Aggregate Ores and Metals Trade Mis-invoicing and Industrial Development in Zambia

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Abstract

The industrial sector development is crucial for achieving sustainable development. In Zambia, efforts to promote industrial development can be traced as far back as the 1960s. However, the increasing volume of illicit financial flow evidenced in trade mis-invoicing deprives the country of the needed resources to spur industrial development. This study, therefore, contributes to the literature by analyzing the effect of all ores and metals trade mis-invoicing on industrial development in Zambia. The study employed the vector error correction model (VECM) and Johansen cointegration test on unit root and cointegrated time series from 1992 to 2023. The study findings show that trade mis-invoicing in aggregate ores and metals has a disastrous long-term effect on industrial development in Zambia. Therefore, policymakers and implementors should curb trade mis-invoicing among mining companies, improve the regulatory quality and ensure a stable exchange rate to foster industrial development.

Keywords: Aggregate ores and metals trade mis-invoicing; Illicit financial flows; Industrial development; Zambia.

JEL Classification Codes: C22, F14, O10

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1. Introduction

Structural economic transformation is important to curb development challenges in developing countries. Industrialization plays a critical role in promoting structural economic transformation in many industrialized and industrializing economies worldwide. Early economists, such as Lewis (1954), argued that a thriving industrial sector should be at the core of transforming a predominantly rural and highly informal economy into a 'modern' economy, necessary for stimulating development. Historically, England and the Netherlands' industrialization (thriving manufacturing sector and a supportive infrastructure), for instance, led to economic development ((United Nations Industrial Development Organization (UNIDO), 2020)). Industrialization enabled the developmental take-off of most developed economies by driving sustained growth in jobs and productivity (Abreha *et al.*, 2021).

Also, Industrial development played a crucial role in structural economic transformation and economic growth of countries like China, Indonesia, South Korea, Malaysia, Singapore and Taiwan (Felipe, 2018). Moreover, it is empirically shown that industrialization drives sustainable development goals due to a high positive correlation between the overall SDG score and manufacturing intensity (UNIDO, 2020). As a result, industry, innovation and infrastructure was incorporated as a developmental goal (SDG 9) in the sustainable development agenda. Synchronously, industrialization and structural transformation are fundamental to the African Union's Agenda 2063 and the development strategies of many Sub-Saharan Africa (SSA) countries (Abreha *et al.*, 2021).

Like in many SSA countries, industrial policy is not a new concept in Zambia. Zambia's industrial policy fluctuated over time with changes in economic policies. Between 1964 and 1968, Zambia implemented the Transitional Development Plan (TDP) to promote industrial growth, among others, as a means of diversifying the economy away from copper (Central Planning Office, 1965). In this period, industrial policy remained relatively market-oriented. With the turn of events, from 1969 to 1991, the state took complete control of the industrial sector through the Mulungushi and Matero Reforms. The state-owned major companies, and promoted industrial growth through state investment and participation (Chansa *et al.*, 2019).

However, in 1989, institutional arrangements were made to privatize state-owned enterprises, given experienced bottlenecks in these enterprises, among others. From 1991, Zambia pursued liberalization policy through the Structural Adjustment Program (SAP) and reverted to the market-led industrialization policy. Subsequently, in 1994, an industrial policy was developed to support firms that maximized domestic inputs and fostered linkages within and without the manufacturing sector. The 1994 industrial policy was revised in 2005, 2010, and 2015, and the industrial policies that followed focused on multi-facility economic zones (MFEZ) to increase domestic and foreign investment in manufacturing for exports to make the industrial sector competitive.

Many developing countries, therefore, made efforts towards industrialization given its diverse economic benefits. However, these countries have had little success. Among many factors that hinder industrial development in resource-rich developing economies is illicit financial flows fuelled by trade mis-invoicing (Claessens and Naude, 1993; Ndikumana and Boyce, 2021; Lemi, 2019; United Nations Conference on Trade and Development, 2020; Yalta, 2010). Scholars maintain that illicit capital flight is larger and over three times higher in developing economies than in developed ones (Barry, 2014; Ndikumana *et al.*, 2015). Signé *et al.* (2020) state that trade mis-invoicing accounts for about 80% of total illicit financial flows from developing economies. On the contrary, industry as a share of GDP declined by 3.9% between 2013 and 2023 in SSA (Galal, 2024).

Illicit financial flows occur through trade mis-invoicing, money laundering, tax evasion and transfer pricings. Illicit financial flows crowd-out domestic investment (Afolabi, 2022a; Kar and Cartwright-Smith, 2010; Miyandazi, 2019), and stifle domestic resource mobilization (Afolabi, 2023; Asmah *et al*., 2020; Muslim *et al*., 2021). In addition, they discourage efficient resource allocation (Combes *et al*., 2019; Thiao, 2021), hinder the pursuit of development goals (Ngwakwe, 2015; Musya *et al*., 2020), and lowers the volume of financial resources available in an economy (Babatunde and Afolabi, 2023; Okojie, 2018). As a result, illicit financial flows undermine industrialization efforts in developing countries.

Trade mis-invoicing bears a lion's share of illicit financial flows. Consequently, the increase in global trade volume increases the possibility of financial resources moving illegally across borders through trade mis-invoicing. The Global Financial Integrity (2020) defines trade mis-invoicing as "intentional falsification of trade invoices information, such as prices, quantity and quality of traded goods to evade customs duties, hide profits offshore and dodge the international commercial trade system". Trade mis-invoicing is classified into four classes, that is, export under-invoicing, export over-invoicing, import under-invoicing and import over-invoicing (Mudenda, 2019). While export under-invoicing and import over-invoicing indicate illicit financial outflows, export over-invoicing and import under-invoicing represent illicit financial inflows.

Zambia is a resource-rich country. For instance, mineral exports account for more than 75% of total foreign exchange earnings. Further, mining is the second largest contributor to Zambia's GDP. The World Bank (2018) estimated 10 to 12 percent mining sector contribution to GDP between 2000 and 2015. Copper exports grew from USD 705 million in 1997 to USD 6.8 billion in 2018. Equally, precious minerals exports increased from USD 8.9 million to USD 143.49 million from 1997 to 2018, while cobalt exports increased from USD 13.7 million to over USD 167 million in the same period (Mudenda, 2019).

