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Determining the Predictive Power of the Gravity Model: A Case for Zambia

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Abstract

Purpose: The purpose of this study was to determine the predictive power of the gravity model in explaining trade flows in Zambia.

Materials and Methods: The study utilized panel data for the period 1990-2020 for the Zambian economy and its 15 top trading partners based on 2018 trade volumes. The data was collected from the Centre for Prospective Studies and International Studies for International Information (CEPII) Gravity Database. The study employed the gravity equation to predict trade flows in Zambia.

Findings: The empirical results show that the gravity model accurately predicts Zambia's trade flows, with GDP positively and distance negatively correlated with exports. The results also show that sharing a common border enhances Zambia's exports. Surprisingly, trade agreements exhibit a negative relationship with exports.

Implications to Theory, Practice and Policy: The significant negative impact of distance on trade highlights the need for improved infrastructure and logistics to reduce transportation costs, thus, facilitating Zambia's trade flows. Further, the findings suggest that Zambia should focus on strengthening trade with neighboring countries. Additionally, Zambia should diversify export bases away from heavy reliance on the mining sector. Besides, there is a need for active participation in regional integration initiatives to address implementation challenges of trade agreements.

Keywords: *Trade Flows, GDP, Gravity Model, Zambia*

JEL Classification: F1, E1

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1.0 INTRODUCTION

The study of trade flows is essential for understanding a nation's economic integration and its position in the global market. Zambia, a landlocked nation in Southern Africa (neighboring eight countries), offers a distinct case for such an analysis due to its unique geographical location, economic structure, and trade policies. The gravity model of trade, which suggests that bilateral trade flows are directly proportional to the economic size of trading partners and inversely proportional to the distance between them, serves as a valuable framework for examining these dynamics.

Zambia has made significant efforts to strengthen its trade relations, especially within the Southern African Development Community (SADC) and with other global partners. Despite these efforts, Zambia faces challenges such as limited access to sea routes, infrastructural constraints, and economic dependence on a narrow range of exports, primarily minerals (copper, cobalt etc). These factors highlight the importance of understanding the determinants of Zambia's trade flows to develop effective trade policies and promote economic growth.

Zambia, with a population of approximately 19.6 million in 2022 and a GDP per capita of $1,457, heavily relies on the mining sector and rain-fed agriculture, making it vulnerable to external shocks from commodity price fluctuations and erratic weather patterns (World Bank, 2023). The agricultural sector employs 85% of the workforce, mainly in subsistence farming. In 2022, Zambia's main export destinations were Switzerland (38.45 percent), China (20.69 percent), the Democratic Republic of Congo (13.73 percent), and Singapore (10.54 percent), with copper as the dominant export (African Export-Import Bank, 2023). Its primary import sources were South Africa (30.03 percent) and China (15.51 percent), with key imports including machinery, vehicles, and fertilizers. Figure 1 below shows Zambia’s top export destinations for 2022 and 2023.

