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ARTICLE

Official development assistance and economic growth in fragile states: Evidence from the Democratic Republic of Congo

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Abstract

This paper investigates the relationship between official development assistance (ODA) and economic growth (GDP) in the Democratic Republic of Congo (DRC) using a Vector Error Correction Model (VECM) over 2000Q1-2021Q4. Given data constraints, annual macroeconomic series are temporally disaggregated to quarterly frequency to examine short-run dynamics and long-run relationships. The results identify a stable long-run relationship among ODA, GDP, investment, and inflation. The error-correction estimates show that ODA and inflation significantly adjust to disequilibrium, with ODA correcting approximately 7% of deviations per quarter. Granger-causality tests provide no evidence that ODA predicts GDP or investment in the short-run. Consistently, impulse-responses show no statistically significant GDP or price response to positive ODA shocks, while investment exhibits only a temporary negative response. Variance decomposition indicates that ODA makes a modest contribution to GDP fluctuations, reaching 5.8% after twelve quarters, while investment shocks become increasingly important, accounting for 37.6%. Overall, ODA participates in long-run macroeconomic adjustment but exhibits limited identifiable effects on short-to medium-term economic growth in the DRC.

Keywords: Official development assistance; Economic growth; Gross domestic product; Vector error correction model (VECM); Democratic Republic of Congo.

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1. Introduction

The effectiveness of official development assistance (ODA) in promoting economic growth remains one of the most debated issues in development economics. While early theoretical frameworks-such as the Harrod-Domar model and the dual-gap theory-emphasize the role of external financing in relaxing savings and foreign exchange constraints, empirical evidence on the impact of aid has produced mixed results. Some studies find that aid can stimulate growth and investment under appropriate policy and institutional conditions, whereas others highlight its limited or even adverse effects due to inefficiencies, weak governance, and macroeconomic distortions. As a result, the extent to which ODA contributes to sustainable development outcomes remains an open empirical question, particularly in fragile and resource-rich economies.

The Democratic Republic of Congo (DRC) provides a compelling case study in this regard. The country is among the largest recipients of ODA in Sub-Saharan Africa. In 2020, it received approximately USD 3.38 billion, representing 7.03 percent of GDP and about 5.05 percent of total ODA flows to the region (World Bank, 2022). Over the period 2000–2021, ODA inflows increased more than elevenfold, reflecting international support in response to the country's fragile context, marked by conflict, political instability, and persistent humanitarian challenges. Despite this substantial inflow of external resources, the DRC continues to experience weak economic performance.

Indeed, the Congolese economy remains heavily dependent on extractive industries, particularly copper and cobalt, which account for the vast majority of export revenues. Although periods of macroeconomic stabilization and reform – especially in the early 2000s – have supported growth, these gains have not translated into broad-based development. Despite substantial aid inflows, the DRC continues to face persistent constraints on economic growth and access to basic services. This apparent disconnect raises important questions about the extent to which ODA has contributed to improved macroeconomic outcomes in the DRC.

Against this backdrop, a key gap in the literature emerges. First, much of the empirical research on aid effectiveness relies on cross-country panel data, which may obscure country-specific dynamics and institutional heterogeneity. Second, existing studies often focus primarily on the relationship between aid and economic growth, with limited attention to broader development outcomes such as macroeconomic stability. Third, relatively few studies explicitly examine the dynamic interactions and transmission mechanisms through which aid affects growth, and investment over time. In particular, the role of macroeconomic variables – such as inflation – as potential channels through which aid influences economic performance remains underexplored.

Moreover, the existing literature provides limited evidence on how aid interacts with the structural characteristics of fragile and resource-dependent economies such as the DRC. In such contexts, the dominance of extractive sectors, weak institutional capacity, and exposure to external shocks may alter the transmission mechanisms of aid, potentially weakening its impact on economic growth. In addition, the volatility and composition of aid flows – whether directed toward humanitarian assistance, infrastructure, or budget support – can produce heterogeneous effects across macroeconomic variables. These factors underscore the importance of adopting a country-specific and dynamic analytical framework capable of capturing both the direct and indirect channels through which ODA influences economic performance. By explicitly incorporating investment, and inflation into the analysis, this study seeks to provide a more nuanced understanding of the conditions under which aid may contribute to sustainable development outcomes.

This study addresses these gaps by providing a county-specific, dynamic analysis of the relationship between ODA, economic growth, investment, and inflation in the DRC. Using a Vector Error Correction Model (VECM) estimated on data over the period 2000–2021, the analysis captures both long-run equilibrium relationships and short-run adjustments among the variables. By adopting a multidimensional framework that goes beyond growth to include investment and inflation, this study offers a more comprehensive assessment of the effectiveness of aid.

The contribution of this paper is therefore threefold. First, it provides new evidence on the aid–growth nexus in a fragile and resource-dependent economy. Second, it highlights the importance of macroeconomic conditions – particularly inflation – in shaping the effectiveness of aid. Third, it advances the literature by explicitly modeling the dynamic interactions between aid and key development indicators, thereby offering deeper insights into the mechanisms through which official development assistance influences economic outcomes.

The remainder of the paper is organized as follows. The next section reviews the theoretical and empirical literature on the effectiveness of official development assistance. Section 2 outlines empirical analysis of the relationship between official development assistance (ODA) and economic

growth (GDP), and the final section concludes with policy implications.

2. Review of Theoretical and Emperical Literatures

2.1 Theoretical Litearatures

Official Development Assistance (ODA) refers to concessional financial flows provided by public institutions in developed countries to promote economic development and improve living standards in developing countries. The concept emerged from post-war reconstruction efforts, particularly the Marshall Plan, and was subsequently formalized by the OECD Development Assistance Committee (DAC) as a central instrument of international development policy.

The theoretical justification for ODA is rooted in the view that developing countries face structural constraints that impede capital accumulation and economic transformation. Early development theories argued that low-income countries are trapped in a cycle of low savings, low investment, and low productivity. Rosenstein-Rodan's (1943, 1961) "Big Push Theory" suggests that large-scale and coordinated investment is necessary to overcome indivisibilities and initiate sustained growth. Similarly, Nurkse (1953) emphasized the vicious circle of poverty, whereby insufficient domestic savings prevent the investment needed to raise productivity and incomes. External financial resources are therefore required to break this cycle.

The most influential aid-growth framework is the dual-gap model developed by Chenery and Bruno (1962) and extended by Chenery and Strout (1966). This framework identifies two major constraints to development: the savings-investment gap and the foreign exchange gap. ODA helps bridge these deficits by supplementing domestic resources and financing imports necessary for productive investment. Later contributions introduced a fiscal gap, suggesting that aid may also relax government budget constraints and support public investment.

The Harrod-Domar growth model further provides a theoretical rationale for aid by linking economic growth directly to capital accumulation. Under this framework, foreign aid increases investment when domestic savings are insufficient, thereby accelerating growth (Harrod, 1939; Domar, 1946).

Despite these theoretical arguments, the effectiveness of aid remains highly contested. Critics such as Bauer (1972, 1984) and Friedman (1958) argue that aid may weaken incentives, foster corruption, crowd out domestic savings, and create long-term dependency. In countries with weak institutions, aid may reinforce rent-seeking behavior and fail to generate sustainable development.