The rise in mineral exports makes Zambia susceptible to the unpalatable menace of illicit financial flows espoused by private ownership of the mining firms. Appraising this, Karl and Spanjers (2015) estimated Zambia's total trade mis-invoicing of USD 81,281 million between 2004 and 2013. In addition, Mudenda (2019) estimated about USD16.7 to 19.66 billion (or USD 34 to 39 billion in constant 2014 dollars) of exports over-invoicing in aggregate ores and metals (copper ore and copper articles, cobalt and precious metals, including gold and emeralds). Mudenda (2019) maintains that traders overstate exports to gain export subsidies possibly, and capital inflow does not come through official channels to benefit the country. Imports mis-invoicing for the period 1997 to 2018 stood at USD 11.1 billion at constant 2014 dollars and absolute trade mis-invoicing ranged between USD 27.12 billion at 5% CIF to USD 30.1 billion at 10% CIF over the same period (Mudenda, 2019).

On the contrary, Zambia has experienced deindustrialization between 1991 and 2019. For instance, the manufacturing sector's contribution to GDP plummeted to less than 6.8% in 2019 from 35% in 1991 (Miamba, 2021). That said, trade mis-invoicing in aggregate ores and metals could have fostered Zambia's deindustrialization process. As such, analyzing the effect of aggregate ores and metals trade mis-invoicing on industrial development in Zambia is important. Thus, this study seeks to answer the question: What is the effect of aggregate ores and metals trade mis-invoicing on industrial development in Zambia?

The empirical literature is overwhelming on the effect of trade mis-invoicing on macroeconomic performance (see, Afolabi, 2023; Asmah *et al*., 2020; Babatunde and Afolabi, 2023; Buehn and Eichler, 2011; Igwe, 2021; Ndikumana and Boyce, 2021; Ngwakwe, 2015; Nitsch, 2017; Ogbonnaya and Ogechuckwu, 2017; Putri and Purwana, 2011). However, no study has been conducted in Zambia. This study therefore makes two contributions to the literature: First, it uses trade mis-invoicing in all ores and metals unlike total trade mis-invoicing employed in many empirical studies. Second, it provides empirical evidence on the effects of trade mis-invoicing in aggregate ores and metals on industrial development in the Zambian context.

The rest of the paper is organized as follows: Section 2 shows stylistic facts for trade, trade mis-invoicing (aggregate ores and metals), and industrial development in Zambia from 1992 to 2023. Section 3 presents the methodology utilized to achieve the study's objective whereas section 4 presents and discusses the findings. In section 5, the study's conclusion and policy implications are provided.

2. Stylistic Facts: Trade, Aggregate ores and metals Trade Mis-invoicing and Industrial Development in Zambia

Stylistic facts enable the understanding of emergent trends in the growth pattern of trade, trade mis-invoicing and industrial output in Zambia. Figure 1 shows the progression of trade, trade mis-invoicing and industrial output from 1992 to 2023. Between 1992 and 2023, total trade (imports plus exports) as a share of GDP fluctuated. Although it grew from less than 60 percent in 1992 to over 70 percent in 2004, indicating a growth rate of 22.3 percent. On the contrary, it plunged by 13.8 percent between 2007 and 2009 from 65.8 percent to 56.12 percent, before gaining momentum until 2013. The drop in trade between 2007 and 2009 could be attributed to the global financial crisis while its steady increase from 2010 to 2013 signifies recovery from the crisis. Overall, trade has significantly improved in Zambia following a shift from One Party State to Multi-Party democracy and the implementation of Structural Adjustment Program (SAP), whose primary objective, among many, is to enhance trade liberalization. The effect of SAP and other trade policies has led to an improvement in Zambia's interaction with the rest of the world. In perspective, World Integrated Trade Solution (2022) reported that Zambia has many trading partners as it exports and imports about 2,020 and 3,877 products to 116 and from 191 partners.

Trade mis-invoicing is expected to move together with trade, because it is through trade that illicit financial flows take effect. This means that trade mis-invoicing increases with growing volume of trade. Therefore, in some instances, trade mis-invoicing fluctuated with trade during the period considered. The diversion of the trend of trade mis-invoicing from trade in some periods is explained by the fact that this study did not consider total trade mis-invoicing in all products. But, between 2006 and 2010, and 2017 and 2021 trade and trade mis-invoicing moved in the same direction. Like trade and trade mis-invoicing patterns, industry output fluctuated throughout the study period. However, its oscillations are opposite to trade mis-invoicing in some cases. This implies a negative relationship between trade mis-invoicing and industrial output. Also, it signals that increases in trade mis-invoicing leads to declines in industrial output. Overall, the share of industrial output in aggregate output has dwindled over the study period, signalling deindustrialization in Zambia.

