{j=1}^{q} \mathfrak{H}_{ij})$, $/(1 - \sum_{K}^{n} \omega_{ij})$,

$$\omega_{ij}^{*} = -\sum_{m=j+1}^{n} \omega_{jm},\ j = 1,\ 2,\ \ldots,\ n-1 \text{ and}$$

$$\mathfrak{H}_{ij}^{*} = -\sum_{m=j+2}^{q} \mathfrak{H}_{jm},\ j = 1,\ 2,\ \ldots,\ q-1$$

The parameter φ_i is the error-correcting speed of the adjustment term, and if it is zero, then there would be no evidence for a long-run relationship. This parameter is expected to be significantly negative under the current assumption that commodity price shocks have a negative impact on main variables (GDP per capita, health spending, and HIV infections) in the long run. The vector θ_i contains the long-run relationship between variables. The author estimated the model using the Pooled Mean Group estimator, introduced by Pesaran, Shin, and Smith [27]. Such a technique caters to both heterogeneous short-run dynamics and typical long-run elasticities. Stata (which was utilized by the author) includes the long-run and averaged short-run parameter estimates.

3. Results

3.1. Long-Run and Short-Run Dynamic Relationships

Table 4 shows the VECM-based panel cointegration procedure allowing for heterogenous effects amongst the cross-sectional units. The model reveals that there are some interesting long-run relationships between the variables. The most striking result is that in all the cases, the error correction term (ECT) is statistically significant, ranging from -0.411 for energy-block countries to -0.62 for agriculture-dependent countries. This finding is interesting since it reveals the extreme importance of the equilibrium relationships between the local macro-variables (GDP per capita, RGH, RPH), HIV infections, and global commodity prices. The implication is that commodity market behavior strongly determines the macro-economic equilibrium conditions in the countries analyzed and affects the investment channeled to HIV prevention.

Furthermore, the long-run relationship (LR) between each individual macro variable (GDP per capita, RGH, RPH), HIV infections, and the commodity prices seems to vary a lot between the various country groupings. For example, GDP per capita in agricultural-dependent countries reacts more negatively in the long-run relationship to the falling of commodity prices (LR-relationship -0.49) compared to the metal block (LR-relationship -0.33), and energy-dependent countries (with coefficient -0.23).

HIV infection reactions are extremely high in the short-run relationship (SR) for the agricultural-dependent countries (SR-relationship 0.16). The energy block and metal block are more resilient groups of counties. Hence, HIV infection reactions are more visible in the LR relationship, not in the SR. These differences are driven by health spending adjustments, which are more aggressive in the agricultural block than in the metal and energy blocks. These rapid adjustments create higher volatility in the spending levels, as reflected by the SR and LR relationship of real government and private health spending.

Overall, the results reported in Table 4 suggest that commodity price variables are extremely important for the stability of the macro-economic environment and the HIV infection rate.

Table 4. VECM estimates for GDP per capita, RGH, RPH and HIV infections.

	Long-Run and Short-Run Relationships between Commodity Prices and Variables of Interest				
Panel 1 Agricultural block (six countries)	Soft price				
		GDP per capita	RGH	RPH	HIV
	LR	−0.491 (0.003) ***	−0.432 (0.007) ***	−0.102(0.005) ***	0.049 (0.098)
	SR	−0.452 (0.226) **	−0.010(0.001) ***	−0.007 (0.004) *	0.153 (0.002) ***
	ECT	−0.611 (0.001) ***	−0.591 (0.002) ***	−0.599 (0.003) ***	−0.622 (0.001) ***
Panel 2 Energy block (six countries)	Oil price				
	LR	−0.231 (0.003) ***	−0.292 (0.007) ***	−0.022(0.005) ***	0.025 (0.001) ***
	SR	−0.282 (0.016) ***	−0.003(0.001) ***	−0.002 (0.002)	−0.001 (0.003)
	ECT	−0.431 (0.005) ***	−0.421 (0.009) ***	−0.411 (0.008) ***	−0.442 (0.009) ***
Panel 3 Metal block (six countries)	Metal price				
	LR	−0.331 (0.003) ***	−0.302 (0.004) ***	−0.020(0.005) ***	0.023 (0.001) ***
	SR	−0.312 (0.111) **	−0.005(0.002) ***	−0.003 (0.009)	−0.001 (0.008)
	ECT	−0.531 (0.001) ***	−0.521 (0.003) ***	−0.561 (0.001) ***	−0.552 (0.007) ***

*, **, *** denote the 10%, 5% and 1% statistical significance levels, respectively.

The mean value of the ECT-term coefficient is −0.524 for the overall panels(agricultural block, energy block, and metal block). This means that about half of the errors in the long-run relationships between the commodity price variables and the macro situation is corrected yearly. This is indeed a strong indication of the power of global commodity prices in developing countries.