Conversely, proponents contend that ODA finances infrastructures, health, education, humanitarian assistance, and macroeconomic stabilization, thereby contributing to long-term development. More recent literature suggests that aid effectiveness is conditional upon the quality of institutions, governance, and economic policies. Under favorable conditions, aid can stimulate investment and growth; under weak institutional environments, its impact is likely to be limited.

Overall, contemporary economics views ODA neither as inherently effective nor ineffective. Rather, its developmental impact depends on how aid interacts with domestic institutions, macroeconomic conditions, and the productive structure of recipient economies. This conditional perspective provides the theoretical basis for empirically examining whether ODA has contributed to economic growth in the Democratic Republic of Congo.

2.2 Emperical Literatures

The literature on aid effectiveness is extensive and often contradictory, reflecting three main perspectives: (i) aid has a positive effect on growth, (ii) aid has no effect or even a negative effect, and (iii) the effectiveness of aid is conditional on the recipient country's policies, institutions, and structural characteristics. More recent contributions have further emphasized issues of identification, heterogeneity across aid types, and the timing of aid effects, thereby deepening the debate on the true macroeconomic impact of aid.

2.2.1 *Positive effect of official development assistance on economic growth and poverty*

Many authors have found a positive relationship between aid and economic growth, which has led to heated debates among researchers, with some concluding that such a relationship is absent. Hansen and Tarp (2000) conducted a cross-country study using a growth model that accounts for the non-linear effects between official development assistance and economic growth. Their results showed that when human capital and investment are uncontrolled, aid increases economic growth, but with diminishing returns. Both authors concluded that capital accumulation is the channel through which aid impacts economic growth. Thus, aid increases national savings and investment and has a positive impact on growth. Likewise, Gomanee et al. (2005) found a positive influence of aid on the human development index and the reduction of infant mortality, the effect being linked to the financing of public expenditure in favor of the poorest.

In another cross-country study, Minoiu and Reddy (2010) structured their research by examining the effect of two types of aid (development aid and non-development aid) on GDP per capita growth over long periods. Their results indicated that development assistance has a positive, large and robust effect on economic growth and GDP per capita growth, while the effect of non-development aid on economic growth is generally neutral and sometimes negative. This distinction echoes later arguments that the aggregate treatment of aid may conceal heterogeneous effects across aid categories, an issue that has become central in the aid effectiveness literature.

In Asia, Mubinzhon and Ricardo (2020) conducted a study assessing the effect of official development assistance on economic growth and poverty reduction in Tajikistan. The two authors used a panel dataset of economic growth and poverty estimates in Tajikistan, and found that a 1% increase in official development assistance caused a 1.6% increase in GDP per capita and a 0.48% decrease in poverty levels in Tajikistan. Similarly, in Laos, Vilaylack (2014) examined the impact of foreign aid in the form of official development assistance on economic growth using time series data over the period 1985–2012. This study showed that official development assistance has a positive effect on the economic growth of this country.

In the African context, Balasha (2021) examines the relationship between official development assistance and poverty reduction in the Democratic Republic of Congo over the period 1990-2018 using an ordinary least squares (OLS) framework. The study found that, following a period of decline during the 1990s, ODA flows increased substantially after 2000 and were associated with improvements in economic growth and poverty outcomes. While this contribution provides valuable country-specific evidence, its reliance on a static, reduced-form approach limits the ability to capture the complex dynamics underlying the aid-growth-poverty nexus. In particular, the OLS methodology does not adequately address potential endogeneity between aid and macroeconomic variables, nor does it account for dynamic interactions and feedback effects among aid, growth, and social indicators.

The present study extends this line of inquiry by adopting a Vector Error Correction Model (VECM), which explicitly models both long-run equilibrium relationships and short-run dynamics among ODA, economic growth, investment, and inflation. By doing so, it addresses key econometric limitations in Balasha (2021), including omitted dynamic adjustments, simultaneity bias, and the absence of feedback mechanisms. Furthermore, the inclusion of additional macroeconomic channels – particularly investment and inflation – allows for a more comprehensive assessment of the transmission mechanisms through which aid influences development outcomes. As such, this study provides a more robust and structurally consistent analysis of the effectiveness of ODA in the DRC.

2.2.2 *Null and negative effect of official development assistance on economic growth and poverty*

Griffin and Enos (1970) were among the first to question the effectiveness of aid in an empirical study, finding a negative relationship between aid and economic growth in 27 countries. Boone (1994) similarly argued that there is no positive relationship between development aid and growth, although

his findings have been subject to methodological criticism. Mosley (1980) reached comparable conclusions, while Radelet et al. (2004) suggested that the relationship between aid and growth is weak or statistically insignificant.

More recent and influential contributions have reinforced skepticism toward positive aggregate aid effects by highlighting serious identification problems in cross-country regressions. Rajan and Subramanian (2008), using various instrumental-variable strategies, found little robust evidence that aid stimulates growth and argued that aid may even undermine competitiveness by appreciating the real exchange rate. Their findings challenged earlier optimistic results and redirected the literature toward a more cautious interpretation of macro-level aid impacts.

In Africa, Tiava (2019) conducted a study that consisted of evaluating the impact of public aid on economic growth in Madagascar. Since its independence, Madagascar has benefited from external financial support in the form of public development assistance in order to initiate growth and ensure the well-being of its population. According to the empirical analyses, the results showed that public aid does not lead to economic growth and there is no long-term equilibrium relationship between public development assistance and economic growth.

Another study was conducted in Cameroon from 1980 to 2013 by Dazoué et al. (2015). These authors analyzed the influence of official development aid on poverty reduction using an error correction model. The objective of the study was to verify the behavior of poverty in the presence of official development assistance. The endogenous variable is the average income per capita. Estimates made using the method of Johansen (1988), it appeared that public development assistance has no effect on the level of poverty in Cameroon. The transformation of public development assistance into a real donation would make it possible to avoid an increase in debt and would thus reduce poverty.

In West Africa, Diallo (2018) studied issues related to development aid in Guinea. This country has benefited from official development aid from technical and financial partners since its independence in 1958. This aid was initially provided mainly by Eastern countries and then came from Western countries, including France as the main donor. Despite these efforts by the donor community in Guinea, it is necessary to note the failure of this aid in view of the mixed results produced.

In a broader African context, Mallik (2008) used cointegration analysis to study the relationship between foreign aid and economic growth in six of the poorest African countries. In five out of six cases, aid had no significant short-term effect on growth, while a significant negative relationship was found in the long run. These results are consistent with the argument that aid effects may materialize with delays or vary depending on the composition and use of aid flows.

2.3 Conditional effect of official development assistance on economic growth and poverty

In the 1990s, the idea that the relationship between official development aid and growth is not necessarily linear became widespread, leading to a new wave of analyses. These studies then attempted to demonstrate that the effectiveness of growth support can be conditioned and dependent on certain specific factors in the beneficiary countries. The culmination of this literature is an article by Burnside and Dollar (2000). According to these two World Bank economists, aid would be effective and would have a positive impact on economic growth in countries with "good" economic institutions and policies. This article sparked lively debates and several studies subsequently attempted to confirm these results, with varying degrees of success. However, other studies have also identified several natural and structural factors that may also influence aid effectiveness.