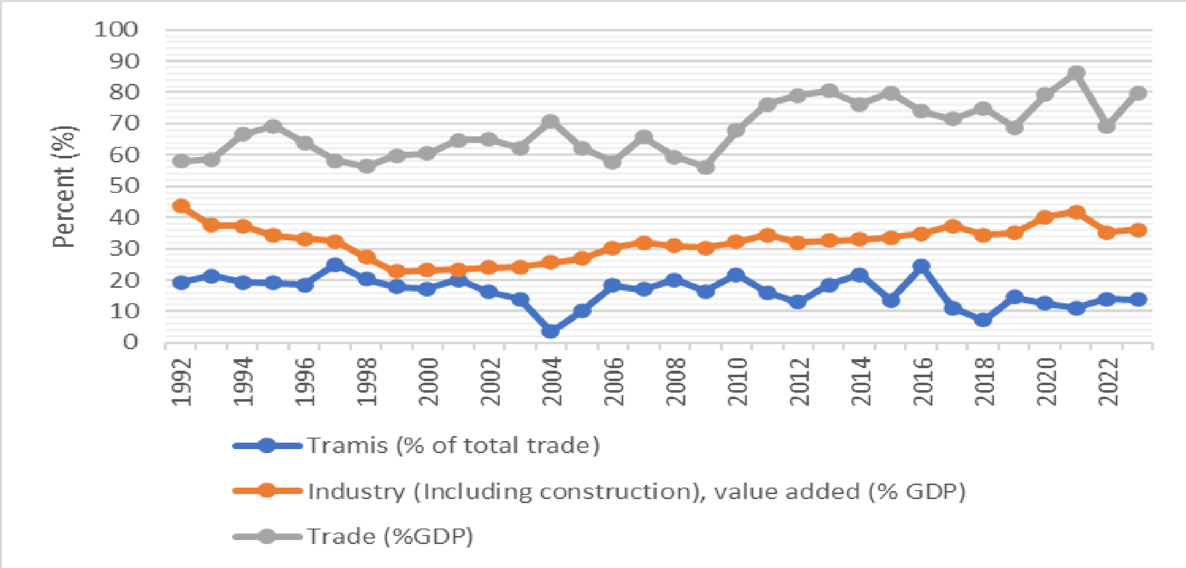

Figure 1: Trends for trade, trade mis-invoicing and industrial output

3. Methodology

3.1 Model Specification and Estimation Technique

Determining the type of the model to be specified and estimation technique to utilize in time series analysis requires the execution of necessary formal and informal preliminary tests (Sasilu, 2016). Tests, such as unit root, cointegration, descriptive statistics, and graphical analyses are inevitable. The model and estimation technique implemented in determining the short-run and long-run effect of aggregate ores and metals trade mis-invoicing in Zambia's industrial development is the Vector Error Correction Model (VECM). The VECM model proved superior to other time series estimation techniques in unit root and cointegrating series. Hence, choosing the VECM model and estimator is empirically supported by the data generation process. The VECM is a VAR model which adjusts to both short-run changes in variables and deviations from long-run equilibrium (Andrei and Andrei, 2015; Winarno *et al.*, 2021). Following Winarno *et al.* (2021), the general VECM model can be formulated as given in equation 1.

$$\Delta y_t = \alpha\beta' y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t \qquad (1)$$

where Δ is the difference operator, in which $\Delta y_t = y_t - y_{t-1}$; y_{t-i} is an endogenous vector variable with i^{th} lag; α is the vector adjustment matrix with order k x r; β is vector cointegration (long-run parameter) matrix with order k x r; ε_t is the vector residual; Γ_i is a matrix with k x k of coefficient endogenous of the i^{th} variable. Considering the speed of adjustment of a series to its long-run equilibrium and control variables, equation 1 is reformulated as shown in equation 2.

$$\Delta y_t = \alpha + \beta_1 ECT_{t-i} + \beta_2 \Delta y_{t-i} + \beta_3 \Delta X_{t-i} + \varepsilon_t \qquad (2)$$

where ECT_{t-i} is the error correction term; X is the set of control variables differenced to account for short-run dynamics. The specification of X allows the introduction of the independent variable into the model. Following the Johansen Cointegration test results, the VECM model with one cointegrating equations, a system of five equations from equation 3 to 7 is estimated with i^{th} lag length selected using the Akaike information criterion (AIC).

$$\Delta Ind_t = \alpha + \beta_1 ECT_{t-i} + \beta_2 \Delta Ind_{t-i} + \beta_3 \Delta Trad_{t-i} + \beta_4 \Delta RegQ_{t-i} + \beta_5 \Delta \log(ExcR_{t-i}) + \beta_6 \Delta Tramis_{t-i} + \varepsilon_t \quad (3)$$

$$\Delta Trad_t = \alpha + \beta_1 ECT_{t-i} + \beta_2 \Delta Trad_{t-i} + \beta_3 \Delta Ind_{t-i} + \beta_4 \Delta RegQ_{t-i} + \beta_5 \Delta \log(ExcR_{t-i}) + \beta_6 \Delta Tramis_{t-i} + \varepsilon_t \quad (4)$$

$$\Delta RegQ_t = \alpha + \beta_1 ECT_{t-i} + \beta_2 \Delta RegQ_{t-i} + \beta_3 \Delta Trad_{t-i} + \beta_4 \Delta Ind_{t-i} + \beta_5 \Delta \log\ (ExcR_{t-i}) + \beta_6 \Delta Tramis_{t-i} + \varepsilon_t \quad (5)$$

$$\Delta \log(ExcR_t) = \alpha + \beta_1 ECT_{t-i} + \beta_2 \Delta ExcR_{t-i} + \beta_3 \Delta Trad_{t-i} + \beta_4 \Delta RegQ_{t-i} + \beta_5 \Delta Ind_{t-i} + \beta_6 \Delta Tramis_{t-i} + \varepsilon_t \quad (6)$$

$$\Delta Tramis_t = \alpha + \beta_1 ECT_{t-i} + \beta_2 \Delta Tramis_{t-i} + \beta_3 \Delta Trad_{t-i} + \beta_4 \Delta RegQ_{t-i} + \beta_5 \Delta \log(ExcR_{t-i}) + \beta_6 \Delta Ind_{t-i} + \varepsilon_t \quad (7)$$

where Ind is industrial development; $Trad$ is trade openness; $RegQ$ is regulatory quality; $ExcR$ is exchange rate; and $Tramis$ is mis-invoicing in aggregate ores and metals trade. In equation 3, industrial development is the function of its i^{th} lagged values, trade openness, regulatory quality, log of exchange rate, and aggregate ores and metals trade mis-invoicing. Subsequently, the dependent variables in the other systems of equations are functions of their i^{th} lagged values and the explanatory variables.

3.2 Data, Measurement and Sources

To analyze the effect of trade mis-invoicing in aggregate ores and metals on industrial development, time series data on variables of concern were collected from 1992 through 2023 from various sources. We chose 1992 following the 1991 regime change from One-Party State to Multi-Party democracy. Equally, Zambia's mines were privatized in the 1990s and 2000s, attracting foreign direct investment in the mining sector, changing the ownership structure (Mudenda, 2019). As such, trade mis-invoicing under private ownership is expected to be rampant. On the other hand, 2023 was chosen as the latest year for which data on most variables was available.

Industrial development is proxied on industrial output, including construction as a percent of GDP. Trade openness indicates Zambia's trade interaction with the rest of the world. Since trade mis-invoicing results from more trade, trade openness is expected to increase the former. Trade openness, therefore, is expected to have a negative long-run effect on industrial output. Trade openness is measured as the sum of Zambia's exports and imports as a percent of gross domestic product (GDP). Regulatory quality impacts industrial development (Asmah *et al.*, 2020). A strong regulatory quality can spur industrial output. Conversely, a weak regulatory quality can achieve the opposite. It is an index ranging between -2.5 and 2.5 (denoting weak and strong regulatory quality) measured as government's ability to frame and implement viable policies and regulations that foster private sector development.

International trade to a large extent is determined by exchange rate, which denotes the value of the Zambian Kwacha against that of foreign currencies such as the United Stated Dollar (USD). In effect, exchange rate can dampen or promote industrial development (Ogunjimi, 2020b). A depreciating Zambian Kwacha can stall industrial development as it becomes expensive for manufacturers to import raw materials and intermediate inputs. On the other hand, a strong Zambian Kwacha promotes industrial output. Trade mis-invoicing in aggregate ores and metals is the sum of aggregate ores and metals exports mis-invoicing and aggregate ores and metals import mis-invoicing as a percent of total trade. It is expected to hurt industrial output as resources needed to develop the industrial sector are syphoned from the economy.

