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Original Research

Environmental Accounting Disclosure and Market Value of Listed Non Financial Firms in Nigeria

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Abstract

This study examined how environmental accounting disclosure influences the market value of listed non financial firms in Nigeria between 2012 and 2020. The research design adopted is the longitudinal design. A total population of one hundred and twelve (112) listed non-financial firms was identified. A purposive sampling was used to generate a sample of seventy-two (72) listed non-financial firms sourced from firms' annual reports. The dependent variable is the market value measured using earnings per share (EPS). The independent variable is environmental accounting measured by the index of environmental disclosure constructed using a content analysis; eight themes of the Global Reporting Initiatives (GRI). The study employed panel feasible generalized least square regression technique for data analyses. The outcomes revealed that environmental disclosure influence earning per share as well as share price positively and significantly. Hence, this study found robust proof which suggests that environmental disclosure significantly influence market value of listed non-financial firms in Nigeria. The implication is that non-financial firms in Nigeria are yet to show much concern about the physical environment in which they operate; in terms of adherence to the environmental laws and standards, process and product related issues including those related to recycling, packaging, waste, pollution emissions and effluent discharges as well as provision of sustainability and other environmental related information. It recommends that corporate firms should prioritize the inclusion of environmental information in their annual reports as such has potential to bring about higher market value.

Keywords: Environmental Accounting Disclosure, Market Value, Earnings Per Share, Share Price.

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Introduction

The spate of technology and industrialization advancement in non-financial sector has greatly contributed to environmental challenges. These have raised the consciousness of both firms and other stakeholders on the environment in which the firms are situated. According to Atang and Eyisi (2020), societal concerns as well as consciousness for the environmental impact of firms have risen to an extent ever since about 4 decades ago. In 1972, the world conference by Head of States all over the world took place in Stockholm. This later resulted into the United Nations Environmental Program (UNEP) that coordinates environmental matters. Also, conferences have been held; Kyoto Protocol in 1997, Bali declaration and Global initiative for gas flaring reduction. These deliberations have stirred concern groups especially government as well as its agencies, employees, customers, as well as the communities concerning the challenges being created by the operations of the firms (Abiola & Ashamu, 2012).

Furthermore, conventional accounting system shortcomings and corporate responsibility matters towards sustainable development have given birth to environmental accounting as a new branch of accounting (Khan & Jui, 2016). According to Mehedy, et al., (2018), environmental accounting entails utilization of data about environmental costs and performance in decision making and operation of business. Also, it avail financial information on the firm's environmental expenditure and the successive gains entails occupational safety, health and environmental protection that convert into fiscal data through systematic methods. It also records as well as summarizes the value of environmental goods and services in monetary terms and also tries to assess the influence of firm's undertakings on environmental resources, which are widely responsible for the viability as well as development of entity (Das, 2017).

More so, the recent pressure on U.S, China as well as other non-financial firms globally to increase transparency through disclosure of new climate change as well as environmental information is imperative. These pressures from firms such as Carbon Disclosure Project (CDP), Ceres, the Global Reporting Initiative (GRI) and the Investor Network on Climate Risk (INCR), as well as the International Integrated Reporting Committee (IIRC). Also, managers were faced with pressure from stakeholders to assess the report on the risks and opportunities their firms encounter as a result to climate change, entailing the subjection of their firms to regulatory and market environment (Ernst and Young, 2011). Firm's market value is a collection of non financial and financial measures, thus offer information on the level of attainment of objectives as well as outcome. Also, it is affected by investor's perception of its managers' capability to foresee as well as respond to future occurrences in the firm's economic environment (Emeka-Nwokeji, 2019).

However, the developed countries have experienced an increase in the demand for environmental accounting as a result of disclosure practices and globalization. There are several laws and regulations enacted for environmental protection (Chavarkar, 2020). Environmental accounting information disclosure in annual reports of the firms supposed to create more awareness as regarding the environment (Bhuiyan, et al., 2017, and Ullah, et al., 2013). Considering the developed counties like USA, UK, China as well as Japan, the disclosure reporting on environmental accounting in Nigeria is still not encouraging.

Consequently, there is no strict adherence to issues of environmental accounting disclosure by listed non financial firms in Nigeria despite regulation by Corporate Governance Code for listed firms on the Nigeria Exchange Group (Mohammed, 2018). Also, studies established that the extent of disclosure of environmental information is approximately three sentences per firm, thus very low, especially in contrast with other developed and developing nations (Worimegbe & Oyewole, 2021; Şimşek & Öztürk, 2021; Ahmed, 2019 and Osazuwa, et al., 2016). This depicts that, the firms are not being responsible to their environment, so they often ignore to disclose necessary information to the stakeholder.

Despite the level of demand in environmental accounting disclosure, it is not clear whether the market assign real value to it in Nigeria (Okpala & Iredele, 2018). In other contexts and the signaling theory suggest that investors use information on sustainability disclosure in making their investment decision (Khandelwal & Chaturvedi, 2021 and Şimşek & Öztürk, 2021). The implication is that the low level of environmental disclosure by Nigeria corporate firms may negatively impact their market value. Thus, this study assesses the influence of environmental accounting disclosure on market value of listed non-financial firms in Nigeria. The specific objective is to assess the connection between environmental accounting disclosure and earnings per share (EPS) of listed non financial firms in Nigeria.

Conceptual Review

Environmental Accounting Disclosure

Environment implies the state in which we dwell. It entails every physical surrounding on Earth and object or conditions and circumstances that enclose us. The cost that a firm expended on natural resources cannot sufficiently be disclosed by traditional accounting. Environmental accounting plays an important part in availing information about the firm's accountability as regards the environment. The understanding of the firm's part in the economy towards the welfare and safety of the environment is being revealed through environmental accounting. Environmental accounting is a subset of accounting that provides numerical data, measures the use of natural resources, its cost expended by the firm and its impact on the environment. It provides data regarding the contribution of the firm toward economic welfare and cost expended on prevention of degraded resources and pollution control (Chavarkar, 2020).

Market Value

The market value of firm is a collection of non financial and financial measures that give information on the level of attainment of objectives as well as outcomes. Market value of a firm is affected by investors' perceptions of its managers' capability to foresee as well as respond to anticipated occurrence in the firm's economy environment (Emeka-Nwokeji, 2019). EPS are a financial ratio, that divides net earnings at hand to regular shareholders by the average outstanding shares over a definite period of time. Earnings are critical when evaluating a firm's profitability and are essential element in deciding a firm's stock price. It reveals how much a firm earns for each share, with a higher EPS showing the stock has a higher worth when compare with others in the industry.

Firm Age

Md. (2018) stated that, in several works, age of firm has been used as an explanatory variable which dictate decisions as regards capital structure. Larger firms in operations for several years need no debt financing because of reasonable steady market. On the other hand, fresh smaller company put in place; more debt financing. Sharif, et al., (2012) submitted that favour big firms that make goodwill in their sector can bring about required short term debt financing because creditors are aware of their ability to pay as at when due.

Revenue Growth

Deitiana (2011) stated that, firm growth described by change in income extent, is one of the measures for evaluating the future expectations of a firm. Sofyaningsih and Hardiningsih, (2011) opined that, firm that present low level of income will definitely encounter a decline in profit, which specified that growth possibility is poor. Firm growth is very essential considering inward and outward parties. Considering the inward group, growth of firm is a basis for corporate achievement as well as a good measure of upcoming corporate expectation. As regard outward group-investors, growth of firm is notice as a beneficial signal for investors, anticipating a pleasant rate of return for their investment (Ulfa & Prasetyo, 2018).

Gross Domestic Product (GDP) Growth

Gross domestic product (GDP) refers to the absolute market value of goods as well as services generated by the economy of a nation throughout a stipulated period of time. It entails final goods as well as services specifically, those generated by the economic representative situated in that nation despite their proprietorship and that are not resold in any form (Egbunike & Okerekeoti, 2018).

Inflation

Akers (2014) revealed that inflation rate evaluate change in the average price level build on a price index. The measure of inflation is in diverse ways; though, two majorly utilized estimates are the CPI indicator or GDP Deflator. The CPI measures change in the price level of a large basket of consumable products while the GDP Deflator is a large index of inflation in the economy. The average retail price is measures by CPI paid by the consumers. An increase CPI shows that inflation is in existence. Increase in prices tend to the reduction of consumer overall spending that leads to GDP decrease while inflation is not negative, quick increase rates of inflation alert the likelihood of poor macroeconomic health.

Literature Review

Theoretical Review

This study rest on the stakeholders' theory, embedded in the management discipline as far back as 1970. The theory was established step by step by Freeman (1984) by including corporate accountability to a broad range of stakeholder (Izedonmi, 2016). Firstly, the stakeholder was applied to the relationship between managers and shareholder with no explicit recognition of other parties fascinated in the well-being of the firm. However, subsequent research effort widened the scope to include: employee, creditor, supplier, government agencies, operating environment to mention few. The stakeholder theory has several uses; in the accounting field, the belief is that a firm's achievement depends on the collaboration of its stakeholders because they supply tangible and intangible resources to secure the existence of the firm. Consequently, the firm is responsible for supplying information describing a firm's business to the stakeholder, conversely simply supplying information to the owners (Nguyen, 2020). In line with the theory therefore, the disclosure of environmental information is key to the survival of the firms. Hence, the theory theorizes a positive influence of environmental disclosure on market value of the firms.

Empirical Review

Several studies have investigated how market value of a firm is affected by the disclosure of environmental information. These studies cut across various context and scopes. In addition, the studies were conducted using varying methodology and conflicting results were reported. Some of these studies have reported on environmental disclosure and market value of the firms.

Şimşek and Öztürk (2021) evaluated the connection between environmental accounting as well as business performance using Istanbul province as a case study. It was found that there is a mutually significant connection between environmental accounting as well as performance. Nevertheless, the environmental accounting attitudes of the firms covered by the work were established to be at low level. Khandelwal and Chaturvedi (2021) examined environmental accounting disclosures as well as financial performance of sampled Indian firms. The multivariate test used in the study reveals that there is significant effect between environmental as well as ROE and ROA. Based on the analysis, it is suggested that the Indian companies need to keep pace with the regulatory framework put in place by the government and other regulatory bodies.

Wasara and Ganda (2019) investigated the link between sustainable business disclosure and the performance of listed mining businesses in Johannesburg. The data were obtained from secondary source particularly from the sustainability report and financial reports of ten listed mining firms on the Johannesburg Stock Exchange (JSE) over a period of five years covering 2010 and 2014. Return on investment was used as proxy for financial performance and sustainability data was obtained using a content analysis. The results from panel data regression described a negative connection between environmental sustainability disclosure as well as corporate financial performance.

McMillan, et al. (2019), examine environmental management's effect on Market Value in terms of the rewards and punishments. The study was set up to evaluate the degree to which the market responds distinctively to service companies as well as non financial companies with respect to environmental reputation signals. The results revealed that there is a favourable response from the market to positive environmental management reputation signals for service companies while negative environmental management reputation signals for non financial companies was found.

Jan, et al., (2019) investigated the moderating influence of Islamic corporate governance on the link between corporate sustainability disclosure as well as financial performance of 16 Islamic banks in Malaysia for a period covering 2008 to 2018. The study employed sustainability reporting index measure corporate sustainability disclosure while corporate financial performance was assessed from three different perspectives which are the market (Tobin's Q), shareholders (return on equity), and management (return on assets). The data for the study was analyzed using the Generalized Method of Moments (GMM) estimation tool. The outcomes revealed that, a positive association exists between sustainable business practices and firm performance from owners and management perspective. On the contrary, the study found negative association between sustainable business practices and financial performance from the view of the market.

Adegbie, et al. (2020), equally used data obtained from food and beverages listed firms on the Nigeria Stock Exchange to assess the impact of environmental accounting on the sampled firms' share value. The results indicated that environmental accounting practices influence positively on the share value of the firms. Also, the results revealed that the impact remain positive and significant even after controlling for the firm size. Atang and Eyisi (2020) studied the factors that determine the environmental disclosures practices among the listed non financial firms in Nigeria. The results showed that a rise in the profitability of non financial firms by 1% results to a rise of 1.8% in the environmental disclosure of the firm.

Emeka-Nwokeji and Osisioma, (2019) conducted an empirical study to analyze how all-inclusive sustainability disclosures as well as it's disaggregated dimensions including social, environment and governance influence market value of the Nigerian firms using company's' specific disclosures. The results revealed that all-inclusive affect firm value positively and significantly. In addition, it was revealed that environmental sustainability disclosure has a significant positive outcome on market value of firm.

Osazuwa, et al., (2016) employed longitudinal research design to assess the environmental disclosure extent of listed firms in Nigeria. The length of environmental information disclosure is roughly, three sentences per firm whereby, very low, mostly in contrast with the developed as well as developing nations. Furthermore, the study discovered a stable rise in the quantity disclosed over time following the events that usher the revision of the 2011 corporate governance code.

The reviewed studies revealed that several attempt have been made in literature to evaluate the influence of environmental disclosure on market value of the firms. However, these studies have largely been based on developed economies and their results were inconsistent as some reported positive, some negative while some other failed to find impact of environmental disclosure on firm market value. This suggests that, generalizing the results in developed and other developing countries to Nigeria corporate environment will not only be erroneous but also be misleading. Hence, the study assesses the link between environmental disclosure and market value of Nigerian non-financial firms.

Methodology

Data and Technique of Analysis

The research design that was adopted is the longitudinal design. This study counts on the use of data collected from the listed non-financial firm on the Nigeria Exchange Group between 2012 and 2020. Based on the information available, the study identified a total population of one hundred and twelve (112) listed non-financial firms as at December 2020. A purposive sampling was used to generate sample of seventy-two (72) listed non-financial firms. The criteria adopted for the sample selection are that the firm must have been listed as at 2012, has not undergone merger or acquisition and publishes its annual report consistently for the period under consideration. The data were manually extracted from the annual reports of these firms using content analysis. The STATA 14.0 was utilized for data analyses as well as descriptive and inferential statistical tool of panel regression. The study is based on panel feasible generalized least square (FGLS) regression.

Model Specification

The model specification takes lead from the work of (Şimşek & Öztürk, 2021 and Khandelwal & Chaturvedi, 2021). In line with these authors, firm' market value hang on earnings per share as well as book value per share while the theoretical framework submits that environment disclosure influence firm value significantly. In addition, it was revealed in the reviewed empirical literature that the earnings per share (EPS) which measures the firm's market value is affected by firm traits namely, revenue growth, firm age as well as firm size. The macroeconomic variables such as GDP growth and Inflation serve as control variables. Consequently, this study hangs on the identified model:

$$EPS = f(ENVD, FIRA, REVG, GDPG, INF) \quad (1)$$

Where:

EPS = earnings per share

$ENVD$ = environmental disclosure

FIRA = the natural log of age

REVG = Revenue growth

GDPG = GDP growth

INF = Inflation

(1) is the transformed into explicit function as:

$$EPS_{it} = \tau + \omega ENVD_{it} + \eta FIRA_{it} + \alpha REVG_{it} + \delta GDPG_{it} + \beta INF_{it} + \mu_{it} \quad (2)$$

Where:

$\mu_{it} = \rho_i + \varepsilon_{it}$ (3)

If (3) does not hold, subsequently (3) could be evaluated using pooled OLS. If it holds however, OLS cannot be utilized and (2) becomes

$$EPS_{it} = \tau + \omega ENVD_{it} + \eta FIRA_{it} + \alpha REVG_{it} + \delta GDPG_{it} + \beta INF_{it} + \rho_i + \varepsilon_{it} (4)$$

For robustness check, the study equally use the share price of the firms to represent the market value and the resulting model for market value is given as

$$SP_{it} = \tau + \omega ENVD_{it} + \eta FIRA_{it} + \alpha REVG_{it} + \delta GDPG_{it} + \beta INF_{it} + \rho_i + \varepsilon_{it} \ (5)$$

Where SP = Share price

Measurement of Variables

There are three classes of variables utilized such as; the dependent variable, independent variables and control variables.