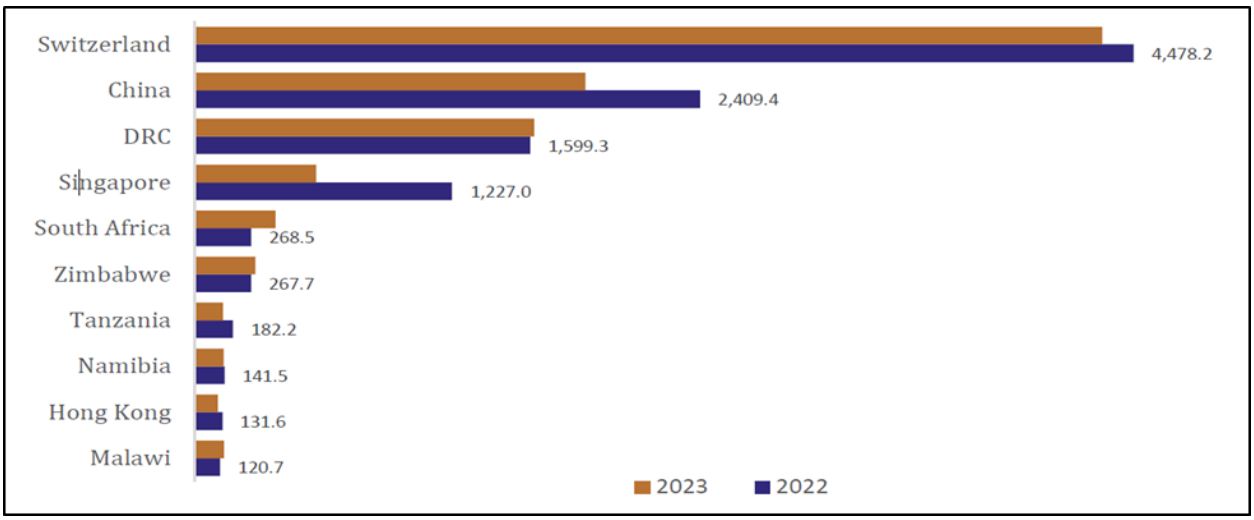

Figure 1: Zambia's Exports by Destination (Millions of USD)

Source: Bank of Zambia, 2023

The Zambian Government has been working to diversify exports and pursuing bilateral trade agreements to create market opportunities and boost exports. In 2022, the Government of Zambia allocated significant resources to upgrade and rehabilitate border points and access roads to facilitate trade (Ministry of Finance and National Planning [MOFNP], 2022). Due to its landlockedness, the country also faces some of the highest transportation costs in Southern Africa.

By examining the effects of economic size, distance, trade agreements, border effects, and other variables, this study aims to provide a comprehensive understanding of the determinants of Zambia's trade patterns. The findings will contribute to the broader literature on trade economics and offer valuable insights for policymakers aiming to improve Zambia's trade performance and economic resilience. This study employs the gravity model to analyze Zambia's trade flows with its major trading partners.

Problem Statement

Despite Zambia sharing borders with 8 countries in Southern Africa, its primary trading partners for exports and imports are Switzerland, South Africa, China, the Democratic Republic of Congo (DRC), and Singapore. Zambia's export market is highly concentrated, with over 75 percent directed toward a few key trading partners. These partners represent a substantial share of Zambia's total trade, yet only DRC shares a border with Zambia. This geographic separation highlights the relevance of economic distance and trade connectivity, which are key considerations in the gravity model of trade. Moreover, Zambia's exports are predominantly primary products, with such exports making up more than 75 percent of the country's total exports as of 2021 (Harvard Growth Lab, 2024).

Given Zambia's reliance on primary exports, the geographic dispersion of its trade partners, and landlockedness, it is important to understand the factors that affect the country's trade, and the gravity equation provides valuable insights on trade flows. This equation postulates that bilateral trade between countries mainly depends on how much they produce (GDP) and the distance between them, a proxy for transport costs. In this case, trade-flows between two countries are directly proportional to GDP size and inversely proportional to the distance. Understanding of these factors could be input into the development of effective trade policies given that the Government is making efforts to boost trade as well as diversify the country's exports. This study aims to determine the predictive power of the gravity model in explaining trade flows in Zambia.

Research Questions

i. Does the gravity model predict trade flows in Zambia?
ii. How do trade agreements affect trade flows in Zambia?

2.0 LITERATURE REVIEW

Theoretical Review-Gravity Model

Many researchers have used the gravity model to analyze trade policy. Tinbergen (1962) and Poyhonen (1963) first applied the gravity model to assess international trade flows. The idea behind the gravity model in international trade originated from Isaac Newton's law of universal gravitation, which describes the force of attraction between two objects based on their masses and distance. The gravity model of trade posits that the trade flow between two countries is directly proportional to the size of their economies, measured by Gross Domestic Product (GDP), and

inversely proportional to the distance between them. Various scholars have developed variations of gravity to incorporate other factors. Since then, the gravity model has become a popular empirical trade approach and remains one of the most successful models in explaining bilateral trade flows between countries.

This simple yet powerful framework has been extensively used in the economic literature to explain and predict bilateral trade flows, considering factors such as economic size, distance, and other barriers or facilitators of trade.

The gravity model is a foundational tool in international trade theory, drawing an analogy from Newton's law of gravity in physics. The model posits that the trade flow between two countries is directly proportional to the size of their economies, measured by Gross Domestic Product (GDP), and inversely proportional to the distance between them. This simple yet powerful framework has been extensively used in the economic literature to explain and predict bilateral trade flows, considering factors such as economic size, distance, and other barriers or facilitators of trade.