Burnside and Dollar (1997) concluded that aid stimulated growth only in countries that adopted sound economic policies. Other researchers have identified other characteristics likely to influence the relationship between public development aid and growth. The conclusion of the investigations carried out by Collier and Dollar (2002) also showed that the quality of economic policies and the quality of institutions were at the center of aid effectiveness. Finally, other studies by Kosack (2003), Collier and Hoeffler (2004) have also highlighted the advantage of institutional quality. Building on

these insights, Clemens et al. (2012) refined the conditionality argument by distinguishing between short-impact aid (such as infrastructure and budget support) and long-impact aid (such as education and health), showing that only the former has a detectable effect on growth within typical empirical horizons. This contribution underscores the importance of timing and dynamics, suggesting that contemporaneous macroeconomic models may underestimate aid effectiveness if lag structures are ignored.

In Latin America, Lacalle-Calderón et al. (2016) analyzed the relationship between official development assistance, social capital, and economic growth in 18 countries over the period 2001–2010. Their results showed that the growth impact of aid is conditional on trust and social capital. Similarly, Isham et al. (1997) found a strong empirical relationship between civil liberties and project performance, providing micro/project-level support for the idea that institutions influence how effectively external development resources are transformed into development outcomes.

Overall, this strand of the literature suggests that aid effectiveness cannot be adequately assessed without accounting for institutional quality, sectoral allocation, timing, and dynamic interactions—considerations that motivate the use of structural time-series frameworks in country-specific analyses.

Our study focuses on the joint dynamics between ODA, economic growth (GDP), investment (GFCF), and inflation (CPI) to address important gaps in the existing literature. First, while a large body of research has examined the relationship between aid and economic growth, relatively fewer studies adopt a multidimensional framework that simultaneously considers growth, investment, and inflation.

Second, most empirical studies rely on cross-country panel data, which often obscure country-specific dynamics and institutional heterogeneity. In contrast, this study provides a country-specific time-series analysis for the Democratic Republic of Congo (DRC), a major recipient of ODA with persistently weak development outcomes, making it a particularly relevant case study.

Third, the literature has largely focused on long-run relationships, with limited attention to the short-run transmission mechanisms and dynamic interactions among variables. By employing a Vector Error Correction Model (VECM), this study explicitly captures both long-run equilibrium relationships and short-run adjustments, including feedback effects between aid and macroeconomic variables.

Finally, the inclusion of inflation addresses an important but often overlooked channel through which aid may affect the economy. Given the evidence that aid inflows can generate macroeconomic imbalances, analyzing CPI alongside growth and investment provides a more comprehensive understanding of the macroeconomic consequences of aid.

Taken together, this study contributes to the literature by offering a dynamic, country-specific, and multidimensional analysis of the aid-growth nexus, thereby addressing key gaps in both methodology and empirical scope.

3. Emperical Analysis

3.1 Methodology

This section presents the empirical strategy used to investigate the impact of official development assistance (ODA) on economic growth (GDP) in the Democratic Republic of Congo (DRC). The analysis relies on quarterly data spanning the period 2000Q1–2021Q4. The choice of the starting date is motivated by the resumption of cooperation between the DRC and the World Bank in 2000, following a prolonged period of suspension during the 1990s associated with conflict, macroeconomic instability, and governance challenges. This date, therefore, marks a structural shift in the country's development financing environment and provides a relevant baseline for assessing the macroeconomic effects of ODA. Given that most variables are originally available at annual frequency, the limited number of observations would constrain the reliability of time-series econometric inference if the

analysis were conducted exclusively at that frequency. To address this limitation and enable a more informative dynamic analysis, annual series were temporally disaggregated to quarterly frequency. This approach increases the effective sample size and allows for a more detailed examination of short-run dynamics and adjustment mechanisms. The methodological justification and implementation of the temporal disaggregation procedure are discussed in detail below.

3.1.1 Temporal Disaggregation of Annual Data

Given the limited availability of quarterly macroeconomic data for the DRC, the annual ODA, real GDP, and GFCF series were temporally disaggregated to quarterly frequency using quadratic interpolation. Quadratic interpolation constructs intermediate high-frequency observations by fitting a second-degree polynomial between adjacent annual data points, ensuring continuity and smooth transitions over time while preserving the exact annual totals.

This approach is commonly used in applied macroeconomic studies when no reliable high-frequency indicator series is available for related-series interpolation. However, temporal disaggregation increases the number of observations available for estimation and facilitates the implementation of a quarterly dynamic specification, but it does not generate independent high-frequency information (see Lütkepohl, 2005; and the literature on temporal aggregation and mixed-frequency data). Consequently, the estimated quarterly dynamics are interpreted cautiously as reflecting, in part, the temporal-disaggregation procedure. They are therefore viewed as evidence of dynamic associations and long-run adjustment rather than definitive evidence of high-frequency causal effects.

Table 1. System variables

Variable	Definition	Source	Unit
ODA	Net official development assistance	World bank	USD (constant prices)
GDP	Real gross domestic product	World bank	USD (constant prices)
GFCF	Gross fixed capital formation	World bank	USD (constant prices)
CPI	Consumer price index	Central bank of congo	Index

Source: Author

3.1.2 The VECM model

We estimated our VECM model based on quarterly data for the vector y_t, consisting of the four variables described above, represented as:

$$\Delta y_t = \Pi y_{t-1} + \Gamma_1 \Delta y_{t-1} + \cdots + \Gamma_{p-1} \Delta y_{t-p+1} + \mu_t, \tag{1}$$

where y_t is a process of dimension K, $\mathrm{rk}(\Pi) = r$ with $0 < r < K$ so that $\Pi = \alpha\beta$, where α and β are $(K \times r)$ matrices with $\mathrm{rk}(\alpha) = \mathrm{rk}(\beta) = r$. All other symbols have their conventional meanings, that is, the Γ_j's $(j = 1, \ldots, p-1)$ are $(K \times K)$ parameter matrices that capture short-run and $\mu_t \sim N(0, \Sigma_u)$ is standard white noise. The VECM form (1) is a more convenient model setup for cointegration analysis Lütkepohl and Krätzig (2004).

2.1.2.1 Cointegration (Long-Run Relationship)

The cointegration component is embedded in the matrix:
$\Pi = \alpha\beta$, where βy_{t-1} represents the cointegration relationships (long-run equilibrium), and α represents the speed of adjustment coefficients.

2.1.2.2 Error Correction Mechanism

The error correction term (ECT) is given by: $ECT_{t-1} = \beta y_{t-1}$,

and the VECM can be rewritten as:

$$\Delta y_t = \alpha ECT_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \mu_t \quad (2)$$

Given that all variables are integrated of order one, I(1), and evidence of cointegration is established using Johansen procedure, the empirical analysis is conducted within a Vector Error Correction Model (VECM) framework. The VECM allows for the joint estimation of short-run dynamics and long-run equilibrium relationships among the variables. The long-run relationship is captured through the cointegration term βy_{t-1}, while the adjustment coefficient α measures the speed at which the system returns to equilibrium following short-run deviations. This framework is particularly suitable for analyzing the impact of ODA on economic growth in the Democratic Republic of Congo, as it distinguishes between transitory effects and persistent long-run relationships.

3.1.3 Analysis of the stationarity of variables

The time series included in the empirical system display pronounced trending behavior, suggesting potential non-stationarity in both their mean and variance. To formally assess their stochastic properties, unit root tests were conducted using the Augmented Dickey–Fuller (ADF) procedure. The null hypothesis of a unit root was tested against the alternative of stationarity, with statistical significance evaluated at the 5 percent level.