Dependent Variable

Firm value is the dependent variable for this study. As a result of insight from previous related studies (Kusiyah & Arief, 2017). The study measures the market value of the firm using EPS and individual firm's share price at the end of financial year (for robustness check). The share price of the firm reflects the extent to which the prospective investors are interested in having stake in the firm which is a reflection of its valuation. For instance, when investors attach higher value to the firm and thus compete to get the share of the firm, there would be pressure on the price of share due to higher demand for the share of the firm. This will eventually results to a higher share price and in turn higher firm value. Thus, share price reflects the value attached to the firm by the shareholders and prospective investors.

Independent Variable

The study has one independent variable which is the environmental disclosure. Environmental or sustainability disclosure in this study is measured by environmental disclosure index relying on Global Reporting Standards (2016) and the International Standards Organization (2014) as used in prior studies such as (Aggarwal, 2013; Nwobu, 2015 and Dilling, 2010) among others. The index was calculated on the basis of the number (occurrence) of indicators disclosed. If there is an occurrence of the indicator in the company reports, 1 is assigned and if otherwise, 0 is assigned. This is termed an un-weighted approach. All items of environmental disclosure are given the same prominence and what is stated is only whether an item is outlined or not. The formula for computing the un-weighted corporate Environmental Disclosure Index (EDI) or reporting scores is expressed as follow:

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$$EDI = \sum_{i=1}^{8} d_i / d \quad (6)$$

Where:

EDI is the corporate environmental disclosure Index and it is expressed as a percentage or ratio.

d = 1 if item 'di' is stated or 0 if item 'di' is not stated

d = maximum number of items stated.

Control Variables

As a result of the theoretical model for this study as well as reviewed empirical literature, the study controls for the age of the firm, revenue growth as well as macroeconomic variables comprising GDP growth and inflation.

Table 1. Variables Definition and Sources

Variables	Descriptions	Sources
Firm Value (EPS)	Earnings per share evaluated as profit after share as a ratio of the outstanding shares	Annual Reports
Firm's value (SP)	Closing stock price of a financial year.	Annual Reports
Revenue Growth (REVG)	Change in sales over time	Annual Reports
Age (FIRA)	Log of the years a firm has been listed on the NSE	Annual Reports
Growth (GDPG)	Change in GDP over time expressed in percentage	WDI
Inflation (INF)	Consumer Price Index	WDI

Results and Discussion

Results

The outcomes gotten from the examination of the data sourced from Nigerian listed sampled non-financial firms annual reports are presented in this section; the results are obtained using various methods including descriptive statistics, correlation and panel regression technique.

Estimated Summary Statistics of Variables

The outcomes of the descriptive statistics are outlined in table 2. The outcomes indicate that the average environmental accounting disclosure of the listed firms within the period under consideration is 0.063 with 0 as a minimum as well as 1 as a maximum. An estimated standard deviation of 0.176 shows that the average environmental disclosure estimated is a widely spread around the average estimated value. The implication is that the disclosure of environmental information among Nigerian listed non financial firms is very low as the degree of environmental disclosure among the sampled firms is found to be about 6.3%. The average share price estimated is 37.337 naira with 0.2 naira as minimum as well as 1555.99 naira as a maximum. The estimated standard deviation of 137.055 shows that, the share price varies widely among the firms. Also, the outcomes in Table 2 outlined the average estimated value of EPS as 1.843 with a maximum and minimum of 57.63 and -20.23 respectively. Averagely, the firm performance represented by revenue growth is 10.533 with -100 as minimum and 1354.255 as maximum. The estimated standard deviation of 66.453 reveals wide variation in the performance of the firms.

Table 2. Estimated Summary Statistics of Variables

Variable	Obs	Mean	Std.Dev.	Min	Max
EPS	648	1.843	5.872	-20.23	57.63
SP	648	37.337	137.055	.2	1555.99
ENVD	648	.063	.176	0	1
REVG	648	10.533	66.453	-100	1354.255
FIRA	648	26.866	13.482	2	55
GDPG	648	3.166	2.564	-1.617	6.671
INF	648	11.588	2.812	8.062	16.524

Estimated Correlation Coefficients among Variables

The outcomes of the correlation among the variables are outlined in table 3. The outcomes specify that environmental disclosure has a positively weak association with earnings per share; however, 0.166 estimated correlation coefficient implies that higher EPS are associated with a lower environmental accounting disclosure. Also, the estimated correlation coefficient of 0.032 reveals a very weak positive relationship between firm performance represented by revenue growth as well as earnings per share. However, the outcomes revealed that GDP growth has a weak negative relationship with environmental accounting disclosure as it recorded an estimated correlation coefficient 0f -0.012. In addition the results indicate that a weak positive relationship exist between firm age and EPS with their correlation coefficient of 0.157. Also, the estimated correlation coefficient of 0.021 implies that a positively weak association exists between inflation and EPS.

Table 3. Estimated Correlation Coefficients among Variables

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) EPS	1.000						
(2) SP	0.819	1.000					
(3) ENVD	0.166	0.171	1.000				
(4) REVG	0.032	0.011	0.005	1.000			
(5) FIRA	0.157	0.166	0.247	-0.013	1.000		
(6) GDPG	-0.012	0.003	-0.078	0.015	-0.125	1.000	
(7) INF	0.021	-0.002	0.035	-0.001	0.074	-0.822	1.000

Furthermore, the outcomes of the correlation indicate that weak relationships are established among the independent variables of this study as the highest correlation coefficient among the independent variable is found to be 0.247 between environmental accounting disclosure and firm age. This implies that the problem of multicolinearity is not envisaged among the variables.

Diagnostic Test

The study carried out diverse diagnostic tests to guarantee the validity of the outcomes gotten among which are the Shapiro-Wilk test for normality, the Breusch-Pagan test for heteroscedasticity and the Wooldridge test for serial correlation. The outcomes of the Shapiro-Wilk examination for normality are presented in table 4. The results reveal that the null hypothesis of normal distribution is rejected for all the variables given the respective p values of all the variables. By implication, the Shapiro-Wilk test results suggest that all the variables are not normally distributed.

Table 4. Shapiro-Wilk W Examination for Normality

Variables	Obs	W	V	Z	Prob>z
EPS	648	0.504	210.925	13.013	0.000
SP	648	0.250	318.522	14.014	0.000
ENVD	648	0.851	63.144	10.080	0.000
REVG	648	0.358	272.828	13.638	0.000
FIRA	648	0.923	32.897	8.494	0.000
GDPG	648	0.965	14.696	6.535	0.000
INF	648	0.928	30.602	8.319	0.000

Variation Inflation Factor

The existences of multicolinearity amid regressors are examined employing variance inflation factors and the outcomes are outlined in table 5. From the outcomes, GDP growth has the highest VIF of 3.132, while the mean VIF was found to be 0.987. Because none of the expository variables possess VIF that is near to the threshold of 10, it is deduced that there is no multicolinearity amid the expository variables.

Table 5. Variance Inflation Factor

	VIF	1/VIF
GDPG	3.132	0.319
INF	3.093	0.323
FIRA	1.08	0.926
ENVD	1.07	0.935
REVG	1.001	0.999
Mean VIF	1.875	.

Model Regression Diagnostic Test

Moreover, the outcomes in table 6 indicate that the model is characterized with an autocorrelation on the basis of Wooldridge test which has 7.212 as F value as well as 0.0000 as corresponding p value implying that the null hypothesis of no autocorrelation is rejected. The model also reveal the existence of heteroskedastcity problem given the estimated Breusch-Pagan chi square of 168.57 with 0.0000 p value of implying that the null hypothesis of no heteroskedasticity is rejected at all conventional level of significance.

Table 6. Model Regression Diagnostic Test

Tests	Test Type	Value	P value	Conclusion
Autocorrelation	Wooldridge Test	7.212	0.0000	Presence of serial correlation
Heteroskedastic	Breush-Pagan / Cook-Weisberg	168.57	0.0000	Presence of heteroskedasticity

Panel Regression (Dependent = EPS)

In line with the results obtained from the various diagnostic tests which suggest non-normality of variables, presence of serial correlation and heteroskedasticity, the study controls for the used feasible generalized least square regression (FGLS) method which has inbuilt mechanism to accommodate non-normally distributed data as well as control for the existence of serial correlation and heteroskedasticity (Baltagi, 2010). Hence, the results of the feasible generalized least square are outlined in table 7.

Table 7. Estimated Panel Feasible Generalized Least Square Regression (Dependent = EPS**)**

EPS	Coef.	St.Err.	t-val.	p-val.	95%Conf	Interval	Sig
ENVD	4.601	1.328	3.47	0.001	1.999	7.204	***
REVG	0.003	0.003	0.83	0.408	-0.004	0.009	
FIRA	0.055	0.017	3.18	0.001	0.021	0.089	***
GDPG	0.136	0.156	0.87	0.384	-0.170	0.441	
INF	0.115	0.141	0.81	0.416	-0.162	0.391	
Constant	-1.720	2.147	-0.80	0.423	-5.927	2.488	
Meandepvar		1.843	SD dep. var			5.872	
Num. of obs		648.000	Chi-square			30.021	
Prob> chi2		0.000	Akaikecrit.(AIC)			4114.841	

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

From the outcomes presented in table 7, 4.601 estimated coefficient with 0.001 p value specifies that environmental accounting information has a positive and statistical impact on the earnings per share (EPS) of listed non-financial companies. In line with the results, an increase in environmental disclosure by a firm is expected to result to an increase in the EPS of the firm and vice versa. This implies that, more environmental disclosure is associated with better firm's market value.

For the control variables, the study established that, the age of the firm is an important determinant of market value as the estimated coefficient of 0.003 with p value indicates that firm age has positive and significant influence on the EPS. Hence, older firms attract higher market value than younger ones. The results show further that firm revenue growth is a key determinant of the EPS as the estimated coefficient and p value of 0.055 and 0.408 respectively indicate that revenue growth has positive but insignificant influence on the EPS of sampled firms. Similar results were obtained for GDP growth and inflation as the respective p value of 0.384 and 0.416 imply that both GDP growth and inflation had positive but insignificant influence on the EPS of the sampled firms.

Panel Feasible Generalized Least Square Rregression (Dependent = SP)

The study conducted a robustness check by using another proxy for market value of the firms. In line with some other extant literature Emeka-Nwokeji and Osisioma, (2019), the closing share price of the firm is used as alternative proxy for the market value as the firm's share price reflects the valuation of the firm by investors. The results were equally obtained with panel FGLS and they are outlined in table 8.

Table 8. Estimated Panel Feasible Generalized Least Square Regression Results (Dependent = SP)

SP	Coef.	St.Err.	t-val.	p-val.	95%Conf	Interval	Sig
ENVD	109.741	30.946	3.55	0.000	49.089	170.394	***
REVG	0.023	0.079	0.28	0.775	-0.133	0.178	
FIRA	1.383	0.406	3.41	0.001	0.588	2.178	***
GDPG	2.662	3.631	0.73	0.463	-4.454	9.778	
INF	1.148	3.288	0.35	0.727	-5.297	7.594	
Constant	-28.775	50.086	-0.57	0.566	-126.941	69.391	
Meandepvar		1.843	SD dep. var			5.872	
Num. of obs		648.000	Chi-square			30.021	
Prob> chi2		0.000	Akaikecrit.(AIC)			4114.841	

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

From the outcomes, environmental disclosure has a positive and significance influence of the share price with 109.74 estimated coefficients and 0.000 p value. This is consistent with the results found when EPS was used to represent the market value. Hence, this study found consistent evidence of positive and significant impact of disclosure of environmental accounting on the market value of non financial firms listed. For the control variables, the results found are as well in agreement with the results found for the baseline model of the study as revenue growth, GDP growth and inflation have insignificant positive influence on the price of share while age of the firm influence share price positively and significantly.

Discussion of Findings

The descriptive result shows that the disclosure of environmental information by corporate Nigerian non financial firms is generally low as the extent of disclosure was found to be just 6.3 percent. The implication of this finding is that non-financial firms in Nigeria are yet to show much concern about the physical environment in which they operate; in terms of adherence to the environmental laws and standards, process and product related issues including those related to recycling, packaging, waste, pollution emissions and effluent discharges as well as provision of sustainability and other environmental related information. In terms of the hypothesis of the study, the findings of positive impact of environmental disclosure suggest that this study rejects the null hypothesis that environmental accounting disclosure is not value relevant. This simply means that shareholders make use of information on how environmentally responsible a firm is while making their investment decision. This implies that environmentally responsible firms have an effect on the firm market value in terms of not only the EPS but also the share price development.

The conclusion on this hypothesis is in agreement with the work of Adegbite et al. (2020) in Nigeria, Simsek and Ozturk, (2021) in Turkey, and Khandelwal and Ganda, (2021) in India who reported value relevance of environmental disclosure but opposed to the findings of Jan, et al., (2019) in Malaysia, and Wasara and Ganda (2020) in South Africa who reported that environmental disclosure has no value relevance. Investors may see a release of better information of sustainability of the company as an indication of good overall business performance. They are thus attracted to those companies which will eventually drive up the price of share as a result of competition among potential investors to have a stake in such companies.

Conclusion and Recommendations

The need to mitigate the negative outcome of business operations on the environment has made the environmental accounting disclosure one of the most discussed issues in corporate finance literature in recent times. One of the areas of discussed is the implication of this disclosure on the performance of the firms as a way of demonstrating what a firm stands to gain by complying with standard environmental disclosure practice. While this issue has been extensively discussed in literature, there is no consensus on the impact of environmental disclosure or firm market performance. The outcomes from the previous literature suggest a country and industry specific studies to understand the link between corporate environmental accounting and the market performance of the firm. This issue has attracted relatively shallow treatment in Nigeria context as none of the study has used a large sample of Nigeria non-financial firms. Hence, this work was able to explore the influence of environmental accounting disclosure on the market value of a sample of seventy-two (72) Nigerian listed non-financial firms between 2012 and 2020 using feasible generalized least square (FGLS) panel regression technique.

The outcomes of the study showed that corporate environmental disclosure has a positive effect on the market value in Nigeria using EPS as a proxy. The results are in consonant even when share price was used as a proxy for firm value to check for the robustness of the findings. Thus, investors consider how environmentally responsible a firm is prior to taking decision as regards investment. Consequently, non-financial firms in Nigeria ought to know that enhancement in the reporting of environmental information is as essential as enhancing the firm's value. In line with the findings, the study recommends that agencies concern with regulation of financial reporting as well as environmental standard: Financial Reporting Council of Nigeria (FRCN) and NESRA (National Environmental Standards as well as Regulatory Enforcement Agency) should enhance the collaboration with relevant stakeholders to establish in Nigeria environmental accounting as well as reporting a framework. Corporate firms should equally, prioritize the inclusion of environmental information in their annual reports as such has potential to bring about higher market value for the firms.

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Original Research

Optimization of Sustainable-Robust Biofuel Supply Chain under Uncertainty

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Abstract

The increased knowledge about environment and decline in reservoirs of fossil resources has led the industry to enhance and produce other sustainable fuels by using renewable, which are environmentally acceptable. Biofuel is a kind of fuel derived from biomass resources. Biomass is also the source of fossil fuels that are used today; however, this biomass has been formed over long years. The reduction in fossil fuel resources and the destructive effect of these fuels on the environment have made researchers replace such resources. Therefore, the extant study presented a multi-objective mathematical model for a biofuel sustainable supply chain, by consideration of demand uncertainty. Finally, the research developed the mathematical model considering uncertainty and using Bertsimas and Sim Robustness Approach. According to the proposed model, sustainability objectives were discussed and investigated, including economic, social, and environmental issues. Ultimately, the presented model was confirmed by using the epsilon constrained method (ε constrained method) and the model was validated using the integrated ε constrained-Benders Approach.