Time series data used was obtained from various sources. Apart from regulatory quality and exchange rate, variables are expressed in percentages. Data for exchange rate was transformed using logarithm while regulatory quality remained in its state because it had negative values. Data on industry output, trade openness and exchange rate were obtained from the World Development Indicators (WDI) while data on regulatory quality was sourced from the World Governance Indicator (WGI). Lastly, we follow Mudenda (2019) in computing data for aggregate ores and metals level trade mis-invoicing in Zambia, who used country to individual partner at product level approach to compare exports and imports as a means of measuring trade mis-invoicing[1]. Data on copper ores and copper articles, cobalt, and precious minerals including gold and emeralds exports and imports was obtained from COMTRADE.

4. Results and Discussion

This section presents the results of the study, and discusses them in relation to other studies. The section starts by presenting preliminary tests as a requirement in time series analysis before the empirical results are presented and discussed.

4.1 Preliminary Tests

Preliminary tests are critical in time series analysis for determining the statistical properties of variables used. Also, they guide on the appropriate choice of variables and estimation technique (Sasilu, 2016). In addition, these tests enable researcher to avoid presenting false results when some series deviate from their long-run equilibrium (Nkoro and Uko, 2016). Correlation test, descriptive statistics and unit root test were conducted given the nature of the study.

4.1.1 Correlation Test

In determining the relationship between two variables as well as the strength of their association, the correlation matrix in table 1 is given. The Pearson correlation coefficient can also help determine which variables should be included or not in the model to avoid multicollinearity. Multicollinearity entails that including two variables with high correlation

[1] Trade mis-invoicing is calculated based on the mirror accounts on both exports and imports side of Zambia and her trading partners. Export discrepancies between Zambia and trading partners are computed by equation $Expmis_{zt} = Imp_{jt} - (1-\pi)Exp_{zt}$ where $Expmis_{zt}$ is exports of all ores and metals by Zambia to trading partner j at time t as reported in Zambia, Imp_{jt} are imports from Zambia as reported and recorded by trading partner j at time t. π is the cost of freight and insurance. A positive sign of export mis-invoicing shows the presence of export under-invoicing (capital outflow) while a negative sign indicates the over-invoicing of exports (capital inflow). Then, import mis-invoicing at trading partner level is computed by equation $Impmis_{zt} = Imp_{zt} - (1-\pi)Exp_{jt}$ where $Impmis_{zt}$ is Zambia's import mis-invoicing at time t, Imp_{zt} is imports reported by Zambia from partner j, Exp_{jt} is exports reported by trading partner. A positive value indicates import over-invoicing while a negative value refers to import under-invoicing. This means, there is import over-invoicing if Zambia's official imports figures are greater than the exports reported by partner countries. Finally, the summation of export mis-invoicing and import mis-invoicing in all ores and metals gives us the total trade mis-invoicing in aggregate ores and metals in Zambia given by equation $Tramis_{zt} = Expmis_{zt} + Impmis_{zt}$. A positive value indicates capital outflow while a negative value shows a reduction in capital flight (Mudenda, 2019). In particular, to capture trade in copper ores and copper articles, the analysis uses the HS -2603 and HS 74, HS 71 and HS 2616 for cobalt and HS 2605, and HS 8105 for precious mineral that include gold and emeralds. The final value of trade mis-invoicing is expressed as a percentage of total trade.

coefficient of say 0.8 and above would lead to spurious results since one of the variables can be predicted by another in the regression model (Bhandari, 2020). Hence, it is an important test in time series analysis. Table 1 shows that our data did not have cases of high correlation.

Table 1: Correlation matrix

Variable	(1)	(2)	(3)	(4)	(5)
(1) Ind	1.000				
(2) Trad	0.423 (0.016)	1.000			
(3) RegQ	0.437 (0.012)	-0.188 (0.303)	1.000		
(4) Log (ExcR)	-0.009 (0.962)	0.343 (0.055)	-0.419 (0.017)	1.000	
(5) Tramis	0.052 (0.776)	-0.331 (0.064)	0.401 (0.023)	-0.114 (0.533)	1.000

In parenthesis are p-values

4.1.2 Descriptive Statistics

Table 2 presents the summary statistics for each of the variables used. The industrial sector's contribution to Zambia's economy is minimal, ranging between 22.82 and 43.745 percent. Zambia has opened her economy to international trade; trade openness averaged 68.078 percent, with minimum and maximum values of 56.121 percent and 86.209 percent, respectively. The country is highly open to international trade. This is explained by the liberalization policies of the 1980s and 1990s. Regarding Zambia's ability to formulate and implement sound policies relevant for private sector development, the country performs poorly within the range of -0.761 and -0.208, indicating weak regulatory environment. This has the potential to hinder industrial development as the private sector is a key player in the economy, whose participation transforms economies.

Exchange rate performance in Zambia shows that there have been episodes of appreciation and depreciation of the Zambian Kwacha, as shown by the minimum and maximum values. A depreciation of a local currency makes it costly for players in the industrial sector to import materials and equipment so much needed for production. Of all trade mis-invoicing taking place in Zambia, the aggregate ores and metals level trade mis-invoicing averages about 16.474 percent. Trade mis-invoicing in aggregate ores and metals is relatively high with the maximum value of 25.092 percent for the study period, indicating that at most Zambia loses about a quarter of her total trade to trade mis-invoicing in aggregate ores and metals trade only. It signals high levels of smuggling between Zambia and her aggregate ores and metals trading partners (Ekananda, 2018). This translates to lost financial resources necessary for industrial development. Hence, trade mis-invoicing negatively impact industrial development. Lastly, the results show that variables are not widely dispersed from their means given by small standard deviation values.

Table 2: Summary statistics

Variable	Obs	Mean	Std. dev.	Min	Max
Ind	32	32.251	5.423	22.82	43.745
Trad	32	68.078	8.495	56.121	86.209
RegQ	32	-0.051	0.143	-0.761	-0.208
ExcR	32	77.975	19.345	47.003	112.59
Tramis	32	16.475	4.579	3.492	25.092

Note: Obs is the number of observations, Std.dev. is the standard deviation, Min is minimum and Max is maximum

4.1.3 Unit Root Test

As elaborated earlier, unit root test help determine the time series analysis's estimation technique. Therefore, knowledge of unit root in the data is therefore critical (Choi, 2015). The presence of unit root in series indicate that the means and variances of series divert from their long-run equilibrium, exposing them to permanent random shocks effect (Engle and Granger, 1987). Many unit roots tests are used in empirical literature. However, the Augmented Dickey Fuller test (ADF) and the Philip-Perron (PP) test are the commonest in time series analysis. The null hypothesis for both ADF and PP tests is that series contain unit root (that is, non-stationery in levels). The results of the ADF and PP tests are given in table 3, demonstrating that all variables are stationary at first difference at all levels of significance when the constant and trend are considered. Consequently, the variables used in this study are integrated of order one [*I* (1)]. The presence of unit root in series requires that Johansen cointegration test is performed to determine the existence of a long-run relationship among the variables (Stata Corp, 2021).