The results of the ADF tests presented in Table 2 indicate that all variables are non-stationary in level but become stationary after first differencing. Accordingly, the series are characterized as integrated of order one, I(1). This finding has important implications for the econometric specification, as it necessitates considering cointegration relationships and adopting an appropriate framework; such as a VECM to jointly capture both short-run dynamics and long-run equilibrium relationships among the variables.

Table 2. Augmented Dickey–Fuller tests

	Dickey–Fuller in level			Dickey–Fuller in first difference		
variable	ADF t-stat	CV at 5%	Conclusion	ADF t-stat	CV at 5%	Conclusion
LODA	-2.4518	-2.8951	NS	-5.1611	-2.8955	S
LGDP	-0.1544	-2.8955	NS	-3.8908	-2.8955	S
LGFCF	0.0192	-2.8972	NS	-3.4653	-2.8972	S
LCPI	-2.7696	-2.8955	NS	-3.5946	-2.8955	S

Source: Author, tests using EViews 10 software.

3.1.4 Determination of the number of lags of the VAR(p) model of the study

Estimating a VAR or VECM model requires knowledge of the length of lags in the model equations. Table 3 reports the optimal lag length for the VAR system selected using multiple information criteria, including the Akaike Information Criterion (AIC), Schwarz Criterion (SC), Hannan-Quinn (HQ), and the Final Prediction Error (FPE). The lag-selection criteria provide mixed evidence regarding the optimal VAR order. The AIC, HQ, FPE, and the sequential LR criterion select a lag length of six, whereas the Schwarz criterion (SC) selects a more parsimonious specification with two lags. Given the relatively small sample size (86 observations) and the substantial parameter proliferation associated with higher-order VARs, the SC-based specification was preferred because of its stronger penalty for model complexity. Accordingly, a VAR(2) specification was retained, corresponding to one lag of the first-differenced variables in the VECM. This choice preserves degrees of freedom

while allowing for short-run dynamics, and its adequacy is subsequently evaluated using residual serial-correlation diagnostics.

Table 3. Optimal Lag Length for VAR(p)

Lag	LogL	LR	FPE	AIC	SC	HQ
0	2.396091	NA	4.69e-06	-0.195026	-0.000396	-0.117927
1	537.7419	1004.671	2.54e-11	-13.14672	-12.17357	-12.76123
2	662.4894	220.8575	1.61e-12	-15.87187	-14.12021*	-15.17800
3	689.1325	44.35760	1.23e-12	-16.14278	-13.61259	-15.14051
4	706.8720	27.75531	1.23e-12	-16.18805	-12.87935	-14.87740
5	742.1089	51.77542	7.92e-13	-16.67745	-12.59023	-15.05841
6	773.4939	43.19625*	5.09e-13*	-17.03735*	-12.17161	-15.85132*
7	787.1537	17.49850	5.73e-13	-16.97882	-11.33456	-14.86700

Source: Author, using EViews 10 software.
* indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion

3.1.5 Cointegration Test

The Johansen cointegration tests presented in Appendix A1 provide strong evidence of a long-run equilibrium relationship among official development assistance, economic growth, investment, and inflation in the Democratic Republic of Congo. However, the estimated rank is not invariant across test statistics. The trace test of Table 4 rejects $r \leq 1$ at the 5% level ($p - 0.021$), indicating two cointegrating vectors, whereas the maximum-eigenvalue test of Table 5 fails to reject $r \leq 1$ ($p = 0.0628$), implying a single cointegrating vector. Given the relatively small sample and the marginal nature of the second trace rejection, the baseline specification adopts $r = 1$; moreover, considering the well-documented tendency of the trace test to overestimate the number of cointegrating vectors, the maximum eigenvalue criterion is preferred, leading to the selection of a single cointegrating vector, Cheung and Lai (1993).

The normalized cointegrating equation indicates the existence of a stable long-run equilibrium relationship among ODA, GDP, investment, and inflation, indicating that the variables are linked by a stationary long-run equilibrium relation despite being individually non-stationary.

The estimated adjustment coefficients reported in Table 6 further show that deviations from this equilibrium are corrected through changes in both ODA and the CPI. Specifically, the error-correction coefficient in the ODA equation is negative and statistically significant ($\alpha = -0.0697$, $t = -2.95$), indicating that approximately 7% of the preceding quarter's disequilibrium is corrected through changes in aid flows each quarter. The adjustment coefficients for CPI is also statistically significant ($\alpha = 0.0250$, $t = 3.03$), indicating that the price level responds systematically to deviations from the long-run equilibrium. By contrast, the adjustment coefficients for GDP ($\alpha = 0.000446$, $t = 0.790$) and investment ($\alpha = -0.0072$, $t = -1.30$) are statistically insignificant at the 5% level, providing no evidence that these variables contribute systematically to equilibrium correction over the sample period. These findings identify ODA and price level as the variables that bear the statistically significant adjustment to long-run disequilibrium, without implying a particular causal or institutional mechanism underlying these responses. Taken together, the evidence of cointegration and statistically significant error-correction dynamics supports the use of a VECM to examine short-run interactions and adjustment toward the long-run equilibrium.

Table 4. Johansen Trace Test

No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	p-value	Decision
None	0.286889	62.01477	47.85613	0.0014	Reject
At most 1	0.211283	32.93666	29.79707	0.0210	Reject
At most 2	0.135365	12.52475	15.49471	0.1334	Do not reject
At most 3	0.000189	0.016258	3.841466	0.8984	Do not reject

Source: Author, using EViews 10 software

Table 5. Johansen Maximum Eigenvalue Test

No. of CE(s)	Eigenvalue	Max-Eigen Statistic	5% Critical Value	p-value	Decision
None	0.286889	29.07811	27.58434	0.0319	Reject
At most 1	0.211283	20.41191	21.13162	0.0628	Do not reject
At most 2	0.135365	12.50849	14.26460	0.0930	Do not reject
At most 3	0.000189	0.016258	3.841466	0.8984	Do not reject

Source: Author, using EViews 10 software.

3.2 VECM Estimation and Long-Run Relationships

3.2.1 Long-run cointegrating relationship

The Vector Error Correction Model (VECM) results offer valuable insights into both the long-run equilibrium relationship and the short-run dynamics that link official development assistance, economic growth, investment, and inflation in the Democratic Republic of Congo. The estimated cointegrating equation presented in Table 7 (see Appendix A2 for the complete results) supports the existence of a stable long-run equilibrium relationship among ODA, GDP, investment, and inflation. Within the ODA-normalized cointegrating vector, both real GDP and inflation are statistically significant at the 5% level, with t-statistics of 2.06 and -5.68, respectively, whereas the coefficient of gross fixed capital formation is not statistically significant at the 5% level ($t = 1.89$).