Keywords: Biofuel, Biomass, Sustainable-Robust, Supply Chain.

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Introduction

The most critical issue that threatens the energy supply for developing countries is severe dependence on rare oil resources. Among different types of renewables, the production of green fuels (biofuels) has received great importance and attention in different parts of the world over recent years (Kumar et al., 2019). Many resources have been used to produce biofuels, which have been classified into several generations over past years (Maity et al., 2014). The first generation includes materials of nutritional nature, such as corn, soybeans, and starch. Although it is cost-effective to produce fuel by using such materials, these materials have been gradually eliminated due to the high price of foodstuff (Babazadeh et al., 2015). The second generation comprises materials that do not have nutritional value, such as agricultural waste, including corn husks, products used for energy production like Jatropha, and industrial waste. Microalgae-based fuel production has been named the third generation due to its different production nature (Mohseni et al., 2016). The integrated management and coordination of production cycles is one of the crucial issues considered in the development of biofuels at the macro scale (Scaldaferri & Pasa, 2019). Hence, it is essential to develop some supply chain design models that can control all phases from feedstock supply to fuel production and supply within an integrated framework (Yue et al., 2014). A supply chain comprises all facilities, tasks, and activities involved in the production and delivery of a product or service, from suppliers (and their suppliers) to customers (and their customers). The supply chain also includes demand-supply planning and management, production and scheduling of a product or service, warehousing, inventory control and distribution, delivery, and customer service. Supply chains exist in manufacturing and service organizations; however, supply chain complexity may severely vary in different industries and companies (Ahmadi et al., 2018). The supply chain is an integration process among suppliers, producers, and distributors in every organization. This integrated process aims to fulfill the organization's policies, minimize circulating inventory, and meet the demand of each customer at the end of the supply chain (Nugroho & Zhu, 2019). To balance and manage the production process of each phase in the supply chain procedure, each input and output value of warehouses must be controlled, and then inputs and outputs of each operational phase should be estimated by defining correlated variables. In general, the supply chain is defined as a process that covers all activities related to commodity flow and materials conversion, from the preparation of raw material to the delivery of the final product to the consumer. Supply chain management integrates supply chain activities with their associated information flows by improving chain relations to achieve a permanent and reliable competitive advantage (Albashabsheh & Stamm, 2019). Urban waste has received great attention as one of the sources for the production of second-generation biofuels over recent years (Ye et al., 2018). Hence, supply chain design can be used for macro scale planning to produce fuel from urban waste. A problem-solving approach is one of the most critical concerns and issues in the design and optimization of the supply chain. The reason is that network design models are usually categorized into complex problems. Therefore, those samples of biofuel supply chain models with small dimensions can be solved by using exact methods. On contrary, there is uncertainty- due to complexity-in basic parameters of the mathematical model in the real world’s problems, which have been neglected in studies in this scope (Chibeles-Martins et al., 2016). To solve this problem, therefore, the present study selects the problem by using a robustness approach, which has led to considerable innovation in this context. On the other hand, supply chain management is a multi-objective decision-making problem that occurs under the supervision of experts and under real conditions. Therefore, it is necessary to develop a multi-objective mathematical model for the concept of a biofuel supply chain. As a result, the extant study presents a multi-objective mathematical model for sustainable biofuels' supply chain by consideration of demand uncertainty. Ultimately, this paper develops the mathematical model by paying attention to the considered uncertainty and using Bertsimas and Sim Robustness Approach. In the last step, this study uses the ε constrained method to evaluate the multi-objective and Benders Approach through GAMS software and CPLEX solver.

Research Background

Over extraction of coal, natural gas, and oil resources has accelerated the destruction of these resources, fuel price oscillation, and unsustainable energy supply. Moreover, energy consumption has increased, especially in industrial countries due to population growth, lifestyle changes, and higher living standards (Max & Johnson, 2019). Hence, the European Commission has set the 20% use of energy production from a renewable resource for EU members up to 2020. Furthermore, greenhouse gases must experience a 20% reduction up to 2020 compared to 1990. Although each member state has defined its goal, biomass plays a key role in new renewables due to the homogeneity and extensive distribution of this biomass all around the world(Ba et al., 2016; Frombo, Minciardi, Robba, & Sacile, 2009; Frombo, Minciardi, Robba, Rosso, et al., 2009; Kanzian et al., 2013) This energy resource provides some advantages in different fields, including environmental pollution, energy diversity and security, and economy (Long et al., 2013; Mobini et al., 2011). Green fuel is a broad term, which comprises some resources: trees, crops, industrial organic algae, human and animal wastes, etc. (Frombo, Minciardi, Robba, & Sacile, 2009; Mafakheri & Nasiri, 2014). In particular, it is possible to use forest biomass for a wide range of uses of generating heat, power, fuel, and chemicals (Cambero & Sowlati, 2014; Rentizelas et al., 2009). In addition, we can save and use this energy resource to produce energy and meet the energy demand, which is a relative advantage of this resource compared to other renewables (Rentizelas et al., 2009; Shabani et al., 2013). Biofuel deals with several problems in its supply chain besides the capabilities mentioned above. For instance, high costs caused by geographical dispersion of resources, variation in quality and available volumes, lower energy density rather than fossil fuels, and heterogeneity of multi-corporate structure can be mentioned as challenges existing in the supply chain of biofuels (Cambero & Sowlati, 2014; Kanzian et al., 2013; Rentizelas et al., 2009; Shabani et al., 2013). According to the mentioned issues, logistic costs indicate the continuous increasing use of forest biomass for energy production. Therefore, we must optimize the supply chain in a way to make it more efficient and competitive (Cambero & Sowlati, 2014; De Meyer et al., 2014; Flisberg et al., 2012). Biomass supply chain management is usually divided into three strategic, tactical, and operational levels (Ba et al., 2016; Lin et al., 2014). Strategic decisions are made regarding long-term decision-making. Strategic decisions also evaluate biomass resources and industries pertained to the customer, location, size, and design of these industries (Lin et al., 2014). On the other hand, tactical planning addresses midterm and short-term decisions, such as production, delivery, and biomass process programs. Ultimately, the operational phase discusses short-term decisions about the intra-field operations from biomass collection and conversion (converting biomass to energy) (Frombo, Minciardi, Robba, & Sacile, 2009; Lin et al., 2014). Babazadeh et al. (2015) argues that the rapid expansion of first-generation biodiesel production from vegetable oils and animal fats has made the development policymakers and experts worried about the allocation of agricultural lands, foodstuff supply, and balance of the food market. In this regard, second-generation biofuel manufactured from inedible feedstock has provided many advantages over recent years. It is necessary to optimize and design the whole biofuel supply chain systematically to accelerate vital biofuel transfer at a large and cons-effective scale. Mirhashemi et al. (2018) presented a two-phase optimization model to design a biological biomass-based biofuel. The first phase considered a Common Weight Data Envelopment Analysis (CWDEA) to rack production farm locations, while the second phase proposed mixed-integer linear programming to find optimum production levels in the strategic and tactical supply chain. Soares et al. (2019) proposed a mixed linear programming model to support the decision made in the initial timeframe, which led to the development of the fuel supply chain. Other studies addressed the developed modeling and optimization of the supply chain (De Meyer et al., 2014; Mafakheri & Nasiri, 2014; Shabani et al., 2013). Habib et al. (2021) presented a robust possibility programming (RPP) approach to the animal fat-based biodiesel supply chain by considering uncertainty in the problem's parameters. They formulated the model by using a mixed-integer programming approach. The objective function is supposed to minimize total construction costs, purchase costs, operations costs, and transportation costs, also the costs pertained to the tax on pollutants emitted by the manufacturing setting. It should be mentioned that a tax rate was considered for CO_2 emission and other pollutants to cover the environmental indicators. The mentioned tax was taken into account in addition to other costs in the objective function of the problem. Moreover, some parameters of the model were considered using the fuzzy approach to deal with parameters' uncertainty. Next, the RPP approach was used to solve the model, and then a case study of Pakistan was proposed. The results obtained from this study indicated the efficiency of the solution approach in real-world dimensions. Yadala et al. (2020) optimized the algal biomass supply chain to biodiesel. It is a common approach to convert algal biomass into biodiesel for biodiesel production. Yadala et al. (2020) formulated this chain by using a single-objective mixed-integer programming model. The objective was to minimize the overall cost of the network, which included production, operation, and transportation costs over a planning horizon of ten years. Kang et al. (2020) suggested a three-stage design for an algae-based biofuel supply chain using a geographic information system (GIS). To do this, they proposed a single-objective mixed-integer programming model. The objective function of this model minimized the total cost of the supply chain, which included costs of transportation, production, and greenhouse gases emission resulting from supply chain activities. Zheng et al. (2020) investigated the role of government policies in making the waste cooking oil-to-biodiesel systems more efficient. In this lieu, they describe various policies and strategies used to make the supply chain more efficient and sustainable. Next, they presented a collaborative game to address these strategies. Mohseni and Pishvaee (2020) designed a robust optimization model for the waste-to-biodiesel supply chain. They used the data-based robust optimization approach to overcome uncertainty in the parameters of the model. Moreover, they employed a fuzzy neighborhood support system of data samples to reduce dependency on the background data. The objective

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function minimized costs of the supply chain, which included costs of setting deployment, costs of the pipeline, operational costs, production costs, and transportation costs. According to the results of reviewed papers, most papers have been conducted at the strategic level in which, supply chain design has been at the center of attention. However, sourcing, supply contracts, and environmental discussions have been neglected at this level. Most reviewed papers have considered the exact state, and there is a literature gap in probabilistic and mixed discussions. However, consideration of uncertainty in climate issues and production of crops is one critical discussion in the biofuel supply chain especially those with agricultural and forest sources. The majority of studies have considered some objective functions, such as profit and cost, while other objective functions, including minimization of greenhouse gases and maximization of the number of jobs that consider sustainability and environmental issues have been ignored (Sarker et al., 2019) The reviewed papers conducted on the biofuel supply chain were classified as shown in Table 1.

Table 1. Evaluation of studies conducted on biofuel supply chain

Author/year	Objectives	Multi-period	Multi-objective	Sustainability	Uncertainty	Uncertainty parameter
Mol et al. (1997)	8					
Nagel (2000)	1					
Tembo et al. (2003)	3	*				
Freppaz et al. (2004)	1					
Gunnarsson et al. (2004)	3	*				
Mapemba et al. (2007)	3	*				
Dunnett et al. (2007)	1	*				
Mapemba et al. (2008)	3	*				
Vlachos et al. (2008)	1					
Frombo, Minciardi, Robba, Rosso, et al. (2009)	1					
Zamboni et al. (2009)	1		*			
Ekşioğlu et al. (2009)	1	*				
Huang et al. (2010)	1	*				
Akgul et al. (2011)	1					
Kim et al. (2010)	2					
Dal-Mas et al. (2011)	3	*			*	Biofuel cost
Zhu et al. (2011)	2	*				
Marvin et al. (2012)	3					
An et al. (2011)	2	*				
You et al. (2012)	7	*	*	*		
You and Wang (2011)	7	*	*			
Lam et al. (2011)	2					
Zhu & Yao (2011)	2					
Kim et al. (2011)	2				*	Supply values, market demand, market prices
Chen and Fan (2012)	1				*	Feedstock supply,

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Author/year	Objectives	Multi-period	Multi-objective	Sustainability	Uncertainty	Uncertainty parameter
						biofuel demand
Balaman and Selim (2014)	2					
Giarola et al. (2013)	3	*	*		*	feedstock, cost fluctuations of carbon trades
Paolucci et al. (2016)	3	*	*			
Roni et al. (2017)	7		*	*		
Azadeh and Arani (2016)	2	*			*	Available biofuel, demand
Duarte et al. (2016)	2	*				
De Meyer et al. (2016)	11	*				
Miret et al. (2016)	10	*	*	*		
Ng and Maravelias (2017)	1	*				
Cambero et al. (2016)	3	*	*			
Cambero & Sowlati (2014)	3	*	*	*		
Mirhashemi et al. (2018)	2	*		*		
Sarker et al. (2019)	3	*	*	*		
Foo (2019)	3	*	*			

The research gap in reviewed studies was non-consideration of sustainability in the biofuel supply chain. Most studies have addressed cost minimization and profit maximization. Robustness of supply chain models was not used, which was another research gap. However, some studies examined a scenario to eliminate uncertainty, which was an efficient approach due to its inapplicability. Therefore, the present study aims to design a biofuel production supply chain, and develop it by minimizing social issues, costs of pollutants, and risk.

Research Methodology

The present study aims to solve the problem of programming the supply chain pertained to biofuels by considering uncertainty in the parameters of the model. The extant supply chain involves three levels of biomass supply, refineries, and supply centers. Refineries purchase the feed stocks required for biofuel production from different biomass suppliers based on the available technology of the refinery. They transfer the feedstock to the refinery by considering the access of the transportation facility, and then convert it to the end product (i.e., biofuel) through a specific process. The transportation facility is chosen based on the distance between biomass supply centers, refineries, and fuel supply centers, as well as the volume of hazardous gases emitted by each transportation option. These considerations are taken into account to minimize costs, reduce pollutants, and increase social welfare.

Assumptions of the problem have been described herein:

- The supply chain is composed of several biomass suppliers, biorefineries, and demand centers

- Refineries have access to transportation facilities to supply biomass and end-product
- Refineries can produce the fuel based on the available technology
- It is possible to produce fuel in refineries based on the available technology
- The cost of inventory maintenance and lost sales are accounted for in producers' expenses
- The demand for the end product is a function of the price
- The planning horizon of several periods is considered
- The initial inventory is given for the feedstock (or raw materials) and end product (final or finished product) in refineries
- Fuel is processed in refineries and demand locations sell the fuel
- The available transportation facilities have been considered equally in all supply chain layers
- Each transportation option has a default rate of hazardous gas production
- The supply risk component is evaluated in a certain space of the model

the extant study has been structured based on the paper published by Mirhashemi et al. (2018) and Nur et al. (2021) egarding the studied problem of study. Production and sustainability were also added to the considered problem. We have the following variables to model the problem.