Table 3: Augmented Dickey-Fuller test and Phillip-Perron test for unit root

		ADF		PP		Order of Integration
		Constant and No Trend				
Variable	Lag (AIC)	*I* (0)	*I* (1)	*I* (0)	*I* (1)	
Ind	1	-1.543	-3.914***	-2.279	-5.088***	*I* (1)
Trad	1	-1.857	-5.795***	-2.165	-6.769***	*I* (1)
RegQ	4	-2.600*	-2.682*	-2.703*	-8.137***	*I* (1)
Log (ExcR)	1	-1.685	-4.444***	-1.973	-5.372***	*I* (1)
Tramis	2	-2.426	-4.062***	-3.867***	-8.245***	*I* (1)
		Constant and Trend				
Ind	1	-2.455	-4.509***	-3.280*	-5.175***	*I* (1)
Trad	1	-3.087	-5.723***	-3.603**	-6.624***	*I* (1)
RegQ	4	-2.302	-6.762***	-2.590	-7.942***	*I* (1)
Log (ExcR)	1	-1.587	-4.713***	-1.757	-5.380***	*I* (1)
Tramis	2	-2.749	-3.976***	-4.200***	-8.078***	*I* (1)

Note: *, **, and *** denotes significance at 10%, 5% and 1%, respectively. The optimal lag order is determined by AIC.

4.1.4 Cointegration Test

Engle and Granger (1987) posit that a cointegration test is used to determine if there is a relationship between time series in the long term. This study employed the Johansen test to provide estimates of all cointegrating vectors. The test is based on eigenvalues of transformation of the data and represent linear combinations of the data with maximum correlation (Winarno *et al.*, 2021). The trace test statistic of the Johansen test was used with the null hypothesis of no cointegration against the alternative of cointegration. As shown in table 4, the null is not rejected at maximum rank value of zero but rejected at maximum rank value of one, at which point our results are flagged with asterisk (*). In other words, the null hypothesis of no cointegration is strongly rejected, but we fail to reject the null hypothesis of at most one cointegrating equation. Therefore, the results suggest the presence of one cointegrating equation among the five variables in the Zambian economy at 5% level. This imply that there is an error correction term which reflects the speed of adjustment to long-run equilibrium in the set of the cointegrated time series.

Table 4: Johansen cointegration test

Trend: Constant					Number of obs = 30
Sample: 1994 thru 2023					Number of lags = 2
Max rank	params	LL	Eigenvalue	Trace Stat	Critical value (5%)
0	30	-188.563		68.562	68.52
1	39	-172.26	0.663	35.957*	47.21
2	46	-165.416	0.366	22.268	29.68
3	51	-159.365	0.332	10.166	15.41
4	54	-165.131	0.194	3.699	3.76
5	55	-154.282	0.116		

4.2 Empirical Results and Discussion

In estimating the effect of trade mis-invoicing in all ores and metals trade on industrial development in Zambia, the VECM model with one cointegrating equation was estimated in Stata 17 with a system of five equations ordered by each variable. The empirical results for the short-run model are presented in Appendix 1. The _ce1 L1. indicates the speed of adjustment of the variable under investigation to its long-run equilibrium. The statistical significance of the coefficient shows that past equilibrium errors play a role in determining the current outcomes that capture the long-run impact (Andrei and Andrei, 2015). In the short-run, the study findings show that trade mis-invoicing in aggregate ores and metals trade does not affect industrial development. Trade mis-invoicing and exchange rate have expected significant signs of the error correction term, signifying that there is high speed of adjustment to their long-run equilibrium.

Table 5 provides the results for the VECM model. The Johansen normalization restriction-imposed test results show the long-run effect of control variables on industrial development. From the results, the long-run VECM model is specified below:

$$Ind = 116.729 - 0.809\,Trad + 93.643\,RegQ + 17.598\,ExcR - 3.472 Tramis \quad (8).$$

Equation 8 provides the individual estimates of trade mis-invoicing and control variables. The negative sign on the coefficient of trade mis-invoicing indicates that trade mis-invoicing inhibits industrial output and, hence, industrial development in Zambia. In other words, trade mis-invoicing exerts a negative impact on industrial development. In particular, the results show that a percent increase in trade mis-invoicing in aggregate ores and metals reduces industrial development by 3.472 percent. This means that, the more financial resources are tapped off the Zambian economy through trade mis-invoicing, the less likely it is for the industrial sector to develop. Also, trade mis-invoicing leads to revenue loss, hindering government's efforts to foster industrial development by taking away the resources critical for financing development agendas, including industrialization (Dickinson, 2014; Qureshi and Mahmood, 2016).

This result conforms to a priori expectation and is consistent with empirical findings of Okojie (2018), who contended that trade mis-invoicing slows industrial growth by reducing foreign exchange earnings. In addition, this result supports the finding of Ngwakwe (2015), in which high volumes of trade mis-invoicing hampered industrialization and sustainable development in Nigeria and plunged the country into huge external debt. In Zambia, trade mis-invoicing can undermine government's development efforts for sustainable and inclusive growth. Therefore, the results indicate the ominous need to curtail trade mis-invoicing in aggregate ores and metals trade, which increases the overall illicit financial flows out of the country.

Regarding the effect of the control variables on industrial development, the study found that trade openness inversely impacts industrial output in Zambia. This signals that higher trade volumes as a share of GDP could be associated with greater volumes of trade mis-invoicing—a channel for illicit financial flows. As such, a one percent increase in Zambia's trade as a share of GDP will undermine industrial development by 0.809 percent. Instinctively, Zambia's interaction with the world outwits industrial development, which could be explained by the suffocation of domestic producers in the presence of competing and imported foreign goods. This result contradicts that of Afolabi (2022) who found trade openness to foster industry productivity in Nigeria.