The estimated cointegrating vector is:

$$\mathrm{LODA}_{t-1} + 4.7506\mathrm{LGDP}_{t-1} + 2.1289\mathrm{LGFCF}_{t-1} - 3.4938\mathrm{LCPI}_{t-1} - 149.9117 = 0 \qquad (3)$$

Solving for LODA_{t-1} gives:

$$\mathrm{LODA}_{t-1} = 149.9117 - 4.7506\mathrm{LGDP}_{t-1} - 2.1289\mathrm{LGFCF}_{t-1} + 3.4938\mathrm{LCPI}_{t-1} \qquad (4)$$

The adjustment coefficients reported in Table 6 indicate that both ODA and the price level respond significantly to deviations from the estimated long-run equilibrium. In particular, the negative and statistically significant error-correction coefficient in the ODA equation ($\alpha = -0.0697$, $t = -2.95$) indicates that approximately 7% of the preceding period's disequilibrium is corrected through changes in ODA each quarter. The CPI adjustment coefficient is also statistically significant ($\alpha = 0.0250$, $t = 3.03$), whereas, the corresponding coefficients for GDP and GFCF are not statistically significant at the 5% level. These findings establish an error-correction role for ODA and the price level within the estimated system but, by themselves, neither imply that aid constitutes a reactive financing mechanism nor identify the institutional processes underlying adjustments in aid disbursements.

Although the variance decomposition indicates that gross fixed capital formation becomes increasingly important in explaining fluctuations in real GDP over longer horizons, the VECM provides no evidence of a statistically significant short-run effect of ODA on investment. Accordingly, the results do not establish investment as the transmission channel through which ODA affects economic growth. Taken together, the evidence is more appropriately interpreted as indicating a long-run equilibrium relationship and dynamic interactions among ODA, output, investment, and prices, without identifying a specific causal mechanism through which ODA affects investment and, subsequently, economic growth.

Table 6. Error Correction Coefficients

Dependent Variable	ECT Coefficient	Std. Error	t-statistic	Significance
ΔLODA	-0.0697	0.0236	-2.9527	Significant
ΔLGDP	-0.000446	0.00056	-0.7901	Not significant
ΔLGFCF	-0.0072	0.0055	-1.2982	Not significant
ΔLCPI	0.0250	0.0083	3.0257	significant

Source: Author, using EViews 10 software

Table 7. Long-run Cointegration Relation

Variable	Coefficient	Std. Error	t-statistic	Significance
LODA	1.0000	–	–	–
LGDP	4.7506	2.3024	2.0633	significant
LGFCF	2.1289	1.1267	1.8896	Not significant
LCPI	-3.4938	0.6150	-5.6807	Significant

Source: Author, using EViews 10 software

3.2.2 Short-run dynamics

As reported in Appendix A2, the short-run dynamics are characterized primarily by strong own-variable persistence: lagged changes in ODA ($\beta = 0.421$, $t = 4.770$), GDP ($\beta = 0.726$, $t = 9.268$), GFCF ($\beta = 0.559$, $t = 6.255$), and CPI ($\beta = 0.57$, $t = 7.694$) are positively and statistically significantly associated with their respective current changes. Crucially, lagged changes in ODA do not have a statistically significant short-run effect on either GDP ($\beta = 0.001$, $t = 0.060$) (See Table 8) or investment ($\beta = 0.0247$, $t = 1.197$) (see Table 9). The results, therefore, indicate that ODA responds significantly to deviations from the estimated long-run equilibrium process but provide little evidence that aid is a direct short-run driver of either output growth or capital formation.

Table 8. Short-run VECM Estimates (GDP equation)

Variable	Coefficient	t-statistic	conclusion
ΔLODA(-1)	0.0001	0.060	Not statistically significant
ΔLGDP(-1)	0.7264	9.268	statistically significant
ΔLGFCF(-1)	0.0094	1.028	Not statistically significant
ΔLCPI(-1)	-0.0031	-0.617	Not statistically significant

Source: Author, using EViews 10 software

Table 9. Short-run VECM Estimates (GFCF equation)

Variable	Coefficient	t-statistic	conclusion
$\Delta LODA(-1)$	0.0247	1.197	Not statistically significant
$\Delta LGDP(-1)$	-1.0055	-1.310	Not statistically significant
$\Delta LGFCF(-1)$	0.5587	6.255	statistically significant
$\Delta LCPI(-1)$	-0.0004	-0.008	Not statistically significant

Source: Author, using EViews 10 software

3.3 Model Validation

3.3.1 VEC Residual Serial Correlation LM Tests

The adequacy of the estimated VECM specification was assessed using residual diagnostic tests for serial correlation (see Appendix B1). The multivariate LM test results indicate that the null hypothesis of no residual autocorrelation cannot be rejected at conventional significance levels for all tested lag orders. Specifically, both the individual and joint lag tests yield p-values well above 0.05, suggesting that the residuals are serially uncorrelated. This finding implies that the selected lag structure is sufficient to capture the underlying dynamics of the system and that no additional lagged terms are required. The absence of serial correlation confirms that the model is dynamically well specified and that the estimated coefficients, impulse response functions, and variance decompositions can be interpreted with confidence. Overall, the diagnostic results provide strong support for the validity and robustness of the estimated VECM.

3.3.2 VEC Model Stability

The dynamic stability of the estimated VECM was assessed using the inverse roots of the autoregressive characteristic polynomial. As shown in Figure 1, all displayed inverse roots lie within the unit circle, with no root located outside the stability boundary. Therefore, the results provide no evidence of explosive dynamics and indicate that the stationary component of the VECM satisfies the required stability condition. This finding supports the use of the estimated system for dynamic analyses such as impulse-response functions and forecast-error variance decompositions. Nevertheless, because the model is a cointegrated VECM involving I(1) variables, the stability result should not be interpreted as implying covariance stationarity of the variables in levels; rather, it indicates stability of the dynamics around the estimated cointegrating relationships.

Accordingly, the stability diagnostics indicate that the VECM contains no explosive dynamics and that deviations from the estimated long-run relations are dynamically well behaved, thereby supporting the interpretation of the IRFs and FEVDs conditional on the maintained cointegration and identification assumptions.

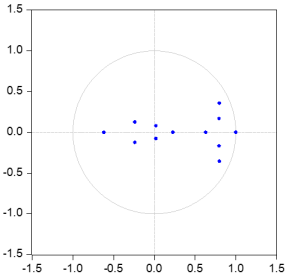

Figure 1. Inverse Roots of AR Characteristic Polynomial

Source: Author, using EViews 10 software.

3.3.3 VEC Residual Normality Tests

The normality of the residuals was assessed using multivariate skewness, kurtosis, and Jarque–Bera tests (see Appendix B2). The results strongly reject the null hypothesis of multivariate normality, as indicated by statistically significant skewness and kurtosis components, as well as a large joint Jarque–Bera statistic (p-value = 0.0000). In particular, the residuals exhibit excess kurtosis, suggesting the presence of fat tails and extreme observations. While this departure from normality may affect the efficiency of small-sample inference, it is a common feature in macroeconomic time-series models, especially in developing country contexts characterized by structural breaks, volatility, and external shocks. Importantly, the absence of residual serial correlation and the stability of the estimated system indicate that the model is dynamically well specified. Therefore, the non-normality of the residuals does not undermine the validity of the VECM estimates, and the results can be interpreted as robust for the purposes of analyzing long-run relationships and dynamic responses.