However, the gravity model has some limitations and one of the limitations concerns the assumption that distance is static nature. The gravity model assumes that distance is a primary determinant of trade flows. However, this assumption can be limiting, as technological advancements, improvements in logistics, and trade agreements have closed the gaps between countries in terms of distance. For instance, digitalization and improvement in aircraft technologies reduce the relevance of geographic distance over time (Feyrer, 2019). As a result, the model may understate potential trade flows between geographically distant countries that have strong logistical or digital connectivity.

Empirical Review

Osabuohien et al (2019) investigated the factors affecting intra-regional trade within the Economic Community of West African States (ECOWAS) by employing a gravity model framework, utilizing data from 15 ECOWAS countries over the period 2006–2013. The methodology includes various estimation techniques such as Ordinary Least Squares (OLS), Fixed Effects, and Poisson Pseudo-Maximum Likelihood (PPML) to analyze the relationship between trade flows and key variables namely GDP of trading partners, distance, and trade complementarity index (TCI). The findings of the study showed that bilateral trade increases with the economic size of the countries involved and decreases with distance, confirming the traditional gravity model's applicability. Additionally, the study highlighted the importance of economic integration agreements and TCI in enhancing trade, while financial development plays a less significant role in influencing bilateral trade performance among ECOWAS countries.

Eaton & Kortum (2002) used cross sectional data from 19 Organization for Economic Cooperation and Development (OECD) countries in 1990 to study how bilateral trade is impacted. The study adopted the Ricardian trade model that incorporates geographic features to analyze bilateral trade. The methodology involves estimating parameters related to absolute and comparative advantage, as well as geographic barriers, using data on trade flows, prices, and geography. The findings of the study were that geographic barriers and increased distance substantially inhibit trade, with its impact somewhat attenuated by a shared language. Borders and economic free trade agreements do not play a major role. Sharing a border reduces the barrier by 4 percent while sharing a language reduces it by 6 percent. They further argued that comparative advantage creates potential gains

from trade. However, the extent to which these gains are realized is attenuated by the resistance imposed by geographic barriers.

Oguledo & MacPhee (1994) and Eita & Jordaan (2007) argue that the effects of population on both imports and exports cannot be assigned a priori as the relationship is ambiguous. For example, a large population signals a large domestic market that could potentially decline cross-border trade due to a higher degree of self-sufficiency. On the other hand, a large population can also encourage division of labor, which could result in economies of scale in production and opportunities to trade with other countries. GDP for both the importing and exporting countries was positively significant. These results also proved the ambiguity of the effect of population on trade. Population variables possessed negative coefficients (in terms of exports), hence negative effects on export flows among the developing countries. In short, a developing country's export supply is positively related to its GDP and negatively related to its population size. The importers' population negative coefficient suggests that as the trading partners' populations grow, they become self-sufficient and have less need to engage in trade. Bendjilali (2000) applied the gravity model to a sample of Organisation of Islamic Cooperation (OIC) countries that represent various geographical regions and levels of economic development and examined the main determinants of intra-OIC bilateral trade in 1994 with reference to the characteristics of these countries. The results showed that the larger the population, the larger the domestic market and the lesser the exports, while a larger population could also be interpreted as a bigger market for imports.

Filippini & Molini (2003) employed the gravity model to examine trade patterns among East Asian nations and some developed countries. The study aimed to illustrate the remarkable trade achievements of East Asian nations. The results were all consistent with the expected signs from the gravity model. He further highlighted a notable inclination among Asian countries to engage in significant trade of high-tech manufactured goods with the USA. Brun et al. (2005) conducted a study using data from 130 countries to assess the Gravity model in light of globalization, with an emphasis on the importance of distance. The paper concluded that despite technological advancements and globalization, distance remains an important determinant of international trade flows. Even when controlling for other factors, such as economic size and trade policies, the authors found that geographic distance still significantly influences trade patterns between countries.

Research Gap

Several empirical studies have been done in various regions such as ECOWAS, OECD and East Asia on factors influencing trade flows. Despite all these studies, there remains research gaps in understanding the determinants of Zambia's trade patterns, particularly in the context of intra-regional trade. Other studies, such as those by Osabuohien et al. (2019) and Filippini (2003), focused on other economic blocs or more developed regions, which do not include Zambia and its unique characteristics when it comes to trade dynamics. Zambia, as a landlocked, developing country in Southern Africa, faces distinct geographic and economic challenges that differentiate it from the contexts studied in existing literature. For instance, while geographic distance is a significant determinant of trade flows globally, its impact on Zambia, with its reliance on neighbouring countries for access to ports and global markets, requires further investigation. Furthermore, given the country's membership to different trade agreements and ongoing economic reforms, the need to investigate Zambia's trade flows and its determinants is important. Thus, addressing these gaps could provide a more comprehensive understanding of Zambia's trade

behaviour and inform policy interventions aimed at enhancing the country's participation in global and regional trade.