Regulatory quality improves industrial development in Zambia, indicating that any improvement in government's capacity to make and enforce sound policies foster industrial output by steering private sector participation in the economy. This result is in line with intuition that business-friendly policies promote industrial development. The coefficient of log of exchange rate is positive and significant, signifying that exchange rate is important in determining industrial development in Zambia. Therefore, industrial development will be spurred/slowed if the exchange rate appreciates/depreciates. Domestic industries depend on imported materials in their production processes. Hence, a depreciating Zambia Kwacha increases the cost of imports, interfering with production activities and processes. Consequently, a stable exchange rate is a recipe for promoting of industrial development in Zambia.

Table 5 VECM results

Cointegrating equations

Equation	parms	chi2	p>chi2
_ce1	4	157.155	0.000

Identification: beta is exactly identified

Johansen normalization restriction imposed

beta	Coeff.	Std. err.	z	p-value	95% Conf. interval	
_ce1						
Ind	1	.	.	.	.	.
Trad	0.809	0.139	5.84	0.000	0.538	1.081
RegQ	-93.643	9.607	-9.75	0.000	-112.472	-74.814
Log (ExcR)	-17.598	4.715	-3.73	0.000	-26.839	-8.356
Tramis	3.472	0.310	11.20	0.000	2.864	4.080
Constant	-116.729	.	.	.	.	.

4.3 Diagnostic Tests

Diagnostic tests help ensure the validity and reliability of estimation results. The normality, serial correlation, homoscedasticity, and model stability tests were conducted.

Figure 2 is the graphical representation of the cointegrating equation. The data distribution in the graph indicates that the cointegrating equation is stationary. The VEC Residual Normality tests are used to check for normality. Hence, Jarque-Bera test, Skewness test and Kurtosis test show that series are jointly normally distributed with p-values of 0.897, 0.901 and 0.651, respectively. The Lagrange multiplier test was used to check for serial correlation up to the lag length 2. The results show that we fail to reject the null of no serial correlation up to the lag length 2 in the data given by a p-value of 0.264. Heteroscedasticity was tested using Breusch-Pagan and White's heteroscedasticity tests with the null hypothesis that errors are homoscedastic against the alternative that they are heteroscedastic. The Breusch-Pagan results retained a chi2 value of 1.40 with a p-value of 0.236, whereas White's test recorded a chi2 value of 13.57 and a p-value of 0.138. These tests show that errors are homoscedastic, hence we accept the null hypothesis. In checking for model stability, the VECM specification imposed 4 units moduli, which shows that the model is unstable. Figure 3 indicates that none of the remaining eigenvalues appear close to the unit circle. Consequently, the stability check does not indicate model mis-specification (Stata Corp, 2021). Based on these diagnostic tests, the model is correctly specified, and our results can be relied upon for policy formulation.

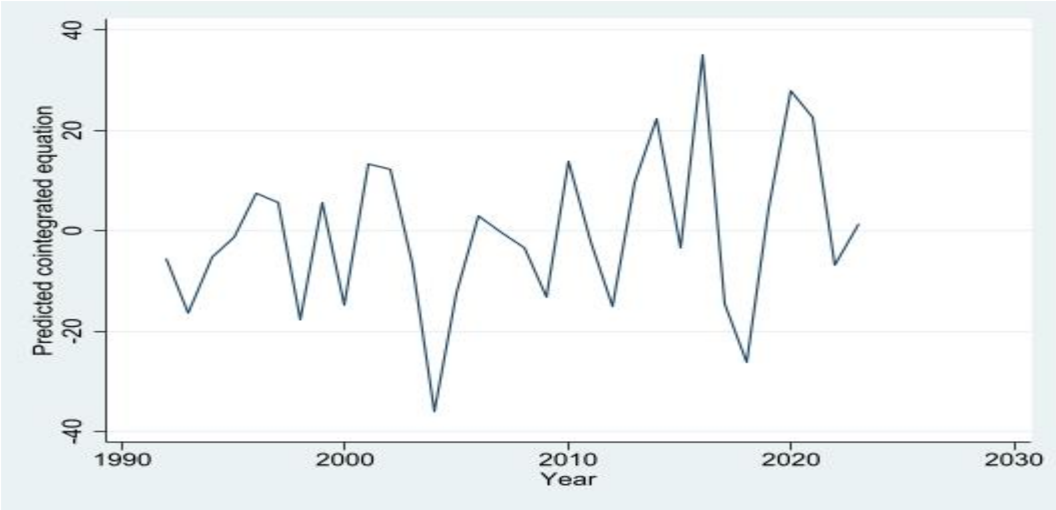

Figure 2: Graphical representation of the cointegrating equation

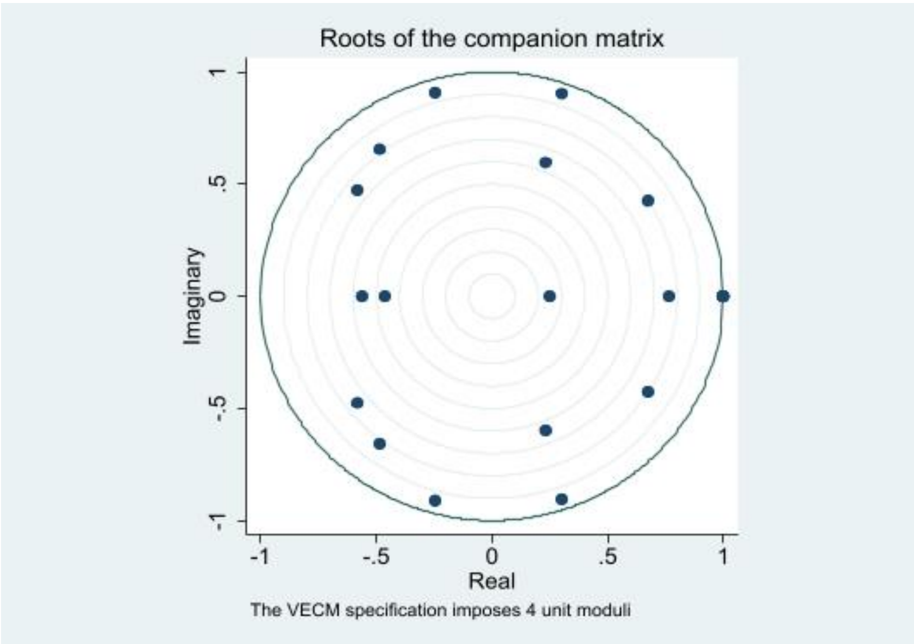

Figure 3: Graphical representation of the remaining eigenvalues for model stability

4.4 Impulse Response Functions for the VEC model.

In this study, the model was well specified, which enabled the estimation and interpretation of the impulse-response functions. Figure 4 shows that orthogonalized shocks to the average log of exchange rates, regulatory quality, trade mis-invoicing and trade openness permanently affect industrial output. Hence, any shock in these variables leads to a shock in industrial output, affecting industrial development in Zambia. Put differently, industrial development is susceptible to shocks in trade openness, exchange rate, regulatory quality and trade mis-invoicing.