Set of indicators

Set of biomass types that are indicated with i	I
Set of biomass area type I	J_i
set of potential locations for refineries	F
set of biofuel types	E
set of consumption markets	M
Set of time stages indexed by t	T
Set of technologies used in refinery f indexed by r	R_f
Set of scenarios	S
Set of transportation facilities	K

Set of parameters

Cost of purchasing urban waste biomass type i	pr_i
Cost of producing urban waste biofuel type e by using technology type r	C_{er}
The average velocity of facility type k	V_k
The fixed capital cost of annual refinery set up in location f using technology r	f^F_{fr}

The annual capital cost of each refinery unit placed in location f using technology r to produce fuel e — f^{V}_{efr}

The distance between nodes x and y — d_{XY}

Solid volumes' distance-dependent shipment cost, such as transport cost of bulk facility per mile, which includes fuel, insurance, repair, and maintenance costs — t^{d}_{bk}

Solid volumes' transfer time-dependent shipment cost, such as the one-hour transport cost of each bulk facility, which includes wages (paid to workers) and capital costs — t^{t}_{bk}

The shipment cost depends on the distance of solid volumes shipped by facility k — t^{d}_{lqk}

The shipment cost depends on the transport time of solid volumes shipped by facility k — t^{t}_{lqk}

Cost of loading and unloading facility k for solid volumes — lu_{bk}

Cost of loading and unloading facility k for liquid volumes — lu_{lqk}

Cost of inventory control for biofuel e in city m — α_{em}

Cost of biofuel e shortage in city m — ${}_{em}\beta$

Solid volume capacity of facility k — Cap_{bk}

Liquid volume capacity of facility k — Cap_{lqk}

The moisture content of biomass i — Mc_{i}

Biomass shipment cost coefficient by facility k from biomass areas to refineries — CC^{1}_{ijifk}

(1)

$$CC^{1}_{ijifk} = \left(\left(t^{d}_{bk} + \frac{t^{t}_{bk}}{V_k}\right) * \frac{d_{jif}}{Cap_{bk}} + lu_{bk}\right) 1/(1 - MC_i)$$

Shipment cost coefficient of biofuel from refineries to demand centers — CC^{2}_{efmk}

(2)

$$CC^{2}_{efmk} = \left(\left(t^{d}_{lqk} + \frac{t^{t}_{lqk}}{V_k}\right) * \frac{d_{fm}}{Cap_{lqk}} + lu_{lqk}\right)$$

The conversion rate of refinery: measuring the amount of biofuel e that can be produced by one ton of dried biomass i using technology r — η_{ier}

Maximum allowed capacity of the refinery in location f using technology r for biofuel e — $Capr_{efr}$

The capacity of biofuel e stored in city m — $Capi_{em}$

Maximum available biomass i in the area j_i at the time phase t under the scenario s	S^t_{jis}
The demand in city m at phase t for biofuel e under the scenario s	D^t_{ems}
Binary parameter equals 1 when the connection between area j_i and biomass in the refinery is usable in the location f under the scenario s	x^t_{jifs}
The binary parameter equals 1 if the interface between refinery and city m is useable in location f under the scenario s	t^t_{fms}
The binary parameter equals 1 if the area j_i of biomass has access to facility k in time phase t	${}^t_{kji}\Upsilon$
The binary parameter equals 1 if refinery f has access to facility k in time phase t	λ^t_{kf}
Probability of scenario s	$Prob_s$
NO_2 emission rate in distance unit for transportation of vehicle k	G_N^k
CO emission rate in distance unit for transportation of vehicle k	G_c^k
Number of jobs created in refinery center f with technology r in time t	A_{fr}^t
Number of accidents occurred in refinery center f with technology r in time t	B_{fr}^t
Risk of supplying biomass i from supplier j in time t	RY^t_{ji}
Set of decision variables	
The volume of biomass i purchased from the j_i area in time phase t under the scenario s	Y^t_{jis}
The volume of biomass i transported from j_i area to refinery f by facility K in time phase t under the scenario s	X^t_{jifsK}
The volume of biofuel e transported from refinery f to city m by the facility K in time phase t under the scenario s	y^t_{efmsK}
The capacity of the refinery f designed by technology r for biofuel e in time phase t under the scenario s	Cap^t_{efrs}
The available volume of biofuel e in city m in time phase t under the scenario s	I^t_{ems}
Shortage of biofuel e in city m in time phase t under the scenario s	q^t_{ems}
Amount of biofuel e produced in refinery f in time phase t under the scenario s	$Prod^t_{efs}$
It equals 1 if refinery f with technology r works in time phase t under the scenario s	Z^t_{frs}

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Mathematical Modelling

The mathematical model of the problem is expressed by considering of parameters set and variables of the problem:

(3) $\text{Min cost} = \sum_{s\in S}\sum_{t\in T} prob_s \{\sum_{f\in F}\sum_{r\in R_f}(f^F{}_{fr}\, Z^t{}_{frs} + \sum_{e\in E}(f^V{}_{efr}\, cap^t{}_{efrs})) + \sum_{i\in I}\sum_{j_i\in J_I} pr_i\, Y^t{}_{jis} + \sum_{e\in E}\sum_{r\in R_f}\sum_{f\in F} C_{er}\, prod^t{}_{efs} + \sum_{i\in I}\sum_{j_i\in J_I}\sum_{f\in F}\sum_{k\in K} CC^1{}_{ijifk}\, X^t{}_{jifsk} + \sum_{e\in E}\sum_{f\in F}\sum_{m\in M}\sum_{K\in k} CC^2{}_{efmk}\, y^t{}_{efmsk} + \sum_{e\in E}\sum_{m\in M}(\alpha_{em}\, I^t{}_{ems} + \beta_{em}\, q^t{}_{ems})\}$

(4)

$$Min\ pollutants = \sum_{s\in S}\sum_{t\in T} prob_s \{\sum_{j_i\in J_I}\sum_{f\in F}\sum_{k\in K} X^t{}_{jifsk} G^k_N\, d_{jif} + \sum_{e\in E}\sum_{f\in F}\sum_{k\in K}\sum_{m\in M} y^t{}_{efmsk} G^k_N\, d_{fm} + \sum_{j_i\in J_I}\sum_{f\in F}\sum_{k\in K} X^t{}_{jifsk} G^k_C d_{jif} + \sum_{e\in E}\sum_{f\in F}\sum_{k\in K}\sum_{m\in M} y^t{}_{efmsk} G^k_C\, d_{fm}\}$$

(5)

$$Min\ Risk = \sum_{s\in S}\sum_{t\in T} prob_s \left\{\sum_{j_i\in J_I}\sum_{f\in F}\sum_{k\in K} \mathrm{Y_{tjis}} * \mathrm{RY_{tji}}\right\}$$

$$Maxwelfare = prob_s \left\{\sum_{t\in T}\sum_{s\in S}\sum_{f\in F}\sum_{r\in R_f} (A^t_{frs} - B^t_{frs}) Z^t_{frs}\right\}$$

$$\sum_{e\in E} Cap^t{}_{efrs} \le \sum_{e\in E} capr_{efr}\, Z^t{}_{frs} \qquad \forall\, f\in F, s\in S, t\in T, r\in R_f$$

(6)

$$prod^t{}_{efs} \le cap^t{}_{efrs} \qquad \forall\, e\in E, f\in F, s\in S, t\in T$$

(7)

$$I^t{}_{ems} \le capi_{em} \qquad \forall\, e\in E, m\in M, s\in S, t\in T$$

(8)

$$\sum_{j_i \in J_I} \sum_{i \in I} \sum_{k \in K} X^t{}_{jifsk}\, \eta_{ier} = prod^t{}_{efs} \quad \forall\, e \in E, f \in F, s \in S, t \in T, r \in R_f$$

(9)

$$\sum_{m \in M} \sum_{k \in K} y^t{}_{efmsk} = prod^t{}_{efs} \qquad \forall e \in E, f \in F, s \in S, t \in T$$

(10)

$$\mathrm{Y}^t{}_{\mathrm{jis}} = \sum_{f \in F} \sum_{k \in K} X^t{}_{jifsk} \qquad \forall j_i \in J_I, s \in S, t \in T$$

(11)

$$Y^t{}_{jis} \le S^t{}_{jis} \qquad \forall j_i \in J_I, s \in S, t \in T$$

(12)

$$\sum_{f \in F} \sum_{k \in K} y^t{}_{efmsk} + q^t{}_{ems} + I^{t_1}{}_{ems} - I^t{}_{ems} = D^t{}_{ems}(p^t{}_{ems}) \qquad \forall e \in E, m \in M, s \in S, t \in T$$

(13)

$$\sum_{r \in R_f} Z^t{}_{frs} \le 1 \qquad \forall f \in F, s \in S, t \in T$$

(14)

$$\sum_{k \in K} y^t{}_{efmsk} \le t^t{}_{fms} M \qquad \forall e \in E, f \in F, m \in M, s \in S, t \in T$$

(15)

$$\sum_{k \in K} X^t{}_{jifsk} \le x^t{}_{jifs}\, M \qquad \forall j_i \in J_I, f \in F, s \in S, t \in T$$

(16)

$$\sum_{f \in F} \sum_{s \in S} X^t{}_{jifsk} \le \Upsilon_{kji\,t}\, M \qquad \forall j_i \in J_I, k \in K, t \in T$$

(17)

$$\sum_{e\in E}\sum_{m\in M}\sum_{s\in S} y^{t}{}_{efmsk} \leq \lambda_{kft}\, M \qquad \forall\ f\in F, k\in K, t\in T$$

Model Description

According to the proposed model, equation (3) represents the economic objective function that minimizes the total costs of the chain. Equation (4) indicates the second objective function (environmental) that minimizes the emission of hazardous gases, including NO_2 and CO. Equation (4) also comprises the third objective function that minimizes social performance of a sustainable supply chain, which considers job creation and the number of accidents occurred in active refineries per period and scenario. Equation (5) minimizes the risk of biomass supply. Equations (6), (7), and (8) represent the capacity constraints. Firstly, these constraints indicate that biofuel capacity will be available only if there is an active refinery in the potential location f. Meanwhile, the capacity of the constructed refinery must not exceed the maximum capacity of the refinery per period and scenario. Secondly, the volume of fuel production must not exceed the refinery capacity. On the other hand, inventory capacity in each city must exist for any type of fuel in each period and scenario. Equations (9), (10), and (11) represent equilibrium constraints. Constraint (12) indicates that the purchase amount of each biomass depends on its upper bound. Equation (13) indicates the constraint, which expresses the inventory balance in demand centers. The demand for final products is a function of price, and the price of final products follows the Geometric Brownian motion. The demand function is an exponential function in which, M_{em} represents demand with price zero and $k_e \geq 0$ is the price scale function. The constraint (14) explains that each refinery only can select one type of technology. Constraints (15) and (16) indicate the connection between refineries and demand centers, as well as the connection between biomass supply chain centers and refineries. Equations (17) and (18) represent access of biomass supply centers and refineries to different types of transportation facilities.

Robustness Approach to Mathematical Model

As mentioned above, the proposed model is linear. The suggested model will be converted to a linear model due to the reasons mentioned above. Moreover, demand uncertainty is added to the mode by using robust programming and Bertsimas and Sim Approach. The index s (considered as a scenario) is added to the variables of the model to linearize it. Therefore, constraint (10) is modified based on the Bertsimas model. Hence, the proposed model serves as a linear model. This study shows that the demand parameter is a substantial parameter that its values can exceed the nominal values. Therefore, the proposed model can approach the problem's reality if this parameter is considered in uncertain conditions. As mentioned above, robust programming and Bertsimas and Sim approach are used to add demand uncertainty. The robust optimization method aims to find optimal or near-optimal solutions that are more likely justifiable. Bertsimas and Sim's approach is one of four main approaches used to consider uncertainty in robust programming. This part of the study explains this approach briefly. To do this, we consider the following linear programming model:

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(19)

$$Min \sum_j c_j x_j$$
$$s.t$$
$$Ax \leq b$$

This model assumes that only right-hand coefficients have uncertain values in constraints, which is matrix A. The elements of this matrix (a_{ij}) vary in the interval $[\tilde{a}_{ij} - \hat{a}_{ij}, \tilde{a}_{ij} + \hat{a}_{ij}]$ in which $\tilde{a}_{ij}$ and $\hat{a}_{ij}$ represent nominal value and a maximum deviation of parameter a_{ij}, respectively. The proposed Bertsimas and Sim robust approaches are shown below:

(20)

$$Min \sum_j c_j x_j$$
$$s.t. \quad \sum_j \tilde{a}_{ij} x_j + z_i \Gamma_i + \sum_{j \in j_i} \mu_{ij} \leq b_i \qquad \forall i$$
$$z_i + \mu_{ij} \geq \hat{a}_{ij} x_{ij} \qquad \forall i,j$$
$$z_i, \mu_{ij} \geq 0 \qquad \forall i,j$$

Where equations z_i μ_{ij} represent dual auxiliary variables and parameter Γ_i (uncertainty budget) indicates the level of conservatism, which is selected based on the importance of constraint and risk-taking level of the decision-maker.

Hence, the mathematical model robustness is done as follows:

Parameters:

$\widehat{D}_{tems}$: demand tolerance in city m and time t for biofuel e under the scenario s

Γ_{tem} : Uncertainty budget

Robustness variables:

p_{tem} and q_{tems}: variables of robust model

(21)

$$\sum_{f \in F} \sum_{k \in K} y^t{}_{efmsk} + q^t{}_{ems} + I^{t_1}{}_{ems} - I^t{}_{ems} + \Gamma_{tems} p_{tem} + q_{tems} = D^t{}_{ems}(p^t{}_{ems}) \qquad \forall e \in E, m \in M, s \in S, t \in T$$

(22)

$$p_{tem} + q_{tems} \geq \widehat{D_{ems}}^{t}({p^t}_{ems}) \quad \forall j \in J, v \in V, t \in T$$

Solution Method of Mathematical Model

The ε constrained method is one of the exact methods used for optimal a Pareto solution which was introduced by Aljedan. This method has an advantage over other multi-objective optimization methods since it can be used for non-convex solution spaces, while other methods, such as weighting combination of the objectives are not applicable in non-convex spaces. The computation time of an algorithm is a significant feature used to evaluate the algorithm. The most considerable shortcoming of exact search-based algorithms, including the ε constrained method, is their high computational time of them. Therefore, a metaheuristic algorithm can be used to reduce computational time.

The general form of an MODM problem is as follows:

(26)

$$\begin{cases} Min\ (f_1(x), f_2(x), \dots, f_n(x)) \\ x \in X \end{cases}$$

Assume that the first objective is taken into the main objective, while other objectives are constrained to the upper bound of epsilon, and then are applied to the constraints of the problem. In this case, the EC method is used and a multi-objective model (27) is formulated:

(27)

$$\begin{cases} Min\ f_1(x) \\ f_i(x) \leq e_i\ i = 2,3, \dots, n \\ x \in X \end{cases}$$

Where the first objective is considered as the main objective, while the rest objectives are constrained to the maximum value of e_i. Various solutions are obtained in model 27 by changing the e_i values, which may not be efficient (or are weakly efficient). We can solve this problem by augmenting the model (28) partially, which is known as the augmented e-constraint method (AEC) (Mavrotas, 2009). We can implement the AEC method better by measuring the suitable range of epsilons (e_i) based on lexicographic optimization (Aghaei et al., 2011). AEC method first determined the suitable range of changes in epsilons and then calculates the Pareto front based on the different values of epsilons.

1. Proper range for e_i values based on Lex method

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Following optimization problems are solved for each objective $[j = 1,2,\dots,n]$ to find the suitable range of e_i corresponding to objective i $(i = 2,\dots,n)$:

(28)

$$\begin{aligned} PayOff_{jj} &= Min\ f_j(x) \\ & x \in X \end{aligned}$$

Where $x^{j,*}$ represents the optimal solution and $PayOff_{jj} = f_j\left(x^{j,*}\right)$ indicates the optimal value of objective j. Now, the optimal value of objective j is formulated as equation (29) by considering one of $j = 1,2,\dots,n; j \neq i$ objective as optima in each case:

(29)

$$\begin{aligned} PayOff_{ij} &= Min\ f_i(x) \\ f_j(x) &= PayOff_{jj} \\ & x \in X \\ & j \neq i \end{aligned}$$

Where optimal solution $x^{i,j,*}$ with optimal value $PayOff_{jj} = f_i\left(x^{i,j,*}\right)$ is calculated for objective i. Therefore, the following payoff matrix is obtained based on the Lex method.

(30)

$$PayOff = \left[payOff_{ij}\right]$$

Following terms are defined for objective $i = 1,\dots,n$ after determining the Payoff matrix:

- $Min(f_i) = Min_j\{payOff_{ij}\} = payOff_{ii}$
- $Max(f_i) = Max_j\{payOff_{ij}\}$
- $R(f_i) = Max(f_i) - Min(f_i)$

Accordingly, the proper range is found for e_i based on the Lex method: $e_i \in [Min(f_i), Max(f_i)]$. The $R(f_i)$ value is used to normalize the objective in the AEC objective function.