3.0 MATERIAL AND METHODS

Data Sources and Description

The study utilized panel data from 1990 to 2020 on Zambia and 15 top trading partners based on 2018 trade volumes. The data was collected from the Centre for Prospective Studies and International Studies for International Information (CEPII) Gravity Database. The top 16 trading partners accounting for over 96 percent of Zambia's exports were Switzerland, China, the Democratic Republic of Congo (DRC), Singapore, South Africa, the United Arab Emirates, Great Britain, India, Hong Kong, Zimbabwe, Tanzania, Malawi, Luxembourg, Kenya, Namibia, and Botswana. The dependent variable is Zambia's exports (trade flow), while the main independent variables are Zambia's GDP, trading partner's GDP, and distance. Based on the literature, the following variables will be used to assess the Gravity model in Zambia;

Table 1: Description of Variables

Variable	Description	Expected sign
ln(Trade flows)	Zambia's exports	
ln(ZGDP)	Zambia's GDP	Positive
ln(TPGDP)	Trading partner's GDP	Positive
ln(Dist)	Distance between Zambia and trading partner (measured between capital cities)	Negative
ln(Zpop)	Natural log of Zambia's population	Ambiguous
ln(TPpop)	Natural log of trading partner's population	Ambiguous
Contig	Binary variable equal to 1 if Zambia shares a common border with a trading partner, and 0 otherwise.	Positive
Comlang_off	Binary variable equal to 1 if Zambia has a common official language with a trading partner, and 0 otherwise.	Positive
TA	Binary variable equal to 1 if Zambia has any type of trade agreement with the country, and 0 otherwise.	Positive

Model Specification

The standard Gravity model given below has been used to predict trade flows for Zambia;

$$Trade\ flows_{ijt} = \frac{GDP_{it} * GDP_{jt}}{Dist_{ij}} \mu \quad \text{.....(1)}$$

The standard gravity model in equation 1 is transformed into a log-linear model by applying natural log to both sides of the equation and has incorporated control variables to improve its predictive power of bilateral trade flows in Zambia as follows;

$$ln\ (Trade\ flows_{ijt}) = \mu + ln\ \beta_1 ln\ (ZGDP_{it}) + \beta_2\ ln\ ln\ (TPGDP_{jt}) - \beta_3\ ln\ ln\ (Dist_{ij}) + \beta_4 Contig_{ij} + \beta_5 ln(ZPop_{it}) + \beta_6 ln(TPop_{jt}) + \beta_7 comlang\_off_{ij} + \beta_8 TA_{ij} + \varepsilon_{ijt} \quad \text{.....(2)}$$

Where the subscript i represents Zambia, j represents the trading partner, and ε_{ij} is the error term. To control for time and country-invariant factors, the study also explored time and country-fixed effects. The specification of the gravity model with time and country-fixed effects is as follows;

$$ln\,(Trade\ flows_{ijt}) = \gamma_i + ln\,\beta_1 ln\,(ZGDP_{it}) + \beta_2\ ln\ ln\left(TPGDP_{jt}\right) - \beta_3\ ln\ ln\left(Dist_{ij}\right) + \beta_4 Contig_{ij} + \beta_5 ln(ZPop_{it}) + \beta_6 ln(TPop_{jt}) + \beta_7 comlang\_off_{ij} + \beta_8 TA_{ij} + \varepsilon_{ijt} \quad \text{.....(3)}$$

Where γ_i is country fixed effects.

4.0 FINDINGS

Presentation of Results

Table 2 below presents the gravity model's results. Column 1 shows the basic gravity model without fixed effects. Column 2 shows the results of the basic gravity equation with country-fixed effects. Columns 3 and 4 are augmented gravity model regressions without and with fixed effects, respectively.