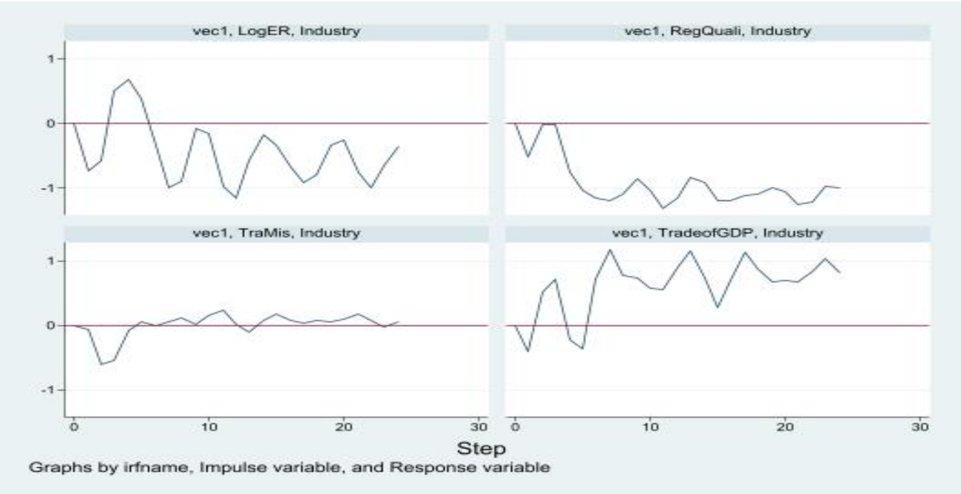

Figure 4: Industrial development's impulse response to the other variables

4.5 Forecasting

Zacharias (2005) used stochastic simulation analysis to investigate the forecasting power of a VEC model. Zacharias found that VEC models can forecast not only one-period ahead but many periods into the future. Figure 5 shows the forecasted values for the variables studied with their asymptotic confidence intervals. The forecasts run from 2024 through 2050, and as expected, the confidence intervals' widths grow with the forecast horizon.

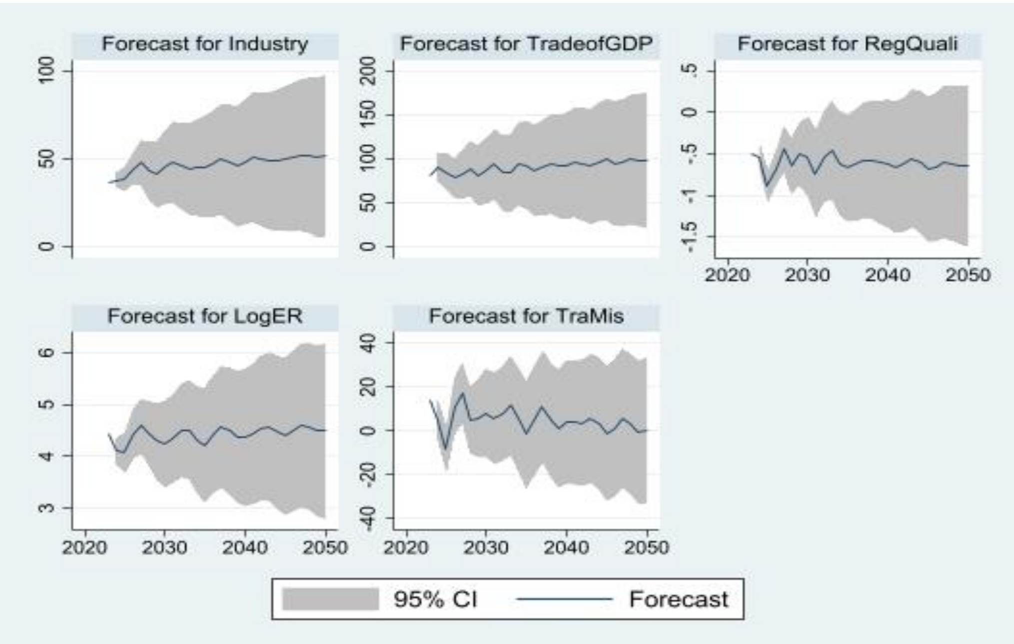

Figure 5: Forecasting with VEC model

5 Conclusion and Policy Implications

The study analyzed the effect of trade mis-invoicing in aggregate ores and metals trade on industrial development in Zambia. Two econometric procedures were performed on time series data from 1992 to 2023. First, we determined the existence of the long-run relation between industry output, trade openness, regulatory quality, exchange rate and trade mis-invoicing, all integrated of order one. Second, the VEC model was employed to determine causality among variables in the long-run.

The study findings revealed that series are stationary at first difference, and the Johansen test indicated a long-run relationship among the variables studied. The results of the VEC model showed that industrial development is determined by trade mis-invoicing and other variables. Precisely, trade mis-invoicing in aggregate ores and metals trade dampens industry output. That is, trade mis-invoicing deprives the economy of the needed financial resources to develop the industrial sector in Zambia. Equally, the impulse response function results showed that industrial output is vulnerable to shocks in trade mis-invoicing, exchange rate, trade openness and regulatory quality.

Hence, from the findings, the Zambia Revenue Authority should curb trade mis-invoicing in aggregate ores and metals trade. First, the Zambia Revenue Authority should bolster its operations in checking trade invoices related to aggregate ores and metals trade. Second, there should be close collaboration with Customs authority of Zambia's aggregate ores and metals importers to ensure data sharing to verify trade transactions. Third, punitive measures should be put in place and enforced for companies engaging in trade mis-invoicing. On the other hand, the Bank of Zambia should ensure a stable exchange rate to facilitate the importation of materials and equipment to spur industrial development. Improving the regulatory quality to foster private sector development and participation is critical for industrial development.