2. Improving EC Method by using AEC

The model of the AEC method is formulated as equation (31) in which, the s_i value represents non-negative variables of shortage and ϕ_i indicates a parameter that is used to normalize the first objective function relative to the objective i $(\phi_i = \frac{R(f_1)}{R(f_i)})$.

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(31)

$$\begin{cases} Min\ f_1(x) - \sum_{i=2}^{n} \phi_i s_i \\ f_i(x) + s_i = e_i\ i = 2,3,\ldots,n \\ x \in X \\ s_i \geq 0 \end{cases}$$

The AEC method formulated in the present study first determines the range $e_i \in [Min(f_i), Max(f_i)]$ for constrained objectives by using the Lex method. Next, the single-objective model (31) is solved afterr quantifying e_i values. This model generates an efficient solution and places the objectives' value in the Pareto front regarding this solution. Note that any change in e_i values at their corresponding ranges leads to another efficient solution and another point in the Pareto front. The next part of the study explains how AEC is used to solve the proposed two-objective model.

Validation of Mathematical Model by Using EC

Stochastic numbers are used in small dimensions to discuss and examine the proposed mathematical model, and then optimal solutions are analysed based on the indexes and parameters of the problem.

A) Introducing Dimensions of the Studies Problem

Stochastic data are used to validate the model formulated in the previous section. Each considered part is described in the table below. Hence, the model was coded in GAMS software and CPLEX solver through the EC method to evaluate and validate the proposed mathematical model. In the first section, the assumed inputs of the mathematical model are discussed and addressed:

Problem's Inputs

This step presented a pilot problem by using random data based on the papers introduced for the proposed model in the previous chapter. It should be explained that the corresponding values for the calculation of transportation costs and other input parameters of the model were evaluated by considering three types of biomasses from two different areas. Moreover, two types of transportation facilities with different capacities and an assumed refinery were taken into account. On the other hand, two demand centers, and two final products were evaluated under two Bertsimas and Sim uncertainty scenarios. According to assumptions of the problem, the fixed cost of refinery setup was 10 billion$. Furthermore, costs of maintenance and fuel shortage depended on the sales cost; 0.5% and 1% out of sales profit, respectively. The maximum capacity of the refinery equaled 100.000 million cubic liters, and the probability of scenarios equaled 0.85 and 0.15, respectively. Tables 2 to 9 indicate other parameters of the mathematical model. It is worth noting that the model was analyzed under two biomass production scenarios because the mathematical model was NP-HARD. These two scenarios were considered because the exact solution cannot evaluate more production scenarios.

Table 2. Cost of purchasing biomass

pr	I		
	1	2	3
	12	30	20

Table 3. Access of refinery to considered facility

$\lambda_{k,f}$	T	
	1	2
	1	0
	0	1

Table 4. The capacity of stored fuel

capi$_e$	M	
	1	2
	7.000	10.000
	80000	9000

Table 5. Cost of fuel production

C	E,r	
	1.1	1.2
	40	32

Table 6. Connection between biomass areas and refinery

X(I,j,f)	(t,s)			
	1.1	1.2	2.1	2.2
1.1.1	1	0	1	1
1.2.1	1	0	1	1
2.1.1	1	1	0	1
2.2.1	1	1	1	0
3.1.1	1	1	0	1
3.2.1	1	0	1	1

Table 7. Demand values for biofuel

D(e.m)	(t,s)			
	1.1	1.2	2.1	2.2
1.1	10	12	12	11
1.2.	17	17	17	23
2.1	21	12	12	20
2.2	27	19	10	22

Table 8. Fuel price in the demand center

p(e.m)	(t,s)			
	1.1	1.2	2.1	2.2
1.1	80	77	70	80
1.2.	57	70	77	50
2.1	70	77	50	57
2.2	70	77	57	50

Table 9. Cost of shipping biomass from biomass areas to the refinery

CCl(I,j)	(f,k)	
	1.1	1.2
1.1	2	7
1.2	2	7
2.1	2	7
2.2	3	7
3.1	3	7
3.2	3	7

The mathematical model was validated in GAMS software by using the AEC method. This method was used based on the inputs of the mathematical model that is described herein.

Finally, we solved the AEC by using GAMS software for obtained epsilons. Table 10 reports the set of Pareto optimal solutions.

Table 10. Optimal values of objective functions

ε	Value of the first objective function	Value of the second objective function	Value of the third objective function
1	525300	351	132
2	525450	351	135
3	525550	352	135
4	525621	355	135
5	525643	356	137

Figure 1 depicts Pareto front of the first objective function.

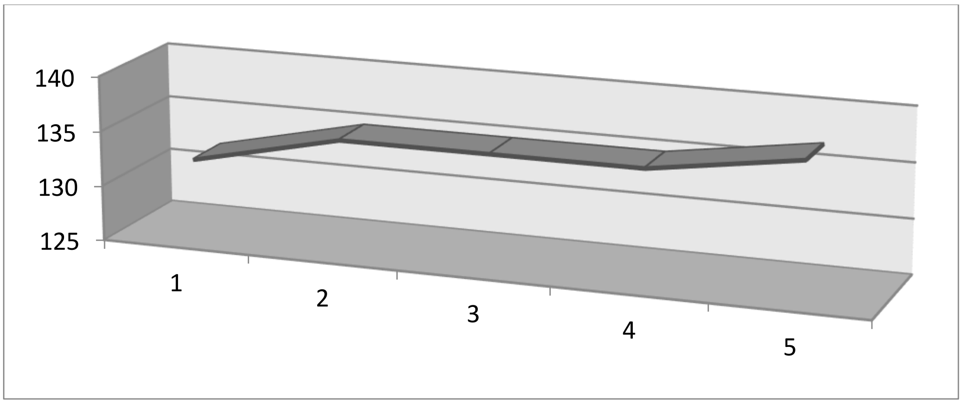

Figure 1. Pareto front of the first objective function

Figure 2 depicts Pareto front of the second objective function.

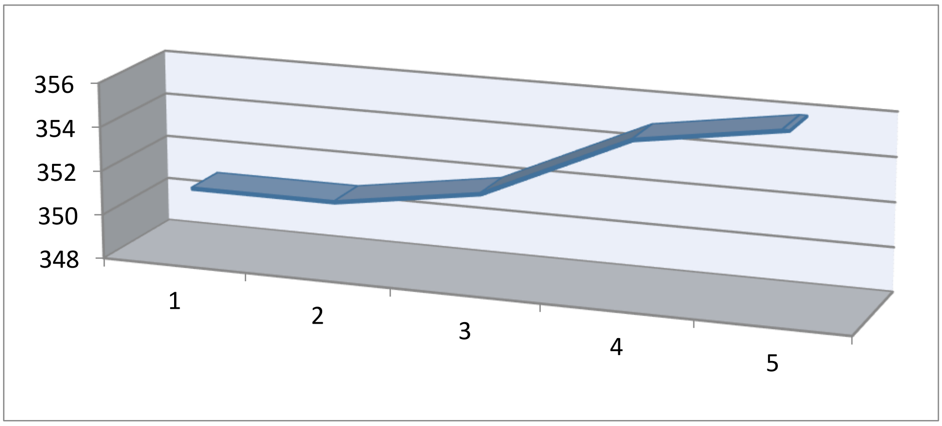

Figure 2. Pareto front of the second objective function

Figure 3 depicts Pareto front of the third objective function

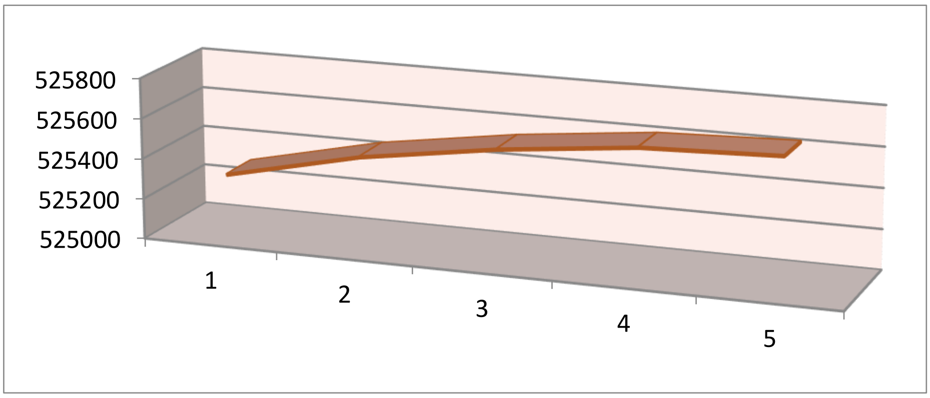

Figure 3. Pareto front of the third objective function

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Benders Decomposition Technique

Benders Decomposition Technique relies on the decomposition of a mixed-integer programming model to one master problem and one subproblem that is solved iteratively using their solutions. The subproblem includes continuous variables and corresponding constraints, while the master problem comprises integer variables and one continuous variable, which connects two problems. The optimal solution to the master problem provides a lower bound for the objective under the question. A dual is solved for the subproblem by using the solution obtained from the master problem and fixing the integer variables subproblem's input. This solution can be used to define an upper bound for the general objective of the problem. Moreover, this solution is used to generate a Bander's cut, which comprises continuous variables added to the master problem. This cut is added to the master problem in the next iteration, and then a new lower bound is found for the master problem by solving it. It is ensured that the new bound is not worsening than the current lower bound. Therefore, the master problem and subproblem are solved interpretively until reaching a termination condition, which occurs when the gap between upper and lower bounds is less than a small number. Benders Decomposition Technique obtains the optimal solution in finite iterations.

The overall problem is formulated before developing the master problems and subproblems based on Banders Technique:

(32)

$$Min\ \ Z_p = \sum_{j\in M}\sum_{r\in R} F_j^r U_j^r + \sum_{k\in L}\sum_{h\in H} G_k^h V_k^h + BSP(x,y|U,V)$$

Or to be more precise:

(33)

$$Min\ \ Z_p = \sum_{j\in M}\sum_{r\in R} F_j^r U_j^r + \sum_{k\in L}\sum_{h\in H} G_k^h V_k^h + BSP(x,y|\widehat{U},\widehat{V})$$

s.t:

(34)

$$\sum_{r\in R} U_j^r \le 1 \quad \forall j \in M$$

(35)

$$\sum_{h\in H} V_k^h \le 1 \qquad \forall k \in L$$

Where $BSP(x, y|\widehat{U}, \widehat{V})$ is Banders' subproblem, which consists of the following details:

Dual Subproblem

The $\mathrm{BSP}(\mathrm{x}, \mathrm{y}|\widehat{\mathrm{U}}, \widehat{\mathrm{V}})$ dual is used to generate Banders' cuts for the master problem. The dual variables $(\pi^1_{\mathrm{ips}}, \pi^2_{ips}, \pi^3_{js}, \pi^4_{\mathrm{jps}}, \pi^5_{\mathrm{ks}})$ are used for constraints (36), (37), (38), (39), and (40) to calculate the duality of this problem. The problem of the subproblem called $DBSP(\pi^1, \pi^2, \pi^3, \pi^4, \pi^5|\widehat{U}, \widehat{V})$ is shown by consideration of these variables:

(36)

$$\max \sum_{i\in N}\sum_{p\in P}\sum_{s\in S}(-\pi^1_{ips} + \pi^2_{ips}) - \sum_{j\in M}\sum_{s\in S}\left(\pi^3_{js}\sum_{r\in R} b^r_j \widehat{U}^r_j\right) - \sum_{k\in K}\sum_{s\in S}\left(\pi^5_{ks}\sum_{h\in H} e^h_k \widehat{V}^h_k\right)$$

s.t:

(37)

$$-\pi^1_{ips} + \pi^2_{ips} - a^p_i v^p \pi^3_{js} - a^p_i v^p \pi^4_{jps} \le p^s C_{ij} a_i \qquad \forall i, j, p, s$$

(38)

$$b^r_j \pi^4_{jps} - b^r_j \pi^5_{ks} \le p^s \bar{C}_{jk} b^r_j \quad \forall j, k, r, p, s$$

(39)

$$\pi^1_{ips}, \pi^2_{ips}, \pi^3_{js}, \pi^4_{jps}, \pi^5_{ks} \ge 0 \ \ \forall i, j, k, p, s$$

Banders' master problem is modeled as follows:

(40)

$$\min_{U,V} z$$

s.t:

(41)

$$z \geq \sum_{j\in M}\sum_{r\in R} F_j^r U_j^r + \sum_{k\in L}\sum_{h\in H} G_k^h V_k^h + \sum_{i\in N}\sum_{p\in P}\sum_{s\in S}(-\hat{\pi}_{ips}^{1k\prime} + \hat{\pi}_{ips}^{2k\prime}) - \sum_{j\in M}\sum_{s\in S}\left(\hat{\pi}_{js}^{3k\prime}\sum_{r\in R} b_j^r U_j^r\right) - \sum_{k\in K}\sum_{s\in S}\left(\hat{\pi}_{ks}^{5k\prime}\sum_{h\in H} e_k^h V_k^h\right) \quad \forall k\prime = 1,\dots,\acute{K}$$

(42)

$$\sum_{i\in N}\sum_{p\in P}\sum_{s\in S}(-\hat{\pi}_{ips}^{1l\prime} + \hat{\pi}_{ips}^{2l\prime}) - \sum_{j\in M}\sum_{s\in S}\left(\hat{\pi}_{js}^{3l\prime}\sum_{r\in R} b_j^r U_j^r\right) - \sum_{k\in K}\sum_{s\in S}\left(\hat{\pi}_{ks}^{5l\prime}\sum_{h\in H} e_k^h V_k^h\right) \leq 0 \quad \forall l\prime = 1,\dots,\acute{L}$$

(43)

$$\sum_{r\in R} U_j^r \leq 1 \quad \forall j \in M$$

(44)

$$\sum_{h\in H} V_k^h \leq 1 \qquad \forall k \in L$$

In this model, equation (36) represents the objective function of Banders' master problem, and equation (37) includes optima cuts that are added to the master problem after obtaining the optimal solution of the subproblem. Parameters $\hat{\pi}_{ips}^{1k\prime}$, $\hat{\pi}_{ips}^{2k\prime}$, $\hat{\pi}_{js}^{3k\prime}$ and $\hat{\pi}_{ks}^{5k\prime}$ show values of dual variables that are calculated after solving Banders' subproblem. These values are considered fixed values in cut constraints. Equation (38) includes feasibility cuts. This equation is added to the master problem if the subproblem is not feasible. Parameters $\hat{\pi}_{ips}^{1l\prime}$, $\hat{\pi}_{ips}^{2l\prime}$, $\hat{\pi}_{js}^{3l\prime}$ and $\hat{\pi}_{ks}^{5l\prime}$ represent values of dual variables that were obtained after solving Banders' subproblem. These values are considered constant values in cut constraints. General Procedure of Benders Decomposition Algorithm

$\{\text{initialization}\}$

$(U, V) = \text{initial feasible integer solution}$

LB := -∞

UB := +∞

$L' = K' = 0$

while $(\text{UB} - \text{LB} > \varepsilon)$ Do

{solve subproblem}

if (Subproblem is Unbounded) then

Get unbounded ray π

Add cut $\sum_{i \in N} \sum_{p \in P} \sum_{s \in S} (-\hat{\pi}_{ips}^{1l'} + \hat{\pi}_{ips}^{2l'}) - \sum_{j \in M} \sum_{s \in S} \left(\hat{\pi}_{js}^{3l'} \sum_{r \in R} b_j^r U_j^r \right) - \sum_{k \in K} \sum_{s \in S} \left(\hat{\pi}_{ks}^{5l'} \sum_{h \in H} e_k^h V_k^h \right) \leq 0$

to master problem

$L' := L' + 1;$

Else

Get extreme point π

Add cut $z \geq \sum_{j \in M} \sum_{r \in R} F_j^r U_j^r + \sum_{k \in L} \sum_{h \in H} G_k^h V_k^h + \sum_{i \in N} \sum_{p \in P} \sum_{s \in S} \left(-\hat{\pi}_{ips}^{1k'} + \hat{\pi}_{ips}^{2k'} \right) - \sum_{j \in M} \sum_{s \in S} \left(\hat{\pi}_{js}^{3k'} \sum_{r \in R} b_j^r U_j^r \right)$