3.3.4 VEC Residual Heteroskedasticity Tests

The presence of heteroskedasticity in the residuals was examined using the VEC residual heteroskedasticity test including levels and squares (see Appendix B3). The joint test fails to reject the null hypothesis of homoskedasticity (p-value = 0.5827). The individual residual-product tests likewise provide little systematic evidence of heteroskedasticity, indicating that the residual variance is stable at the system level. This result suggests that the estimated VECM is not affected by systematic volatility in the error terms. Although one component is borderline depending on the test statistic considered; such behavior is not uncommon in macroeconomic time-series data, especially in developing economies characterized by structural shocks and price volatility. Importantly, the absence of heteroskedasticity at the system level confirms the adequacy of the model specification and supports the reliability of the estimated coefficients and dynamic simulations.

3.4 Granger Causality

The VEC Granger-causality/block-exogeneity test (see Appendix B4) reveals relatively limited short-run predictive linkages among the variables. In particular, the null hypothesis that ODA does not Granger-cause GDP cannot be rejected ($\chi^2 = 0.060914$, $p = 0.8051$), indicating that past changes in aid inflows do not contain significant incremental information for predicting short-run output growth. Similarly, ODA does not Granger-cause GFCF ($\chi^2 = 1.102$, $p = 0.294$) or CPI ($\chi^2 = 1.639$, $p = 0.201$), but GDP strongly Granger-cause CPI ($\chi^2 = 16.7301$, $p = 0.000$). These findings provide no support for a direct short-run ODA-growth effect or for the proposition that investment constitutes an empirically established short-run transmission channel from aid to growth.

3.5 Analysis of Impulse Responses

The impulse response analysis in Figure 2 provides important insights into the dynamic effects of official development assistance shocks on macroeconomic and development outcomes in the Democratic Republic of Congo.

The impulse-response functions (IRFs) and forecast-error variance decomposition (FEVDs) are identified using Cholesky decomposition with the ordering: LODA → LGDP → LGFCF → LCPI. The ordering reflects assumptions regarding the relative speed with which the variables respond to contemporaneous innovations. ODA is ordered first because aid commitments and disbursements are typically determined through donor budgeting, approval, and administrative processes, making them relatively predetermined within a quarter with respect to contemporaneous changes in recipient-country macroeconomic conditions. GDP is ordered second, allowing economic activity to respond contemporaneously to ODA innovations, while GFCF is ordered third to capture the response of investment to contemporaneous aid and output shocks. Finally, CPI is ordered last, allowing the price level to respond contemporaneously to innovations in all preceding variables. Since recursive

identification may be sensitive to variable ordering, the resulting impulse responses are interpreted as conditional on these identifying assumptions rather than as model-free causal effects.

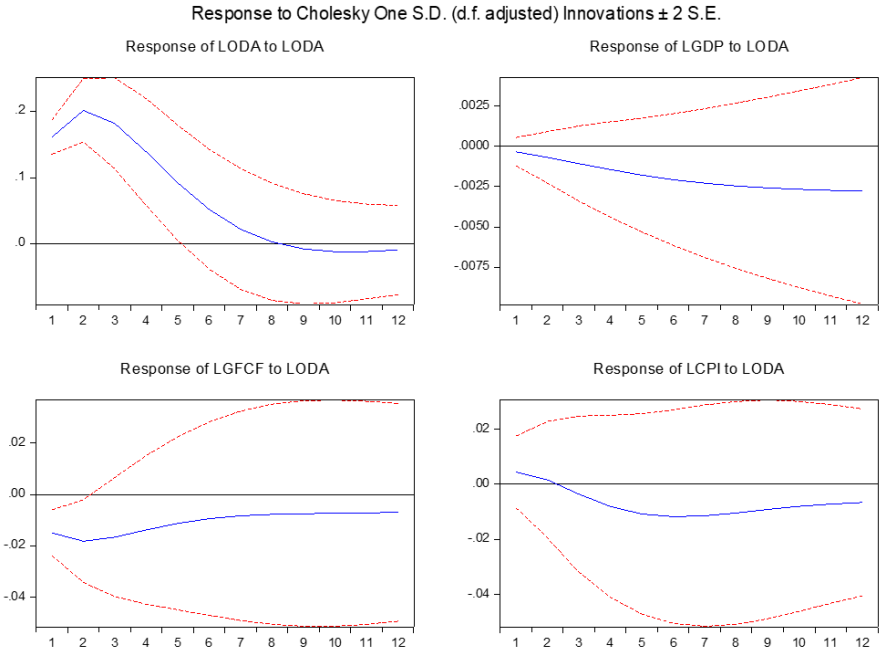

Figure 2. Impulse-response
Source: Author, using EViews 10 software

The impulse-response analysis further elucidates the magnitude and persistence of the dynamic responses to ODA innovations. Following a positive one-standard-deviation shock to ODA, aid inflows exhibit substantial short-run persistence before gradually converging toward their baseline. Although the point estimates suggest that GDP declines following a positive ODA shock, with negative response becoming more pronounced over medium-term, the 95% confidence interval includes zero throughout the forecast horizons.

Consequently, the estimated GDP response is not statistically significant at the 5% level, providing insufficient evidence that ODA shocks exert a systematic negative effect on economic growth. GFCF exhibits an immediate negative response to a positive ODA shock, with evidence of statistical significance at the 5% level confined to the initial quarters. The response subsequently diminishes and converges toward zero, with the 95% confidence interval encompassing zero at later horizons, indicating no statistically significant persistent effect of ODA shocks on investment.

CPI exhibits a modest positive response on impact following a positive ODA shock, before turning negative in subsequent periods. However, the 95% confidence interval encompasses zero throughout the entire forecast horizon, indicating that the response is not statistically significant at the 5% level. Thus, the IRF provides no statistically robust evidence that ODA shocks systematically affect the price level. Taken together, these results provide little evidence of statistically robust effects of ODA innovations on output or prices and only limited evidence of a temporary investment response.

3.6 Analysis of Shocks by Forecast Error Variance Decomposition

The variance decomposition results are broadly consistent with the Granger-causality and impulse-response evidence, while providing additional information on the relative quantitative importance of shocks over longer horizons. Although ODA does not Granger-cause GDP and its lagged change is

statistically insignificant in the short-run GDP equation, ODA innovations account for an increasing but quantitatively modest share of GDP forecast-error variance, rising from approximately 0.8% in the first quarter to 5.8% after twelve quarters. This does not contradict the absence of Granger-causality, since the FEVD captures the cumulative propagation of innovations through the dynamic system rather than testing whether lagged ODA significantly improves the prediction of GDP.

Consistent with this interpretation, the impulse-response estimates show a negative point response of GDP to a positive ODA shock, but the associated 95% confidence interval encompasses zero throughout the forecast horizon. Investment shocks, by contrast, become quantitatively important, accounting for approximately 37.6% of GDP forecast-error variance after twelve quarters. However, the absence of significant short-run predictive effects from ODA to GFCF precludes interpreting this result as evidence of an ODA–investment-growth transmission channel. Taken together, the results suggest that ODA innovations contribute modestly to medium-term GDP fluctuations, but provide no statistically robust evidence that aid systematically drives economic growth or does so through investment.