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Appendix

Appendix 1 Short-run dynamics

Variable	Coeff.	Std. err.	z	P-value	95% Conf. Interval	
D_Ind						
_ce1 L1.	-0.033	0.105	-0.31	0.753	-0.24	0.173
Ind						
LD	0.435	0.349	1.25	0.213	-0.249	1.119
L2D	0.029	0.385	0.08	0.940	-0.725	0.783
L3D	0.145	0.296	0.49	0.624	-0.436	0.726
Trad						
LD	-0.084	0.121	-0.70	0.486	-0.322	0.153
L2D	-0.028	0.103	-0.27	0.787	-0.231	0.175
L3D	0.096	0.093	1.03	0.304	-0.087	0.279
RegQ						
LD	-7.194	10.092	-0.71	0.476	-26.956	12.588
L2D	1.253	9.947	0.13	0.900	-18.243	20.748
L3D	1.343	6.653	0.20	0.840	-11.698	14.383
Log (ExcR)						
LD	-7.344	5.12	-1.43	0.151	-17.379	2.691
L2D	0.32	7.076	0.05	0.964	-13.548	14.188
L3D	5.244	5.938	0.88	0.377	-6.395	16.883
Tramis						
LD	0.082	0.313	0.26	0.794	-0.533	0.696
L2D	-0.216	0.256	-0.84	0.398	-0.719	0.286
L3D	-0.118	0.175	-0.67	0.502	-0.461	0.226
Constance	0.088	0.505	0.17	0.861	-0.902	1.078
D_Trade						
_ce1 L1.	0.041	0.368	0.11	0.912	-0.681	0.762
Ind						
LD	-0.789	1.218	-0.65	0.517	-3.177	1.599
L2D	-0.183	1.343	-0.14	0.892	-2.815	2.45
L3D	0.241	1.035	0.23	0.816	-1.787	2.268
Trad						
LD	-0.064	0.423	-0.15	0.879	-0.893	0.765
L2D	-0.296	0.361	-0.82	0.412	-1.004	0.411
L3D	0.208	0.326	0.64	0.523	-0.431	0.846
RegQ						
LD	12.698	35.237	0.36	0.719	-56.366	81.761
L2D	5.557	34.747	0.16	0.873	-62.507	73.62
L3D	8.599	23.229	0.37	0.711	-36.929	54.127
Log (ExcR)						
LD	-15.847	17.875	-0.89	0.375	-50.882	19.188
L2D	-0.305	24.703	-0.01	0.990	-48.721	48.112
L3D	1.966	20.732	0.09	0.924	-38.668	42.601
Tramis						
LD	0.162	1.094	0.15	0.883	-1.983	2.306

L2D	0.009	0.895	0.01	0.992	-1.745	1.763
L3D	-0.601	0.611	-0.98	0.326	-1.799	0.598
Constance	1.073	1.764	0.61	0.543	-2.384	4.53
D_RegQ						
_ce1 L1.	-0.002	0.004	-0.57	0.570	-0.01	0.005
Ind						
LD	0.019	0.013	1.52	0.127	-0.006	0.044
L2D	0	0.014	0.00	0.998	0.027	0.028
L3D	0.025	0.011	2.28	0.023	0.003	0.046
Trad						
LD	0.001	0.004	0.31	0.760	-0.007	0.010
L2D	0	0.004	0.13	0.897	-0.007	0.008
L3D	0.003	0.003	0.75	0.453	-0.004	0.009
RegQ						
LD	-0.891	0.368	-2.42	0.015	-1.612	-0.170
L2D	-0.689	0.363	-1.90	0.058	-1.399	0.022
L3D	-0.075	0.243	-0.31	0.757	-0.551	0.400
Log (ExcR)						
LD	0.117	0.187	0.63	0.530	-0.249	0.483
L2D	-0.063	0.258	-0.24	0.807	-0.569	0.443
L3D	-0.268	0.217	-1.24	0.217	-0.692	0.157
Tramis						
LD	0.011	0.011	1.00	0.318	-0.011	0.034
L2D	0.012	0.009	1.26	0.207	-0.007	0.03
L3D	0.015	0.006	2.35	0.019	0.002	0.027
Constance	-0.015	0.018	-0.82	0.413	-0.051	0.021
D_Log (ExcR)						
_ce1 L1.	-0.012	0.006	-1.94	0.052	-0.023	0.000
Ind						
LD	0.023	0.02	1.14	0.254	-0.016	0.061
L2D	-0.003	0.022	-0.14	0.891	-0.046	0.04
L3D	-0.0001	0.017	-0.01	0.995	-0.033	0.033
Trad						
LD	0.003	0.007	0.45	0.651	-0.100	0.017
L2D	0.008	0.006	1.32	0.187	-0.004	0.019
L3D	-0.001	0.005	-0.27	0.787	-0.012	0.009
ReqQ						
LD	-0.88	0.573	-1.53	0.125	-2.004	0.244
L2D	-0.516	0.565	-0.91	0.361	-1.623	0.592
L3D	-0.562	0.378	-1.49	0.137	-1.303	0.179
Log (ExcR)						
LD	-0.174	0.291	-0.60	0.550	-0.744	0.396
L2D	-0.465	0.402	-1.16	0.247	-1.253	0.323
L3D	-0.695	0.337	-2.06	0.040	-1.356	-0.033
Tramis						
LD	0.028	0.018	1.56	0.119	-0.007	0.063

L2D	0.022	0.015	1.5	0.132	-0.007	0.050
L3D	0.021	0.01	2.09	0.037	0.001	0.04
Constance	0.023	0.029	0.79	0.428	-0.034	0.079
D_Tramis						
_ce1 L1.	-0.809	0.224	-3.62	0.000	-1.248	-0.371
Ind						
LD	0.016	0.741	0.08	0.934	-1.391	1.513
L2D	0.175	0.817	0.21	0.830	-1.426	1.776
L3D	1.279	0.629	2.03	0.042	0.046	2.511
Trad						
LD	0.545	0.257	2.12	0.034	0.041	1.049
L2D	0.223	0.22	1.01	0.310	-0.208	0.653
L3D	0.179	0.198	0.90	0.367	-0.210	0.567
ReqQ						
LD	-61.361	21.423	-2.86	0.004	-103.349	-19.374
L2D	-44.171	21.113	-2.09	0.036	-85.551	-2.791
L3D	-18.688	14.122	-1.32	0.186	-46.368	8.991
Log(ExcR)						
LD	-17.149	10.867	-1.58	0.115	-38.449	4.151
L2D	-21.619	15.018	-1.44	0.150	-51.055	7.816
L3D	-34.35	12.604	-2.73	0.006	-59.054	-9.646
Tramis						
LD	1.872	0.665	2.81	0.005	0.568	3.176
L2D	1.392	0.544	2.56	0.011	0.325	2.458
L3D	0.901	0.371	2.42	0.015	0.173	1.63
Constance	0.05	1.072	0.05	0.963	-2.052	2.152