The findings in column 1 are consistent with the predictions of the gravity model. Both Zambia's GDP and trading partner countries' GDP are positively correlated with exports, while distance has a negative effect. Holding other things constant, a 10 percent increase in Zambia's GDP is associated with an 11.5 percent increase in Zambia's exports. A 10 percent increase in a trading partner's GDP is associated with a 7.6 percent increase in Zambia's exports. Meanwhile, a 10 percent increase in the distance between trading partners is associated with a 13.6 percent decrease in Zambia's exports. All the coefficients are statistically significant at the 1 percent level. Similarly, in Column 2, both Zambia's GDP and trading partners' GDP were statistically significant at the 1 percent level. A 1 percent increase in either GDP's holding other things constant is associated with a 1 percent increase in exports.

In Column 3, after controlling for other variables, the coefficients for the standard gravity model remained statistically significant at the 1 percent level and consistent with its predictions. A 10 percent increase in Zambia's GDP is associated with a 9.9 percent increase in exports. Similarly, a 10 percent increase in a trading partner's GDP is associated with a 7.2 percent increase in exports. Meanwhile, a 10 percent increase in the distance is associated with a 14.4 percent decrease in exports. Exports to countries with which Zambia has trade agreements are 76 percent lower than those without trade agreements, at a 1 percent significance level. Countries that share a common border with Zambia have an average of 42.9 percent higher exports than countries that do not share the border. Other control variables, namely the official language, Zambia's population, and trading partners' population, have no statistical significance.

Table 3: Regression Results

	(1)	(2)	(3)	(4)
VARIABLES	**ln(Trade flows)**	**ln(Trade flows)**	**ln(Trade flows)**	**ln(Trade flows)**
lnZGDP	1.145***	1.027***	0.992***	0.944***
	(0.110)	(0.192)	(0.267)	(0.243)
lnTPGDP	0.764***	1.029***	0.715***	0.802***
	(0.070)	(0.245)	(0.090)	(0.287)
lnDist	-1.356***		-1.440***	
	(0.148)		(0.169)	
TA			-0.760***	-0.530*
			(0.248)	(0.298)
Contig			0.429*	
			(0.254)	
comlang_off			-0.222	
			(0.275)	
lnZpop			1.056	0.689
			(0.890)	(0.902)
lnTPpop			0.094	0.702
			(0.068)	(0.625)
Constant	-11.208***	-24.896***	-17.778***	-32.651***
	(1.657)	(2.251)	(4.974)	(4.907)
Observations	468	468	468	468
R-squared	0.461	0.582	0.482	0.587
YEAR FE	No	No	No	No
Country FE	No	Yes	No	Yes

Where robust standard errors are in parentheses

**** p<0.01, ** p<0.05, * p<0.1*

Robustness Check

The Hausman test was used to assess whether the random or fixed-effects model is the most efficient and, therefore, the preferable model. Hausman's test assumes that the random effects model is appropriate and provides consistent estimates. The Hausman test is indicated by a p-value greater than the critical value of 5 percent, implying that the null hypothesis is not rejected. Therefore, the random effect model in Column 3 of Table 3 is efficient.

Discussion of the Results

As highlighted above, estimated results show that variables of the standard Gravity model are consistent with the model's prediction. This aligns with the empirical findings of Fillipini (2003), who examined trade patterns among East Asian countries. The positive correlation between GDP and trade flows reflects the complex interplay of economic factors, including demand dynamics,

comparative advantage, investment patterns, and globalization trends. Higher GDP levels tend to be associated with increased trade activity as countries engage in the exchange of goods and services to meet domestic demand, exploit specialization opportunities, and capitalize on global market access. Distance is negatively correlated with trade flows due to several factors. Firstly, physical distance often entails higher transport costs due to expenses such as fuel, labor, and infrastructure, discouraging trade between geographically distant countries. Longer shipping times associated with greater distances can increase inventory costs and lost sales opportunities. This diverts traders to engage with closer partners to mitigate these time-related expenses. Additionally, geographically distant countries may face additional trade barriers, including fees and bribes, customs procedures, and regulatory requirements, elevating the cost and complexity of trading across long distances. Maintaining effective communication and information exchange over long distances can also be challenging and costly, which increases the risk associated with loss of goods and theft.

The observed negative association between sharing a trade agreement and Zambia's exports, contrary to the expectations based on the literature, suggests a complex relationship influenced by various factors. Theoretically, trade agreements are expected to foster exports by eliminating tariffs, reducing non-tariff barriers, streamlining customs procedures, facilitating trade, and enhancing market access. Nonetheless, many studies undertaken in Africa have different findings on the impact of Trade Agreements. Haile & Geda (2006) found that COMESA had an insignificant effect on the flow of bilateral trade. Gunning (2001) in assessing the relevance of trade blocks for Africa found that African economies were so small for any meaningful gains from regional blocks to be attained. Several reasons could explain the unexpected negative relationship in this case. For example, increased market access for foreign competitors under the agreement can intensify competition in foreign markets, potentially killing local firms and reducing export volumes for domestic producers. This could be true for Zambia, which has a weak manufacturing sector and imports most processed food and non-food items from South Africa.