$- \sum_{k \in K} \sum_{s \in S} \left(\hat{\pi}_{ks}^{5k'} \sum_{h \in H} e_k^h V_k^h \right)$ to master problem

$K' := K' + 1;$

UB := min{UB, $\sum_{j \in M} \sum_{r \in R} F_j^r U_j^r + \sum_{k \in L} \sum_{h \in H} G_k^h V_k^h + \sum_{i \in N} \sum_{p \in P} \sum_{s \in S} \left(-\hat{\pi}_{ips}^{1k'} + \hat{\pi}_{ips}^{2k'} \right) - \sum_{j \in M} \sum_{s \in S} \left(\hat{\pi}_{js}^{3k'} \sum_{r \in R} b_j^r U_j^r \right)$

$- \sum_{k \in K} \sum_{s \in S} \left(\hat{\pi}_{ks}^{5k'} \sum_{h \in H} e_k^h V_k^h \right)$}

end if

{solve master problem}

LB := $\bar{z}$ //result of master problem

end while

This pseudocode indicates that we must find a feasible solution for the master problem at the first stage. The feasible solution is found after solving the master problem without any cut. Next, the solutions obtained by the master problem are added to the subproblem, and then the subproblem is solved. If the subproblem is not feasible and the dual solution of the subproblem is infinite, an infinite orientation is taken from the duality. This orientation is used to generate a feasibility cut, and then this cut is added to the master problem. The optimal solutions of dual subproblem are used to generate an optimal cut and add to the master problem if the subproblem is feasible and has an optimal solution. If the resulted solution creates a better upper bound, the upper bound will be updated. Next, the master problem is resolved by using the new cut to update the lower bound. The iterative procedure continues until the gap between upper and lower bounds is less than a value.

This algorithm has been developed by using GAMS.23 software. This algorithm was implemented for the example mentioned above and outcomes were presented. As we know, the direct solution to this problem through GAMS.23 software requires 109.118 seconds. According to the results of this Table, less time is required to solve the problem by using Banders Decomposition Technique compared to the case in which, the model is solved directly based on the mixed-integer programming model. This implies the efficiency of the Banders Decomposition Technique.

Table 11 shows the lower and upper bound resulting from Banders Decomposition Technique within different iterations. Figure 4 depicts that the method reaches convergence after 17 iterations.

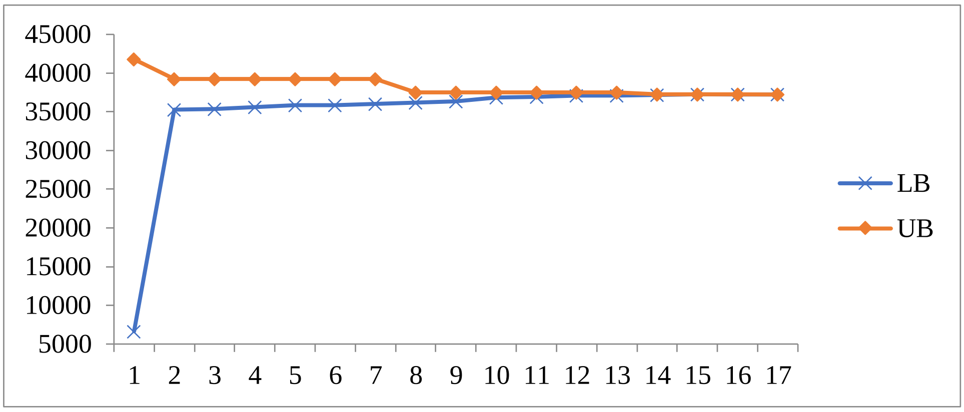

Figure 4. Convergence of Banders Decomposition Technique

Table 11. Results of numerical example solved by Banders Decomposition Technique

Model	Total variables	Total constraints	Implementation time (s)	Objective function' value
Probabilistic	286786	31758	78.698	37235.000

Evaluating performance of two EC and Banders Algorithms

Two EC and Banders Relaxation algorithms were used to evaluate solutions obtained from solving mathematical models. These two algorithms examined 12 dimensions of the problem. Therefore, this part of the study addresses the efficiency of these two algorithms in terms of the number of Pareto front of optimal solutions, quality of obtained solutions, the gap between obtained and ideal solutions, and diversity of solutions generated by EC and Banders Algorithms. The mentioned points have been reported in the Table 12.

Table 12. Evaluating performance of two EC and Banders Algorithms

Sample	N		Q		MID		DM	
	EP	RL	EP	RL	EP	RL	EP	RL
1	8	8	0.33	0.33	0.35	0.35	0.34	0.34
2	6	6	0.40	0.40	0.38	0.38	0.37	0.37
3	5	5	0.32	0.32	0.33	0.33	0.20	0.20
4	7	7	0.97	0.97	0.80	0.80	0.72	0.72
5	5	5	0.26	0.26	0.34	0.34	0.30	0.30
6	4	4	0.07	0.07	0.05	0.05	0.04	0.04
7	9	9	0.23	0.23	0.06	0.06	0.06	0.06
8	6	6	0.49	0.49	0.40	0.40	0.38	0.38
9	4	4	0.67	0.67	0.66	0.66	0.64	0.64
10	10	10	0.07	0.07	0.01	0.01	0.01	0.01
11	9	9	0.86	0.86	0.46	0.46	0.44	0.44
12	2	2	0.05	0.05	0.73	0.73	0.70	0.70

The normality of solutions was tested by using Kolmogorov-Smirnov (K-S) test through SPSS software to implement this procedure. The corresponding tests are done by using a t-test value after determining the normality of the evaluated data. Table 13 shows K-S test results used to test the normality of solutions generated by EC and Banders Relaxation algorithms.

Table 13. One-Sample Kolmogorov-Smirnov Test

N		n_epsilon	q_epsilon	MID_epsilon	DM_epsilon
		12	12	12	12
Normal Parameters[a,b]	Mean	6.2500	0.3933	0.3808	0.3500
	Std. Deviation	2.41680	0.30407	0.25889	0.24750
Most Extreme Differences	Absolute	0.125	0.166	0.172	0.129
	Positive	0.125	0.166	0.142	0.129
	Negative	-0.122	-0.129	-0.172	-0.129
Test Statistic		0.125	0.166	0.172	0.129
Asymp. Sig. (2-tailed)		0.200[c,d]	0.200[c,d]	0.200[c,d]	0.200[c,d]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

According to the results of the K-S test on the EC method used to solve 12 samples, Sig. was greater than 0.05. Therefore, the data were normal.

Table 14. One-Sample Kolmogorov-Smirnov Test

		n_RL	q_RL	MID_Rl	DM_RL
N		12	12	12	12
Normal Parameters[a,b]	Mean	6.2500	0.3933	0.3808	0.3500
	Std. Deviation	2.41680	0.30407	0.25889	0.24750
Most Extreme Differences	Absolute	0.125	0.166	0.172	0.129
	Positive	0.125	0.166	0.142	0.129
	Negative	-0.122	-0.129	-0.172	-0.129
Test Statistic		0.125	0.166	0.172	0.129
Asymp. Sig. (2-tailed)		0.200[c,d]	0.200[c,d]	0.200[c,d]	0.200[c,d]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

According to the test analysis of NSGAII, the Sig. value was greater than 0.05. Therefore, both EC and NSGAII methods generated normal solutions. Moreover, the t-test value was used for presumptions formulated for an equal number of Pareto solutions, quality of solution, the distance from the ideal solution, and diversity of solutions.

Table 15. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	n_epsilon	6.2500[a]	12	2.41680	0.69767
	n_RL	6.2500[a]	12	2.41680	0.69767
Pair 2	q_epsilon	0.3933[a]	12	0.30407	0.08778
	q_RL	0.3933[a]	12	0.30407	0.08778
Pair 3	MID_epsilon	0.3808[a]	12	0.25889	0.07474
	MID_Rl	0.3808[a]	12	0.25889	0.07474
Pair 4	DM_epsilon	0.3500[a]	12	0.24750	0.07145
	DM_RL	0.3500[a]	12	0.24750	0.07145

a. The correlation and t cannot be computed because the standard error of the difference is 0.

As was anticipated, EC and Banders Relaxation algorithms had the exact solution. Hence, they were identical in generating Pareto solutions, quality of solutions, the gap between generated and ideal point, and solution diversity. The reason for such similarity is that the Benders Relaxation algorithm only affects the solution time while analyzing optimal solutions as the EC algorithm does.

Conclusion and Recommendations

A biofuel supply chain involves major activities: harvesting, storing, and transporting the biomass, converting biofuel, transporting biofuel, and using biofuel. A point must be considered for preprocessing amenities and biofuel byproducts, for instance. The warehouse must be constructed near biofuel demand locations to reduce biofuel transportation costs. Therefore, the cost of biomass transportation will be increased if the warehouse is far from the waste disposal locations. It is not possible to independently make logistic decisions, which influence the supply chain. Biofuels and corresponding production procedures are divided into three generations in classifying biomass feedstock, biofuels, and corresponding production procedures. First-generation biofuels are made from sugar and vegetable oils, which can be converted to biofuels by using conventional technologies. Most feedstocks that are used in this process can also be a food source. Therefore, the process of using food items has changed to non-edible materials. On the other hand, it is highly challenging to use this category of biofuel. Biomass production and biofuel production technology are some of these challenges. Second-generation biofuels are obtained from non-edible materials, such as lignocellulosic biomass, crops, agriculture residue, or wastes that can produce fuel. Third-generation biofuels that have been recently introduced are produced from algae. The complicated production process has prevented the commercialization of second and third-generation biofuels. The biomass flow from supply sites to demand centers is required for biofuel production. The biomass passes through some facilities in this process, which is called the biomass supply chain. Each supply chain loop requires special knowledge, technology, and activities, including growth, harvest, transportation, collection, storing, conversion, distribution, and consumption. Therefore, the present study has introduced and addressed a multi-level supply chain from supplying to distributing biofuel products. The proposed model has investigated the sustainability objectives, such as economic, social, and environmental issues of supply risk. Ultimately, the introduced model was validated by using the EC approach and then confirmed by using the integrated EC-Banders Relaxation algorithm.

Here are some recommendations based on the mathematical model formulated in the extant study:

1. Third-generation biofuels made from algae have been developed; hence, it is suggested to use them in supply chain studies for hard and soft time windows.

2. The routing and location issues can be developed in a mathematical model by considering the studied supply chain.

3. It is recommended to estimate and evaluate fuzzy logic when evaluating the costs of the mathematical model.

4. Metaheuristic algorithms have evaluation errors; hence, it is suggested to evaluate the solution time by solving the large dimensions of a mathematical model. Next, the results of solving the mathematical model can be evaluated by Banders Algorithm.

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Original Research

Dynamic Connectedness between Global Commodity (Fuel and Non-fuel) Prices and Middle East Stock Market: Stock Exchange Perspective

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Abstract

In this article, we provide an in-depth study of the link between global commodity prices and the shocks market. Many Middle East countries are exports dependent and rely heavily on the global price of their primary commodities to make rational economic decisions. It is against this background that this study investigates the level of interdependence between global commodities prices and stock market returns in selected Middle East countries. For this empirical investigation, the two largest stock markets were selected based on market capitalization namely Tehran Stock Exchange (TSE) and Saudi Stock Exchange, TADAWUL (TASI). Specifically, we examined the relationship between global commodities prices and stock market returns and the direction of causality between the variables following Eagle Granger causality procedures. In addition, we determined the effect of global commodities` price movement on stock market returns using the ARDL estimation technique. The results of our analyses show that there is a significant long-run relationship between global commodities prices and stock market returns. Also, there exists a largely bidirectional causal relationship between global commodities prices and stock market returns in the two markets. Furthermore, the results of ARDL estimation reveal that global commodities prices have short-run and long-run effects on stock market returns in the two markets. These findings are robust to a battery of robustness checks. These results support the investor's decision-making process. In addition, the results of this survey are important for policymakers to strengthen the stock market to drive economic growth.

Keywords: Commodity, Stock Market, Causality, ARDL.

JEL Classification: G1, C2, C5

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Introduction

The entire world has become a global village, which is affecting the speed of information transfer from one market to another, including the Tehran stock market. Around the world, more and more attention is being paid to the relationship between global commodity prices and stock price performance. However, most of these studies focus on market equities in developed countries. (Choi and Hammoudeh, 2010). In recent times, studies that focused on emerging market stocks are also springing up (Chebbi and Derbali, 2015); (Ben Rejeb and Arfaoui, 2016). Generally, many of these studies mostly determine the movement or otherwise between the global commodity prices and stock performances without examining the issue of causality. Supposedly, if a relationship exists between commodity prices and stock performances, is it a short-term relationship or long-term relationship? More importantly, various types of commodities exist in the market namely hard commodities and soft commodities. The nature of the commodity price index included in the study may influence the outcomes of the empirical investigation. Volatile commodity prices have impacted the global economy. Especially due to the expansion of the global economy after the 2000s, investors are paying more and more attention to commodity prices. Policymakers and market participants have focused on the dynamics of commodity price volatility because of its impact on economic growth and financial development. On the other hand, the main research area in finance deals with the factors that affect stock prices and the sensitivity of stock prices to these factors. As a result, understanding the behavior of stock markets has become a primary goal of investors is emerging. The interaction of commodity markets with financial markets is an important area of study. There is increasing evidence that fair markets and commodities are linked and that commodity-equity correlations have increased since the early 2000s., (Vivian & Wohar, 2012).

Due to oil price uncertainty, regional political tensions, and improvements and innovations in the Middle East stock markets over the last decade, we should focus on these markets and look at their relationship to global factors. became. In particular, to ensure the uniqueness of this study and generally enrich the literature in this direction, the causal relationship between global commodity prices using different commodity indexes and the stock performance of the two selected Middle Eastern countries. Examine you. It also determines if the relationship is short-term or long-term. We will also consider the impact of global commodity price indexes on subregion stock market returns. This is very important as it provides potential investors and market analysts with more information related to the two variables. Apart from this introductory section, this study is divided into four sections. Section 2 focuses on global commodity prices and financial variables in the two selected countries, while Section 3 outlines existing literature. Methods and empirical analyses are presented in sections 4 and 5, and the final section focuses on the results and their discussion.

Global Commodity Prices and Stock market performances in The Middle East

Figure 1 shows a graph of the annual rate of change of the TSE Index from 2008 to 2020 in Iran and the Global Fuel and Non-Fuel Commodity Price Index. Primarily, there is evidence of periodic movements common to the three variables. It is also noteworthy that expansion stage of the TSE index precedes the expansion stage of the fuel commodity

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price index, but it is consistent with the non-fuel commodity price index from 2008 to 2020. However, the 2008 financial crisis seems to have put pressure on the three variables to shrink at the same time. After that, the three variables show a higher degree of cooperation. In summary, as an oil-producing economy, Iran's stock performance appears to be more linked to the fuel commodity price index than to the non-fuel commodity price index.