The short-term results are much more heterogeneous. However, one can still see that in various countries, see Tables 5 and 6 for example, the short-run fall in commodity prices is associated with worsening HIV infections. These results are consistent with findings reported in Greece, where it was discovered that the GDP decline worsened HIV outcomes [16,17].

Table 5. HIV infections outcomes in Brazil and Jamaica during 2008–2009 price shock.

Commodity	**Brazil** **Tin** **%Δ**	**Jamaica** **Alumina** **%Δ**
Price	−26.67	−8.58
RGH (g %)	−10.76	−8.19
RPH (g %)	−7.80	−19.50
HIV new infections (%)	5.10	8.00

Source: Authors analysis using global datasets.

Table 6. HIV infection outcomes in Egypt and Malaysia during 2000–2002 price shock.

Commodity	**Egypt** **Oil** **%Δ**	**Malaysia** **Gas** **%Δ**
Price	−17.17	−18.10
RGH (g %)	−2.70	−57.84
RPH (g %)	−7.98	−24.03
HIV new infections (%)	10.44	10.00

Source: Authors analysis using global datasets.

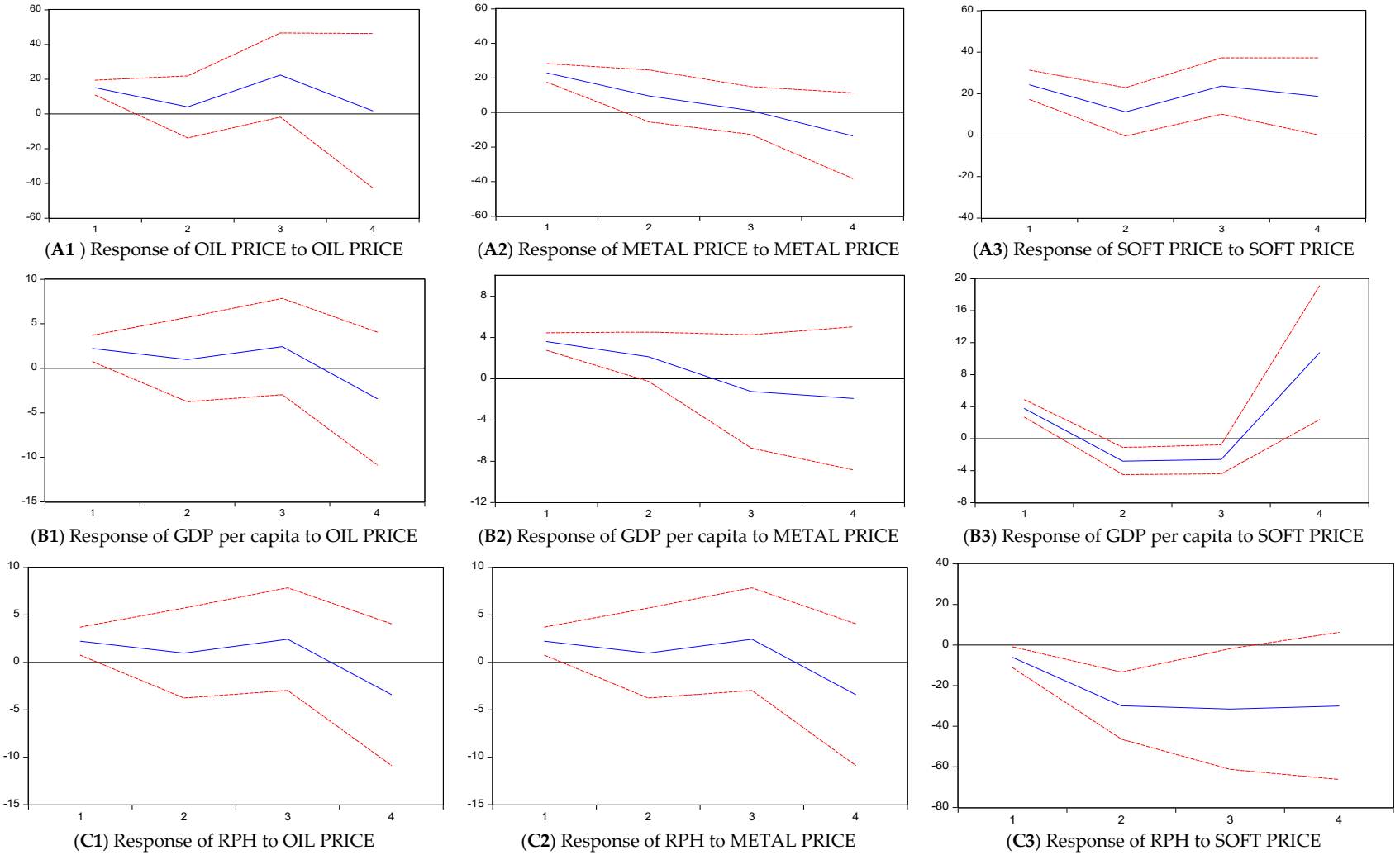
3.2. Shock Estimation

This section presents the impulse responses (IRF) results from the SVAR model presented in Equation (1). The IRFs were obtained from one standard deviation shock of

commodity prices for the individual block of countries. The author opted for this analysis because it enables one to compare the results with some previous studies, such as Ben-Zeev, Pappa, and Vicondoa [28], Fernández, Gonzalez, and Rodriguez [29], Schmitt-Grohé and Uribe [30], who also found that global commodity price shocks have varying effects on different block of countries.