Another reason Zambia’s exports to countries with trade agreements are lower is that implementation and compliance challenges hinder their effectiveness. Zambia is a Southern African Development Community (SADC) member, which has successfully reduced tariffs since 2000. However, significant non-tariff measures (NTMs) remain, which impede trade. The most common NTMs in SADC are sanitary and phytosanitary restrictions, certification procedures, quantity control measures, other technical regulations, investment restrictions, and bribes (UNCTAD, 2016). Another factor contributing to the limited impact of trade agreements on Zambia's exports is the presence of Double Taxation Agreements (DTAs) with countries such as China, Switzerland, India, and Singapore. These countries host multinational corporations (MNCs) that are major investors in Zambia's mining sector, which serves as the country's primary export industry. Despite having DTAs in place, Zambia lacks comprehensive trade agreements with these nations. Consequently, the MNCs operating in Zambia often trade primarily with their parent companies in their respective countries. This arrangement further hampers the trade agreement’s ability to have a positive association with exports. In addition, porous borders and informal trade may contribute to this result (Mijere 2009).

The coefficient for the common language was statistically insignificant, implying that sharing the common language between Zambia and its trading partner had no significant effects on Zambia’s exports. This can be backed by the fact that Zambia’s top export destinations (Switzerland and

China) do not have a common official language with Zambia. Similarly, the population had no statistical significance in explaining trade.

5.0 CONCLUSION AND RECOMMENDATIONS

Conclusion

The study showed that the standard Gravity model does well in predicting Zambia's trade flows. It highlights the gravity model's relevance, which links trade between countries to their economic size and distance. Despite technological advancements, distance remains a significant determinant of trade, impacting transport costs and trade barriers. Surprisingly, the study reveals a negative relationship between trade agreements and Zambia's exports, attributed to implementation challenges and competition from foreign firms. Additionally, factors like shared language and population size showed no significant impact on trade flows. The study underscores the importance of addressing trade facilitation measures, including streamlining customs procedures and enhancing infrastructure, to reduce transaction costs and boost export competitiveness. It also advocates for leveraging regional cooperation initiatives to promote intra-regional trade and diversifying Zambia's export base away from heavy reliance on the mining sector. Policymakers are urged to address implementation challenges in trade agreements to ensure tangible benefits for Zambia's exports. However, limitations in data availability and accuracy suggest caution in interpreting results. One major limitation is the lack of data on the infrastructure index, which is essential for explaining trade flows as it directly impacts transport efficiency and connectivity between trading partners.

Recommendations

The positive correlation between sharing a common border and Zambia's export levels implies significant policy implications. Policymakers should prioritize implementing trade facilitation measures to reduce transaction costs and boost export competitiveness. This includes streamlining customs procedures through establishment of one-stop border posts, reducing border delays by reducing the number of government agencies at the border, and enhancing border infrastructure such as automating the inspection process of goods crossing the borders. Additionally, Zambia's membership in regional bodies such as the SADC provides opportunities for deeper economic integration and enhanced market access. Policymakers should leverage regional cooperation initiatives to harmonize trade policies, reduce non-tariff and tariff barriers, and promote intra-regional trade. Given the concentration of exports in the mining sector, policymakers should prioritize efforts to diversify Zambia's export base. This could involve promoting value-added industries in sectors such as agriculture, manufacturing, and services. Special attention should be given to enhancing the competitiveness of non-mining sectors to reduce reliance on commodity price fluctuations. While Zambia has pursued bilateral trade agreements, the effectiveness of these agreements in boosting exports appears limited. Policymakers should address implementation and compliance challenges to ensure that trade agreements deliver tangible benefits.

Limitations

One limitation of this study was the unavailability of data such as the infrastructure index, which plays a key role in explaining trade flows, which may lead to omitted variable bias. In addition, the data set had some data gaps and outdated information in variables such as countries with trade

agreements. Inaccurate or incomplete data could lead to biased estimations and undermine the validity of the model's predictions.

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