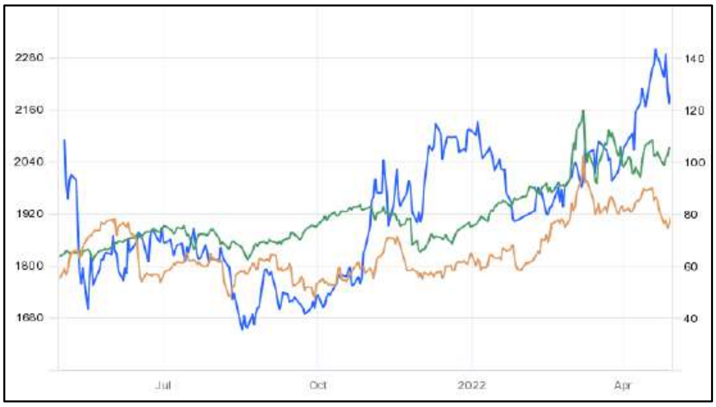

Figure.1. TSE Index and Global Commodity Prices

In Figure 2., the graphs show annual percentage change in the TASI index and global prices indices of fuel and nonfuel commodities between the years 2008-2020 in the Middle East. Just like the situation in Iran, there is discernible evidence of cyclical movement in the TASI stock index and global commodity prices for fuel and nonfuel. By expectation, the Middle East is a net importer of fuel, and should not ordinarily have its stock price index moving together with the price of fuel commodity index but this seems to be the case in the years 2008-2020. In the year 2008, the Fuel and Nonfuel commodity prices index experienced simultaneous contraction with the TASI stock price index and they faced expansion in the year 2009. This movement seems to be persistent till 2012 when there is a bit of divergence in their movements. However, there is still evidence of shock and response in the three variables in the figure. As expected, the non-fuel price index and the Tokyo Stock Price Index show better evidence of joint movement than the fuel price index.

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Figure 2. TASI Index and Global Commodity Prices

Table 1. shows selected key indicators of the TSE and TASI exchange markets. Looking at the first column, there are quite a few listed companies in the two markets. However, the number of listed companies is constantly increasing. The second and third columns show the total value and market capitalization of the traded stocks as a percentage of GDP. The reported figures show that there is a significant difference between TSE and TASI based on these two indicators. The total TSEC value of equities traded as a 227.3% percent of GDP in 2020 shows high liquidity in the economy compared to TASI's 69.3. TSEC market capitalization will account for 598.8% of GDP in 2020. This shows a high degree of fiscal deepening in Iran's economy, in contrast to Saudi Arabia, which accounted for 347% during the same period.

Table. 1. Indicators of TSE and TASI

Listed domestic companies, total				Stocks traded, total value (% of GDP)			Market capitalization of listed domestic companies (% of GDP)		
Year	2008	2014	2020	2008	2014	2020	2008	2014	2020
TSEC	356	315	367	3.5	5.4	227.3	11.8	27	598.8
TASI	127	169	207	100.7	75	69.3	74.3	63.9	347

In figure 3. The graphs show the annual percentage change in the TASI index and TSE index with global prices indices of fuel and non-fuel commodities between the years 2008 and 2020.

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Figure 3. TASI Index and Global Commodity Prices

Literature Review

The issue of the relationship between global commodity prices and stock performance has received a great deal of attention in the literature. However, the lack of consensus between the important places these variables occupy in the economy and the literature required constant rethinking of the relationships between these variables. Some authors have used different methods to study this association and sell it in both developed and developing countries.

Developed Countries and Global Commodity

Starting with developed countries, (Henriques, Irene, Sadorsky, and Perry, 1999) used vector auto regression to investigate the impact of oil price shocks on equity returns in OECD countries. After rigorous analysis, the study concluded that fluctuations in oil prices account for the majority of the actual stock return forecast error variance. The study further argued that oil price shocks were more important to stock returns than interest rates in OECD countries. (Papapetrou, 2001) adopting a similar technique on monthly data for Greece concludes that oil prices drive stock price dynamics. This finding downplays the assertion of (Adelman, 1993), however, most of these studies only identified oil prices from available commodity prices without investigating how other commodity prices could affect stock returns. Another study by (Park, Jungwook, Ratti, Ronald, 2008), using multivariate VAR analysis, reported that oil price shocks have a significant effect on real stock returns for the US and 13 European countries from 1986 to 2005 using monthly data. A separate study by (Malik et al., 2009) used the bivariate GARCH model to study the transfer of volatility between weekly WTI oil prices and equity sector returns from 1992 to 2008 provided evidence of a spillover effect. Stay away from the oil price, study by (Choi and Hammoudeh, 2010) investigated the relationship between Brent crude, WTI oil, copper, gold, and silver commodity prices and the S & P 500 Index and concluded that global commodity prices are affecting the stock market portfolio.

Developing Countries and Global Commodity

In developing countries, the study (Johnson, 2009) applied Geweke feedback measurements to study the interactions between global commodity markets and stock markets in the Americas. They reported the existence of a simultaneous relationship between commodity prices and the stock market, after considering changes in exchange rates and interest rates. Therefore, there are no signs of a lead or lag relationship. Similarly, Chebbi and Derbali (2015) using Dynamic Conditional Correlation established a high correlation between commodity returns and QE Al Rayan Islamic index. On the contrary, the study by (Ildırar and Iscan, 2016) used panel data from 10 countries from 2012 to 2015. We investigated the interaction between stock prices and commodity prices in Eastern Europe and Central Asian countries. They argued that there was no relationship between commodity prices and the stock market. Another study (Iscan, 2015) also provided evidence of the non-association by examining the association between commodity prices and the Turkish stock market using the multivariate Johansen test. In SSA, the study by (Kusi et al., 2016) Using the bivariate VARGARCH BEKK model, we analyzed the impact of oil and gold prices on Ghana's stock market performance, and research provided evidence of a two-way link between Ghana's stock market and gold and oil prices. A similar study in South Africa (Sadorsky, 2014) used quarterly statistics cowl the length from 1994 to 2013. With the useful resource of the Engle-Granger steps econometric technique, the examination reaffirmed that the boom in commodity fees is related to advanced inventory marketplace performances in South Africa. A recent study by (Musawa, 2017) for Zambia arrived at a similar conclusion.

Fuel Commodities and Stock Market

(Chen, Rogoff, & Rossi, 2010), Studies on the relationship between commodity prices and stock returns have mainly focused on oil using the single frequency VAR method. Keep in mind that oil prices in the UK, US, and Granger have spurred both resumption and production, except for the UK. (Huang, Masulis and Stoll, 1996) Using the VAR method, no relationship was found between the daily returns of oil futures and the daily returns of US equities between October 9, 1979, and March 16, 1990. The VAR method was also used by (Sadorsky, 1999), This confirms that both monthly oil prices and fluctuations in oil prices play an important role in US economic performance. The authors state that changes in oil prices are predicting market inventories. Rising global profits and oil prices have significantly reduced future equity returns. They also did not predict future market returns in three of the 18 developed markets (Hong Kong, Japan, and Singapore) where oil price changes were surveyed, while oil prices were among the 30 emerging markets surveyed. Forecast future market returns in 11 (Brazil, Finland, India, Ireland, Israel, Jordan, New Zealand, Portugal, South Korea, Taiwan, Thailand). In addition, (Cong et al., 2008) No evidence of a relationship between Chinese oil prices and real stock returns using the standard VAR framework was found. As mentioned at the beginning, several papers report evidence of a time-varying relationship between oil and the stock market. (Ciner, 2001) Using a non-linear Granger causal approach, we will study the dynamic relationship between future daily oil prices and the US stock market. The author uses two data samples from October 9, 1979, to March 16, 1990. (Huang, Masulis and Stoll, 1996), In this study, the S & P 500 indexes returned in both samples showed a significant non-linear Granger causality of crude oil futures returns. (Park and Ratti, 2008) We use linear and non-linear multivariable VAR specifications to estimate the impact of oil price shocks and oil price fluctuations on the actual stock returns of 14 developed country samples. They found that oil price shocks had a statistically significant impact on actual stock returns, either simultaneously or with a one-month delay. (Apergis and Miller, 2009), Find out if oil price changes from 1981 to 2007 affect inventory returns for samples from eight developed countries in the United States. In Australia, only oil supply shocks temporarily increase inventory revenue, while in France, only global oil demand shocks temporarily increase inventory revenue in Canada and Japan. These have no causal relationship. (Kang, Ratti and Yoon, 2015) use the time-varying VAR model to investigate the impact of oil price shocks on US stock market returns based on monthly data for the period ending January 1, 2015. They state that while oil price shocks contain information for predicting actual equity returns, the coefficients and nature of the shocks change over time. Several articles have investigated the relationship between commodity prices and stock market returns in developing countries. (Yang, 2012; Yang et al., 2012) During the period, limited evidence of the impact of monthly oil prices on stock market returns was found for groups of nine oil importers and seven oil exporters. Empirical testing has shown that the oil crisis is more likely to affect stock market returns in oil-exporting countries than in oil-importing countries. However, in most of the countries included in the sample, there is no significant (non-linear) causal link between oil price changes and stock market returns. Use daily data to calculate variability between commodity prices. H. Gold and oil, and the BRICS stock market from September 29, 1997, to March 4, 2016.Non-fuel Commodities and Stock MarketUsing a vector automatic regression (VAR) model, (Sadorsky, 2014) pointed out the importance of oil prices for industrial production, (Basher and Sadorsky, 2016). (Barsky and Kilian, 2004) In her dissertation, she experimented with the volatility of Asian stock markets, crude oil futures prices, and the interaction between gold. They found that the stock market volatility shock was related to the oil and gold futures markets. (Arestis and Demetriades, 1997). A closer look at the relationship between stock markets, commodities and exchange rates found that the value of a country's stocks is likely to match the expectations of the commodity price index of some commodities exporters. (Cong et al., 2008) investing in commodity markets has been shown to increase commodity volatility between 2006 and 2010 by increasing changes in current commodity prices in the stock markets of South American countries. (Chen, Rogoff and Rossi, 2010) Return on equity was found to be affected by financial assets, commodities, and real estate assets using a common Markov transformation model. Their results, based on the wavelet method, show that BRICS stock returns are subject to long-term WTI crude oil prices. In addition, the authors found a strong copper movement at the start of GFC.

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Methodology

Objectives of Study

The main purpose of this study is to analyze the impact of the global market on selected Middle Eastern indexes. In addition, evaluating interrelationships and integration of TSE and TASI validates the dynamic links between these markets.

Data

To carry out the empirical studies required for this study, we obtained monthly data on fuel and non-fuel global commodity prices from the IMF Global Commodity Index. Also, in the case of the Tehran Stock Exchange (TSE) and the Saudi Stock Exchange (TASI), data on the stocks that specifically sell all stock indexes were obtained from the Stock Exchange Commission. Income data per, used as control variables for the two markets, was taken from the WDI database. All data were taken on a monthly basis, except for per capita income, which was converted to a monthly series using a quadratic polynomial.

Table 2. Stock Exchange Markets

Type	Markets	Nations
Bahrain	Bahrain Bourse	BHBX
Cyprus	Cyprus Stock Exchange	CSE
Egypt	Egyptian Exchange	EGX30
Iran	Tehran Stock Exchange	TSE
Iraq	Iraq Stock Exchange	ISX
Israel	Tel Aviv Stock Exchange	TASE
Jordan	Jordan Stock Market	ASE
Kuwait	Boursa Kuwait	BK Main 50
Lebanon	Beirut Stock Exchange	BLOM
Oman	Muscat Securities Market	MSM 30
Palestine	Palestine Exchange	PEX
Qatar	Qatar Stock Exchange	QE General
Saudi Arabia	Saudi Exchange	TADAWUL
Syria	Damascus Securities Exchange	DSE
Turkey	Borsa Istanbul	BIST
United Arab Emirates	Abu Dhabi Securities Exchange	ADX
Yemen	Yemen does not have a stock exchange	
Fuel Global Commodity		FGC
Non-fuel Global Commodity		NFGC

Table 3. The dataset contains a daily timeline of the Middle East stock market covering the period from January 1, 2008, to December 30, 2020. Iran has the highest standard deviation (3305.19), followed by Saudi Arabia (1063.962)., Israel, Turkey, Cyprus, Qatar, Lebanon, United Arab Emirates, Syria, Jordan, Palestine, Egypt, Kuwait, Iraq, Bahrain, Oman (0.019430). This shows that the Iranian and Saudi Arabian markets are

showing strong fluctuations from average yields. All 16 countries have a positive distribution of excess altos and a strong tail. H. They are Lepontic compared to normal. This means that the distribution of stock returns on these exchanges tends to be extreme. According to the Jacque Berra test, normality is rejected for all returned series tested. The Cypress, Qatar, and United Arab Emirates stock exchanges show the most extreme daily return values compared to other markets. This suggests that the volatility of these markets is much higher. Syria has the lowest median yield of 0.265474, followed by Iraq, Saudi Arabia, Turkey, Bahrain, Kuwait, Israel, Lebanon, Iran, Egypt, Jordan, Oman, Palestine, UAE, Qatar, and Cyprus. The ADF shows the results of a unit root test that examines the stationarity of all-time series, both at the level and at the first difference.

Table 3. Data Description

Country	Stock Exchange	Mean	S.D	Skew.	Kurt.	JB	ADF
Bahrain	BHBX	0.602693	0.075791	-0.470617	2.744717	0.515174	0.0992
Cyprus	CSE	1.33276	19.00584	2.020323	5.849137	10.18517	0.0000
Egypt	EGX30	0.679723	0.255206	0.752652	3.163126	0.859706	0.0994
Iran	TSE	5.97554	3305.19	0.306594	1.956141	0.793890	0.5635
Iraq	ISX	1.166269	0.092614	0.109372	2.029868	0.288460	0.3310
Israel	TASE	5.7569	199.4862	-0.350842	2.110958	0.694826	0.1498
Jordan	ASE	3.599566	0.656597	0.725395	2.419577	1.322577	0.1546
Kuwait	BK Main 50	0.57374	0.246836	0.63684	2.217849	0.67384	-4.420245
Lebanon	BLOM	1.84258	2.307510	0.482519	2.271359	0.792032	0.6795
Oman	MSM 30	0.154633	0.019430	0.932396	2.369583	1.614530	0.1687
Palestine	PEX	0.826794	0.425110	0.832287	2.011160	2.030498	0.6051
Qatar	QE General	3.169405	5.48365	1.767275	4.668692	8.275357	-3.175352
Saudi Arabia	TADAWUL	7.8074	1063.962	0.185772	2.359547	0.296956	0.0983
Syria	DSE	1.23675	0.861473	0.987537	1.23648	0.265474	-4.322528
Turkey	BIST	4.3956	95.13165	-0.155788	1.885774	0.501967	0.9344
United Arab Emirates	ADX	2.670874	2.095114	0.987316	2.722750	2.153688	0.2991
Fuel Global Commodity	FGC	4.8114	149.9855	0.377374	1.582690	1.396641	0.5695
Non-fuel Global Commodity	NFGC	1.7725	17.19260	0.239005	2.374957	0.335385	0.0219

Note: JB stands for the Jarque-Bera normality test; the ADF is the unit root test with a constant and trend.
a denotes the statistical significance at the 1% level.

Tanble 4. examines dynamic connectivity to show the spillover of volatility between the Middle East stock market and the global commodity market (fuel and non-fuel). Conversely the second-highest pairwise association is between MSM (Oman) and CSE (Cyprus) (94%). This indicates that pairwise connectivity measurements in the Middle East stock market are relatively high and that the spillover effect of volatility between

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them is high. The next largest pairwise associations are MSM (Oman) and EGX30 (Egypt) (94%), suggesting a spillover effect of volatility from the Middle East stock market. pairs. This shows that these stock markets in the Middle East are well connected. However, the results of pairwise relevance are very low in other Middle Eastern markets. Pairwise connectivity with other markets, including BHBX, NFC, and ISX, is also low. Our results show that the Middle East stock market can offer investors and portfolio managers the benefits of diversification.