Table 10. Variance Decomposition of LGDP

Period	S.E.	LODA	LGDP	LGFCF	LCPI
1	0.003862	0.783347	99.21665	0.000000	0.000000
2	0.007174	1.160023	98.74879	0.050245	0.040943
3	0.010170	1.688904	97.67122	0.421826	0.218053
4	0.012811	2.340708	95.54207	1.505036	0.612190
5	0.015158	3.058579	92.00830	3.656927	1.276196
6	0.017311	3.770342	86.95828	7.053661	2.217720
7	0.019370	4.407754	80.60053	11.59778	3.393940
8	0.021407	4.924929	73.41243	16.93872	4.723922
9	0.023464	5.306809	65.98042	22.59893	6.113843
10	0.025549	5.564939	58.82649	28.12698	7.481596
11	0.027648	5.725853	52.30553	33.19856	8.770055
12	0.029736	5.819560	46.59112	37.64136	9.947957

Source: Author, using EViews 10 software

4. Conclusion and Policy Implications

This study examines the dynamic relationship between official development assistance (ODA) and economic growth in the Democratic Republic of Congo using a VECM framework for the period 2000Q1-2021Q4. The analysis considers ODA, real GDP, gross fixed capital formation (GFCF), and the consumer price index (CPI), allowing the distinction between long-run equilibrium adjustment and short-run macroeconomic dynamics. The results indicate a stable long-run relationship among the four variables. Within the normalized cointegrating vector, GDP and CPI are statistically significant in the ODA-long-run relation, while GFCF is not. The adjustment coefficients indicate that ODA ($\alpha = -0.0697$, $t = -2.95$) and CPI ($\alpha = 0.0250$, $t = 3.03$) respond significantly to deviations from long-run equilibrium, whereas GDP and GFCF do not.

The short-run evidence provides little support for a direct growth-enhancing effect of ODA. Lagged ODA does not significantly predict changes in either GDP or GFCF, consistent with the Granger-causality results. The impulse-response analysis reinforces this conclusion. Although GDP exhibits a negative point response following a positive ODA shock, its 95% confidence interval encompasses zero throughout the 12-quarter horizon. GFCF responds negatively in the initial quarters, after which the response converges toward zero and becomes statistically insignificant. CPI initially responds modestly positively and subsequently negatively, but its response remains

statistically insignificant at the 5% level throughout. Thus, the IRFs provide no robust evidence that ODA innovations systematically affect output or prices and only limited evidence of a temporary investment response.

The FEVD complements these findings. GDP's own innovations decline from 99.2% of its forecast-error variance in the first quarter to 46.6% after twelve quarters, while the contributions of ODA, GFCF, and CPI rise to 5.8%, 37.6%, and 9.9%, respectively. Thus, ODA innovations make a modest contribution to medium-term GDP fluctuations, whereas investment shocks become quantitatively important. This result does not, however, establish an ODA-investment-growth transmission mechanism, since neither the causality tests nor the IRFs provide robust evidence that ODA systematically drives investment.

Overall, the results suggest that ODA is embedded in the DRC's long-run macroeconomic dynamics but provide limited evidence that aid directly drives short-to medium-term economic growth. From a policy perspective, the results provide no evidence that larger aid inflows alone are sufficient to generate sustained growth. Greater emphasis should be placed on macroeconomic stability, institutional capacity, public-investment management, and the efficient allocation of development resources. Given the growing importance of investment shocks for GDP dynamics, improving the efficiency and productivity of capital formation appears particularly important, although this study does not establish investment as a causal transmission channel from ODA to growth.

Finally, the findings are interpreted in light of the temporal disaggregation of annual data into quarterly observations and the identifying assumption underlying the Cholesky decomposition. Future research using genuinely higher-frequency data and stronger structural identification strategies – including structural VAR models or external instruments – could provide more definitive evidence on the causal mechanisms linking ODA, investment, and economic growth in the DRC.

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Appendix

Appendix A1: Johansen Cointegration Results

Date: 08/15/26 Time: 20:12
Sample (adjusted): 2000Q3 2021Q4
Included observations: 86 after adjustments
Trend assumption: Linear deterministic trend
Series: LODA LGDP LGFCF LCPI
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.286889	62.01477	47.85613	0.0014
At most 1 *	0.211283	32.93666	29.79707	0.0210
At most 2	0.135365	12.52475	15.49471	0.1334
At most 3	0.000189	0.016258	3.841466	0.8984

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.286889	29.07811	27.58434	0.0319
At most 1	0.211283	20.41191	21.13162	0.0628
At most 2	0.135365	12.50849	14.26460	0.0930
At most 3	0.000189	0.016258	3.841466	0.8984

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

LODA	LGDP	LGFCF	LCPI
1.286348	6.110951	2.738480	-4.494294
-1.924655	2.070095	0.307212	-0.929736
0.812987	17.08738	-7.297799	-0.556358
-0.479118	-0.323333	3.164511	-1.106306

Unrestricted Adjustment Coefficients (alpha):

D(LODA)	-0.054192	0.059974	-0.011321	0.000563
D(LGDP)	-0.000347	-0.000650	-0.001276	-1.43E-05
D(LGFCF)	-0.005580	-0.005310	0.005244	-0.000448
D(LCPI)	0.019408	0.017694	-0.005119	-0.000359

1 Cointegrating Equation(s): Log likelihood 679.6364

Normalized cointegrating coefficients (standard error in parentheses)

LODA	LGDP	LGFCF	LCPI
1.000000	4.750629	2.128883	-3.493846
	(2.30240)	(1.12666)	(0.61504)

Adjustment coefficients (standard error in parentheses)

D(LODA)	-0.069709 (0.02361)
D(LGDP)	-0.000446 (0.00056)
D(LGFCF)	-0.007178 (0.00553)

Continued on next page

Appendix A1: Johansen Cointegration Results – Continued from previous page

D(LCPI)	0.024965 (0.00825)			
2 Cointegrating Equation(s): Log likelihood 689.8423				
Normalized cointegrating coefficients (standard error in parentheses)				
LODA	LGDP	LGFCF	LCPI	
1.000000	0.000000	0.262858 (0.56463)	-0.251107 (0.39723)	
0.000000	1.000000	0.392795 (0.18079)	-0.682592 (0.12719)	
Adjustment coefficients (standard error in parentheses)				
D(LODA)	-0.185139 (0.03955)	-0.207011 (0.11023)		
D(LGDP)	0.000806 (0.00100)	-0.003465 (0.00279)		
D(LGFCF)	0.003042 (0.00985)	-0.045090 (0.02747)		
D(LCPI)	-0.009090 (0.01413)	0.155230 (0.03937)		
3 Cointegrating Equation(s): Log likelihood 696.0966				
Normalized cointegrating coefficients (standard error in parentheses)				
LODA	LGDP	LGFCF	LCPI	
1.000000	0.000000	0.000000	-0.042062 (0.10220)	
0.000000	1.000000	0.000000	-0.370211 (0.01955)	
0.000000	0.000000	1.000000	-0.795277 (0.04171)	
Adjustment coefficients (standard error in parentheses)				
D(LODA)	-0.194343 (0.04180)	-0.400450 (0.31119)	-0.047363 (0.13291)	
D(LGDP)	-0.000231 (0.00100)	-0.025263 (0.00746)	0.008160 (0.00319)	
D(LGFCF)	-0.013251 (0.01035)	0.067763 (0.07701)	-0.055185 (0.03289)	
D(LCPI)	-0.013251 (0.01491)	0.067763 (0.11096)	0.095941 (0.04739)	