Row B in Figure 1 shows the macro-economic variables' response to one standard deviation shock from the commodity prices. The reactions suggest that GDP per capita contract immediately when a commodity price shock hits the energy and metal economic block. RGH and RPH also contract instantly (Row C and D). HIV infections begin worsening three years after the shock due to a persisting decline in real government health spending and real private health spending (Row E). These impacts are statistically significant within a 95% confidence margin and can potentially reverse the positive HIV infection gains achieved in the past three years (Row E).

GDP per capita contracts immediately when a commodity price shock hits the agricultural-dependent countries. RGH and RPH also contract instantly (Row C and D). HIV infections start worsening in the second year after the shock due to a rapid decline in actual government health spending and real private health spending (Row E). These findings show the agricultural block's vulnerability compared to the energy and metal block of countries that absorb shocks better. As stated by the IMF, these groups of countries are more at risk from economic shocks [31], which is a testament to the early upswing in HIV infections compared to the other block of countries.



(**A1**) Response of OIL PRICE to OIL PRICE

(**A2**) Response of METAL PRICE to METAL PRICE

(**A3**) Response of SOFT PRICE to SOFT PRICE

(**B1**) Response of GDP per capita to OIL PRICE

(**B2**) Response of GDP per capita to METAL PRICE

(**B3**) Response of GDP per capita to SOFT PRICE

(**C1**) Response of RPH to OIL PRICE

(**C2**) Response of RPH to METAL PRICE

(**C3**) Response of RPH to SOFT PRICE

Figure 1. *Cont.*

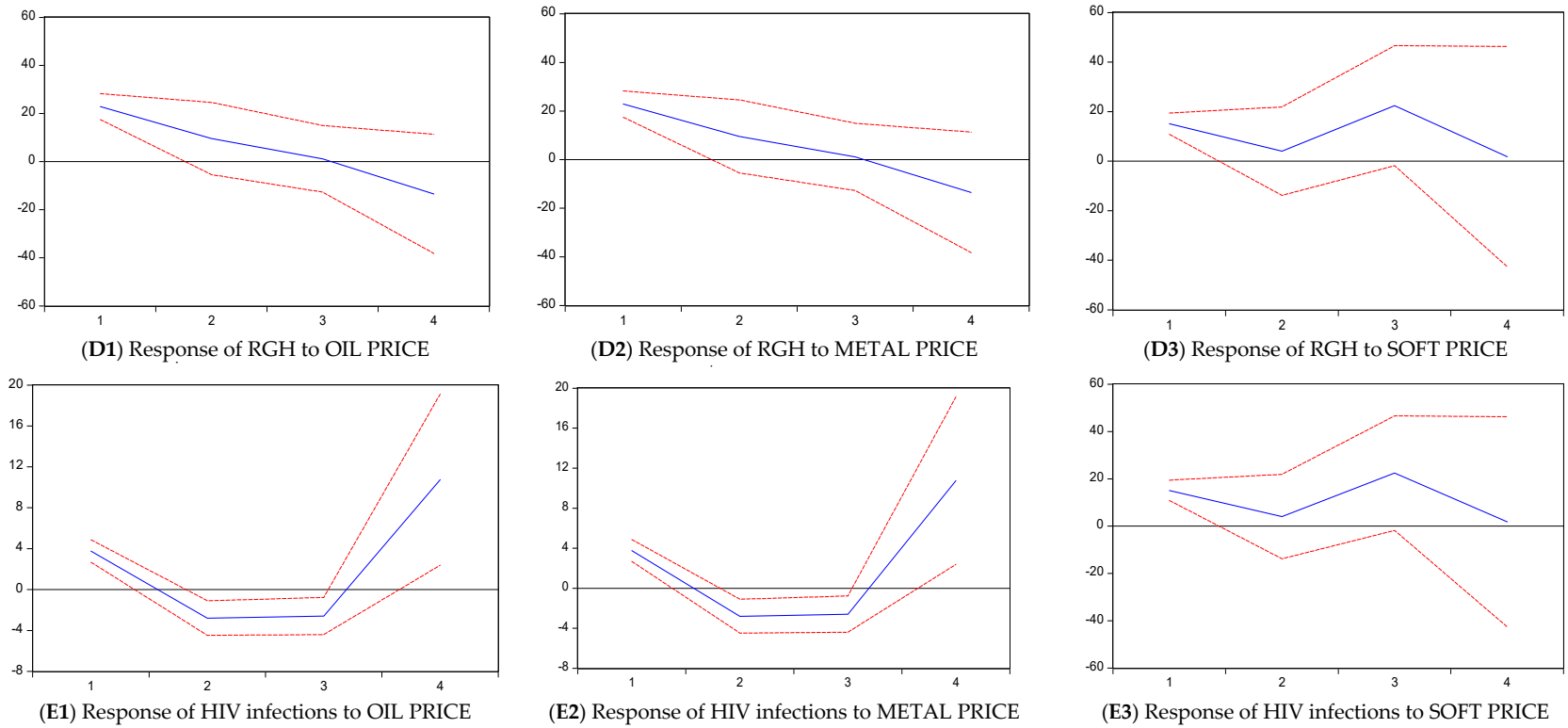


Figure 1. Impact of commodity price shocks on percentage changes in GDP per capita, RPH, RGH and HIV infections. The red lines show the 95 percent confidence interval bands, and the blue line shows the response to shock intensity. Oil and Metal blocks absorb the shocks better, hence the similarities in the health spending adjustments. These factors assist the two blocks in delaying the upswing in HIV infections (3 years). The agricultural block is more vulnerable—hence the sharp fall in RPH, which never recovered, and the volatile RGH. The combination of these factors causes an early upswing in HIV infections (2 years). Source: panel VAR model estimations using global datasets.

4. Discussion

This study assessed the commodity prices of different developing countries and how they impact economic development, health spending, and HIV infections. For this purpose, the author first constructed a theoretical model identifying the main exogenous shocks affecting some key macroeconomic variables in 18 developing countries. Based on this theoretical framework, the author analyzed the long- and short-run relationships between commodity price series, three critical macroeconomic indicators (GDP per capita, RGH, and RPH), and HIV infections.

The main results can be summarized as follows:

1. The long-run relationships between commodity prices and the analyzed four macroeconomic variables reveal a powerful, long-run relationship among the analyzed data. Commodity price shocks cause instant adjustment in the macro-economy environment of developing countries, worsening HIV infections.
2. GDP per capita are more exposed to price fluctuations in the agricultural block. Hence, price shocks cause a rapid upswing in HIV infections. This reflects the fragility of the agricultural economies [32].
3. GDP per capita of the energy and metal block are more resilient [33,34] and absorb the price fluctuations better compared to the agricultural block. Hence, the HIV infection upswing is delayed in these block of countries for three years before rising sharply.
4. HIV infections tend to respond the same way in metal and energy blocks due to modest adjustments in health spending arising from price shocks.
5. Agricultural economies are more volatile [35]. Health spending in this block is also more volatile, driving a quick upswing in HIV infections.

Therefore, this study suggests that future policies and decision making should carefully acknowledge the impact of these world trade price shocks, especially for agricultural countries, which are most exposed to these shocks, hurting health spending instantly and worsening HIV infections more rapidly than the other block of countries. In addition, the paper proposes that policymakers should pay attention to macro-economic shocks to mitigate unfavorable commodity price environments. Emergency funds, government health spending, insurance schemes, and international aid for HIV need to discharge more funds to counter these shocks. There is a significant risk of reversing HIV infection gains arising from commodity price shocks. In the future, developing a country's health systems may need to consider more comprehensive adaptive strategies to defend against HIV gains achieved during good economic times. The idea of a new international health systems funding model [36] seems desirable to cushion health systems from the downward spirals of economic shocks.

Limitations

The current analysis has a few limitations. Firstly, while useful, the relationships derived from aggregate panel analysis can mask essential differences in feedback at an individual country level. Therefore, caution should be exercised when interpreting these estimations at the country level. Secondly, the commodity price increase can make a difference in a health system's ability to continue rendering quality HIV services. In this regard, useful quarterly data permitting an after-crisis analysis could enrich the current understanding with specific price thresholds required to stabilize HIV infections. Due to the lack of such data, the author could not perform such an analysis. This angle should be a priority for future investigation.

5. Conclusions

The long-run relationship between commodity prices and health spending highlights the need for more studies to be conducted about the economic vulnerabilities that directly and indirectly affect HIV outcomes in developing countries. As I have discovered in this analysis, commodity price shocks negatively affect economic development and worsen the HIV infection rate due to falling health spending. Therefore, to achieve resilience im-

provement in developing countries with worsening HIV infection outcomes, governments may need to ensure that health budgets are protected from bust cycles of global commodity prices. Without improved action on managing these price fluctuations, there is a looming crisis of high HIV infections as countries battle to maintain price stability.

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