Appendix A2: VECM Estimates Results

Vector Error Correction Estimates
Date: 08/15/26 Time: 20:33
Sample (adjusted): 2000Q3 2021Q4
Included observations: 86 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1			
LODA(-1)	1.000000			
LGDP(-1)	4.750629 (2.30240) [2.06333]			
LGFCF(-1)	2.128883 (1.12666) [1.88956]			
LCPI(-1)	-3.493846 (0.61504) [-5.68066]			
C	-149.9117			
Error Correction:	D(LODA)	D(LGDP)	D(LGFCF)	D(LCPI)
CointEq1	-0.069709 (0.02361) [-2.95268]	-0.000446 (0.00056) [-0.79013]	-0.007178 (0.00553) [-1.29819]	0.024965 (0.00825) [3.02566]
D(LODA(-1))	0.420620 (0.08819) [4.76954]	0.000126 (0.00211) [0.05963]	0.024713 (0.02065) [1.19658]	-0.031072 (0.03082) [-1.00812]

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Appendix A2: VECM Estimates Results – Continued from previous page

D(LGDP(-1))	-2.562841	0.726370	-1.005490	-3.696822
	(3.27789)	(0.07837)	(0.76765)	(1.14561)
	[-0.78186]	[9.26797]	[-1.30983]	[-3.22694]
D(LGFCF(-1))	0.455960	0.009378	0.558665	-0.014949
	(0.38138)	(0.00912)	(0.08932)	(0.13329)
	[1.19555]	[1.02845]	[6.25498]	[-0.11215]
D(LCPI(-1))	0.385992	-0.003125	-0.000377	0.569727
	(0.21187)	(0.00507)	(0.04962)	(0.07405)
	[1.82182]	[-0.61692]	[-0.00759]	[7.69398]
C	0.008911	0.003675	0.028880	0.071638
	(0.05633)	(0.00135)	(0.01319)	(0.01969)
	[0.15819]	[2.72880]	[2.18929]	[3.63888]
R-squared	0.455407	0.706032	0.420888	0.733463
Adj. R-squared	0.421370	0.687659	0.384694	0.716804
Sum sq. resids	2.317516	0.001325	0.127104	0.283081
S.E. equation	0.170203	0.004070	0.039860	0.059485
F-statistic	13.37972	38.42769	11.62852	44.02920
Log likelihood	33.36689	354.4444	158.2065	123.7752
Akaike AIC	-0.636439	-8.103358	-3.539686	-2.738958
Schwarz SC	-0.465206	-7.932125	-3.368452	-2.567724
Mean dependent	0.027314	0.012721	0.035891	0.062399
S.D. dependent	0.223751	0.007282	0.050815	0.111781

Determinant resid covariance (dof adj.)	2.15E-12	Log likelihood	679.6364
Determinant resid covariance	1.61E-12	Akaike information criterion	-15.15433
Number of coefficients	28	Schwarz criterion	-14.35524

Appendix B1: Residual Serial Correlation

VEC Residual Serial Correlation LM Tests

Date: 08/16/26 Time: 13:16

Sample: 2000Q1 2021Q4

Included observations: 86

Null hypothesis: No serial correlation at lag h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	16.99154	25	0.8821	0.670828	(25, 235.5)	0.8825
2	24.03309	25	0.5175	0.982638	(25, 235.5)	0.5186

Null hypothesis: No serial correlation at lags 1 to h

Lag	LRE* stat	df	Prob.	Rao F-stat	df	Prob.
1	16.99154	25	0.8821	0.670828	(25, 235.5)	0.8825
2	45.14365	50	0.6682	0.896150	(50, 267.9)	0.6722

*Edgeworth expansion corrected likelihood ratio statistic.

Table B2. Residual Normality Tests

VEC Residual Normality Tests

Orthogonalization: Cholesky (Lutkepohl)

Null Hypothesis: Residuals are multivariate normal

Date: 08/16/26 Time: 16:52

Sample: 2000Q1 2021Q4

Included observations: 86

Component	Skewness	Chi-sq	df	Prob.*
1	0.430694	2.658790	1	0.1030
2	-1.151034	18.98994	1	0.0000
3	0.571323	4.678549	1	0.0305
4	0.045843	0.030254	1	0.8619
Joint		26.35753	4	0.0000

Component	Kurtosis	Chi-sq	df	Prob.
1	8.803492	120.6885	1	0.0000
2	7.341321	67.53584	1	0.0000
3	10.10384	180.8315	1	0.0000
4	12.16593	301.3136	1	0.0000
Joint		670.3690	4	0.0000

Component	Jarque-Bera	df	Prob.
1	123.3473	2	0.0000
2	86.52578	2	0.0000
3	185.5100	2	0.0000
4	301.3439	2	0.0000
Joint	696.7265	8	0.0000

*Approximate p-values do not account for coefficient estimation

Appendix B3: VEC Residual Heteroskedasticity Tests

VEC Residual Heteroskedasticity Tests (Levels and Squares)
Date: 08/17/26 Time: 16:54
Sample: 2000Q1 2021Q4
Included observations: 86

Joint test:

Chi-sq	df	Prob.
353.2712	360	0.5827

Individual components:

Dependent	R-squared	F(10,75)	Prob.	Chi-sq(10)	Prob.
res1*res1	0.125446	1.075800	0.3915	10.78835	0.3742
res2*res2	0.143213	1.253636	0.2722	12.31634	0.2644
res3*res3	0.161692	1.446595	0.1770	13.90553	0.1773
res4*res4	0.143853	1.488690	0.2570	9.89132	0.4570
res2*res1	0.209312	1.985412	0.0468	18.00085	0.0549
res3*res1	0.131049	1.131092	0.3511	11.27017	0.3369
res3*res2	0.158917	1.417071	0.1894	13.66683	0.1887
res4*res1	0.192385	1.786604	0.0777	16.54511	0.0851
res4*res2	0.061444	0.490998	0.8908	5.284179	0.8714
res4*res3	0.141091	1.232008	0.2851	12.13383	0.2762

Appendix B4: Granger Causality

VEC Granger Causality/Block Exogeneity Wald Tests
Date: 08/17/26 Time: 17:00
Sample: 2000Q1 2021Q4
Included observations: 86

Dependent variable: D(LODA)

Excluded	Chi-sq	df	Prob.
D(LGDP)	0.021309	1	0.8839
D(LGFCF)	1.396884	1	0.2372
D(LCPI)	2.755491	1	0.0969
All	5.973648	3	0.1129

Dependent variable: D(LGDP)

Excluded	Chi-sq	df	Prob.
D(LODA)	0.060914	1	0.8051
D(LGFCF)	1.339644	1	0.2471
D(LCPI)	0.338588	1	0.5606
All	1.917855	3	0.5896

Dependent variable: D(LGFCF)

Excluded	Chi-sq	df	Prob.
D(LODA)	1.102363	1	0.2937
D(LGDP)	1.344652	1	0.2462
D(LCPI)	0.027438	1	0.8684

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Appendix B4: Granger Causality – Continued from previous page

All	3.028671	3	0.3872
Dependent variable: D(LCPI)			
Excluded	Chi-sq	df	Prob.
D(LODA)	1.638854	1	0.2005
D(LGDP)	16.73007	1	0.0000
D(LGFCF)	0.064589	1	0.7994
All	18.28282	3	0.0004