Table.4. Descriptive Statistics

	ADX	ASE	BHBX	BIST	BLOM	CSE	EGX30	FC	ISX	MSM	NFC	PEX	TASE	TDW	QE	TSE	BK50	DSE
ADX	1	0.83	-0.29	0.86	0.33	0.37	0.48	0.14	0.46	0.23	-0.68	-0.78	0.95	-0.17	0.59	0.63	0.31	0.24
ASE	0.83	1	-0.17	0.59	0.35	0.04	0.18	-0.16	0.35	-0.04	-0.39	-0.68	0.73	-0.19	0.43	0.50	0.24	0.49
BHBX	-0.29	-0.17	1	-0.11	0.11	0.43	0.34	0.50	-0.84	0.57	0.27	-0.19	-0.39	0.76	0.35	0.31	-0.32	0.12
BIST	0.86	0.59	-0.11	1	0.43	0.66	0.78	0.46	0.18	0.60	-0.72	-0.82	0.90	0.13	0.77	0.78	0.37	0.11
BLOM	0.33	0.35	0.11	0.43	1	0.49	0.47	0.41	-0.33	0.32	0.24	-0.73	0.47	0.24	0.67	0.69	0.41	0.11
CSE	0.37	0.04	0.43	0.66	0.49	1	0.97	0.96	-0.48	0.94	-0.36	-0.71	0.43	0.69	0.89	0.85	0.01	-0.10
EGX30	0.48	0.18	0.34	0.78	0.47	0.97	1	0.90	-0.39	0.94	-0.51	-0.75	0.54	0.67	0.92	0.90	0.46	0.29
FC	0.14	-0.16	0.50	0.46	0.41	0.96	0.90	1	-0.63	0.92	-0.24	-0.54	0.21	0.81	0.80	0.75	-0.28	0.46
ISX	0.46	0.35	-0.84	0.18	-0.33	-0.48	-0.39	-0.63	1	-0.56	-0.41	0.12	0.44	-0.89	-0.40	-0.36	-0.18	-0.67
MSM	0.23	-0.04	0.57	0.60	0.32	0.94	0.94	0.92	-0.56	1	-0.38	-0.58	0.27	0.77	0.80	0.76	0.32	0.18
NFC	-0.68	-0.39	0.27	-0.72	0.24	-0.36	-0.51	-0.24	-0.41	-0.38	1	0.33	-0.63	-0.03	-0.38	-0.38	-0.19	0.38
PEX	-0.78	-0.68	-0.19	-0.82	-0.73	-0.71	-0.75	-0.54	0.12	-0.58	0.33	1	-0.79	-0.29	-0.90	-0.90	-0.13	0.21
TASE	0.95	0.73	-0.39	0.90	0.47	0.43	0.54	0.21	0.44	0.27	-0.63	-0.79	1	-0.18	0.62	0.65	0.12	0.23
TDW	-0.17	-0.19	0.76	0.13	0.24	0.69	0.67	0.81	-0.89	0.77	-0.03	-0.29	-0.18	1	0.63	0.59	0.48	0.01
QE	0.59	0.43	0.35	0.77	0.67	0.89	0.92	0.80	-0.40	0.80	-0.38	-0.90	0.62	0.63	1	0.99	0.76	0.60
TSE	0.63	0.50	0.31	0.78	0.69	0.85	0.90	0.75	-0.36	0.76	-0.38	-0.92	0.65	0.59	0.99	1	0.28	0.18
BK50	0.31	0.24	-0.32	0.37	0.41	0.01	0.46	-0.28	-0.18	0.32	-0.19	-0.13	0.12	0.48	0.76	0.28	1	0.60
DSE	0.24	0.49	0.12	0.11	0.11	-0.10	0.29	0.46	-0.67	0.18	0.38	0.01	0.23	0.21	0.23	0.01	0.60	1

Model Specification

To empirically estimate the relationship between Global Commodity Price and stock performances in TSE and TASI, we estimated the following models within the framework of ARDL using monthly data between 2008 and 2020.

$$\Delta \ln NINDEX_t = \lambda_0 + \sum_{j=1}^{n1} a_{j_i} NINDEX_{i,t-j} + \sum_{j=1}^{n2} b_{j_i} \Delta FUEL_{t-j} + \sum_{j=1}^{n3} c_{j_i} \Delta NFUEL_{t-j} + \sum_{j=1}^{n4} d_{j_i} \Delta PNGDP_{t-j} \quad (1)$$

$$\phi_1 NINDEX_{i,t-j} + \theta_1 FUEL_{t=1} + \theta_2 NFUEL_{t=1} + \theta_3 PGDP_{t=1} + \varepsilon_t$$

$$\Delta \ln JINDEX_t = \lambda_0 + \sum_{j=1}^{n1} g_{j_i} JINDEX_{i,t-j} + \sum_{j=1}^{n2} h_{j_i} \Delta FUEL_{t-j} + \sum_{j=1}^{n3} i_{j_i} \Delta NFUEL_{t-j} + \sum_{j=1}^{n4} j_{j_i} \Delta PGDP_{t-j} \quad (2)$$

$$\phi_1 JINDEX_{i,t-j} + \varphi_1 FUEL_{t=1} + \varphi_2 NFUE_{t=1} + \varphi_3 PGDP_{t=1} + \varepsilon_t$$

Each equation contains both short-term (first derivative) and long-term (single-period delay level) variables. For short-term coefficients, each delay length n is selected by minimizing the Akanke Information Criterion (AIC), and each model is estimated with the optimal delay. In Equation 1, TASI represents a return on equity and is a substitute for the performance of the Saudi Arabian Exchange (TADAWUL) stock market. It acts as the dependent variable of the model. FUEL and NFUEL also represent the model's independent variables, the global commodity price index for fuels and non-fuels. Similarly, PIGDP represents per capita income. It is introduced into the model as a control variable and also serves as one of the model's independent variables. Equation 2 repeats all variables in Equation 1 except TSE and PEGDP. Equation 1 focuses on the Tehran Exchange Market (TSE) variable and the Global Commodity Price Index, while Equation 2 focuses on the TSE variable and the Global Commodity Price Index. This means that the only difference is the introduction of TSE and PEGDP as dependent and control variables, respectively. TSE will introduce equity returns to replace the stock market performance of the Tehran Stock Market.

Empirical Result

Econometric Properties of Data

To base this research on solid econometrics, we conducted a study of the econometric properties of the data to determine its suitability for ARDL analysis. For this purpose, unit root and co-integration tests have been performed and the results are shown in Tables 5 and 6. The results of the Phillips-Peron (PP) unit root test are shown in Table 5 for both the level and the first difference. From the results, we can accept the hypothesis that there is a root of unity for all variables. However, all variables are resting at the first difference, indicating that the first-order I (1) is integrated. Based on the criticism offered by (Schwert, 1989) on traditional unit root tests Phillips-Peron (PP) inclusive, we performed a robustness check on these results obtained from Phillips-Peron (PP) unit root tests using one of the modified unit root tests. Specifically, Dickey-Fully GLS (ERS) proposed by (Bonel-Elliot, 1996) The results used are shown in Table 6. The results show that we can accept the hypothesis that there is a root of unity for all variables. All other variables are resting on the first difference, as obtained by the Phillips-Peron (PP) unit root test. This confirms the results obtained in the previous test.

Table 5. Phillips-Peron (PP) unit root test

Level				First Difference		
Variables	constant	Constant and Trend	None	Constant	Constant and Trend	none
TSE-Index	-0.079	-3.56	2.362	-1.2	-57.82	-2.3
TASI-Index	-0.001	-5.2	-0.406	-1.21	-48.39	-3.4
Fuel	-0.05	-3.9	0.05	-1.17	-21	-3.5
Non-Fuel	-0.052	-4	-5.2	-0.88	-25.90	-3.4
PEGDP	-1.012	-0.83	1.32	-7.38	-2.284	-1.45
PIGDP	-1.820	-0.72	1.01	-.6.28	-2.240	-1.12

Table 6. Dickey-Fully GLS (ERS)

Level			First Difference	
Variables	Constant	Constant and Trend	Constant	Constant and Trend
TSE-Index	1.12	-1.25	-1.72	-3.26
TASI-Index	0.64	-1.02	-1.35	-2.87
Fuel	-0.75	-0.54	-2.28	-2.95
Non-fuel	-0.34	-0.25	-2.10	-2.34
PEGDP	0.276	-1.28	-2.09	-3.87
PIGDP	0.14	-1.02	-1.98	-3.21

Bound tests Co-integration

Since the data on the plane are non-stationary, it is essential to perform a co-integration test to determine their long-term equilibrium behavior. For this purpose, we used the join co-integration test. The boundary test can be thought of as a test based on the combined F statistic using the null hypothesis that there is no co-integration. According to (Pesaran, 2001) two sets of critical values for a given significance level can be established in the bounds test. The first level is estimated assuming that all variables are integrated into the 0th-order ARDL model, and the second level is estimated assuming that the variables are integrated into the 1st-order ARDL model. The rule of digging is that the null hypothesis without co-integration is rejected if the value of the test statistic is greater than the upper critical limit and accepted if the F statistic is less than the lower limit. To get the most out of the ARDL model estimates, we investigated the optimal delay length for all estimated models. The optimal delay length was selected based on Akaike's Information Criterion (AIC). Based on these criteria, the optimal delay of 2 was selected for all models. Subsequently, co-integration tests were carried out using the bound test approach with the stock markets variables as dependent variables. The results are reported in table 7. Following the rule of the tomb, the hypotheses of no co-integration can be rejected in the two cases. This provides shreds of evidence to support the fact that there is long-run equilibrium between stock returns and global commodity prices in the two markets.

Table 7. Bound tests

Product	F-Statistics	lower critical value5%	Upper critical value 5%	Co-integrated
TSE-Index	1.76	-4.20	-2.72	Yes
TASI-Index	5.63	-4.12	-2.71	Yes

Granger Short Run and Long Run Causality Tests

In general, establishing a co-integration indicates that there is at least one long-term equilibrium relationship between the variables. Therefore, it is convenient to say that there is Granger causality between these variables in at least one way, but the direction of the causality is not indicated (Granger and Engle, 1987). Similarly, when two unsteady variables are co-integrated, it is argued that specifying a vector auto-regressive (VAR) with the first difference is equivalent to a specification error. It is consistent with the work

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of (Narayan and Smyth, 2006), We specify the following dynamic error correction representation for TSE and TASI.

$$\Delta \ln NINDEX_t = \theta_{1i} + \sum_p \theta_{11ip} \Delta \ln NINDEX_{it-p} + \sum_p \theta_{12ip} \Delta \ln FUEL_{it-p} + \sum_p \theta_{13ip} \Delta \ln NFUEL_{it-p} + \sum_p \theta_{14ip} \Delta \ln NGDP_{it-p} + \sum_p \theta_{15ip} \psi ECT_{t-1} \quad (3)$$

$$\Delta \ln FUEL_t = \theta_{1i} + \sum_p \theta_{11ip} \Delta \ln FUEL_{it-p} + \sum_p \theta_{12ip} \Delta \ln NINDEX_{it-p} + \sum_p \theta_{13ip} \Delta \ln NFUEL_{it-p} + \sum_p \theta_{14ip} \Delta \ln NGDP_{it-p} + \sum_p \theta_{15ip} \psi ECT_{t-1} \quad (4)$$

$$\Delta \ln NFUEL_t = \theta_{1i} + \sum_p \theta_{11ip} \Delta \ln NFUEL_{it-p} + \sum_p \theta_{12ip} \Delta \ln NINDEX_{it-p} + \sum_p \theta_{13ip} \Delta \ln FUEL_{it-p} + \sum_p \theta_{14ip} \Delta \ln NGDP_{it-p} + \sum_p \theta_{15ip} \psi ECT_{t-1} \quad (5)$$

$$\Delta \ln NGDP_t = \theta_{1i} + \sum_p \theta_{11ip} \Delta \ln NGDP_{it-p} + \sum_p \theta_{12ip} \Delta \ln NINDEX_{it-p} + \sum_p \theta_{13ip} \Delta \ln FUEL_{it-p} + \sum_p \theta_{14ip} \Delta \ln FUEL_{it-p} + \sum_p \theta_{15ip} \psi ECT_{t-1} \quad (6)$$

$$\Delta \ln JINDEX_t = \theta_{1i} + \sum_p \theta_{11ip} \Delta \ln JINDEX_{it-p} + \sum_p \theta_{12ip} \Delta \ln FUEL_{it-p} + \sum_p \theta_{13ip} \Delta \ln NFUEL_{it-p} + \sum_p \theta_{14ip} \Delta \ln SGDP_{it-p} + \sum_p \theta_{15ip} \psi ECT_{t-1} \quad (7)$$

$$\Delta \ln FUEL_t = \theta_{1i} + \sum_p \theta_{11ip} \Delta \ln FUEL_{it-p} + \sum_p \theta_{12ip} \Delta \ln JINDEX_{it-p} + \sum_p \theta_{13ip} \Delta \ln NFUEL_{it-p} + \sum_p \theta_{14ip} \Delta \ln SGDP_{it-p} + \sum_p \theta_{15ip} \psi ECT_{t-1} \quad (8)$$

$$\Delta \ln NFUEL_t = \theta_{1i} + \sum_p \theta_{11ip} \Delta \ln NFUEL_{it-p} + \sum_p \theta_{12ip} \Delta \ln JINDEX_{it-p} + \sum_p \theta_{13ip} \Delta \ln FUEL_{it-p} + \sum_p \theta_{14ip} \Delta \ln JGDP_{it-p} + \sum_p \theta_{15ip} \psi ECT_{t-1} \quad (9)$$

$$\Delta \ln SGDP_t = \theta_{1i} + \sum_p \theta_{11ip} \Delta \ln SGDP_{it-p} + \sum_p \theta_{12ip} \Delta \ln JINDEX_{it-p} + \sum_p \theta_{13ip} \Delta \ln FUEL_{it-p} + \sum_p \theta_{14ip} \Delta \ln FUEL_{it-p} + \sum_p \theta_{15ip} \psi ECT_{t-1} \quad (10)$$

All variables are as previously defined in the ARDL specification, where it represents the difference between the variables and p represents the delay length selected based on the Akaike's Information Criterion (AIC). In addition, the first derivative indicates the direction of short-term Granger causality, and the t-statistic of the error-correction term with a one-period delay indicates long-term Granger causality. The results of the TSE and TASI markets are shown in Tables 7 and 8. The results shown in Table 7 show that there is a long-term causal link between global fuel, non-fuel commodity prices, and per capita income to a significant level of stock market returns of 0.10 on the TSE. is showing. However, in the short term, only global non-fuel commodity prices have a strong causal link to TSE stock market returns. There is also evidence of weak causality, from per capita income to stock market returns. As expected, global fuel and non-fuel commodity prices show evidence of a two-way causal relationship at a significance level of 0.56 in the short term. Similarly, non-fuel stock market returns and global commodity prices show evidence of a two-way causal relationship at a significance level of 0.028. In addition, the results in Table 8 provide evidence of a causal link between TASI stock market returns and global commodity prices. The results show that there is a long-term causal link between global fuel and non-fuel commodity prices to TASI stock market returns at a significance level of 0.10. In the short term, there is a strong causal link between global fuel and non-fuel commodity prices to TASI stock market returns (0.95). It seems that the short-term relationship is stronger than the long-term one. Similarly, there is evidence of a causal relationship of feedback from stock market returns to global commodity prices. This means that in TASI there is a bidirectional causal link between stock market returns of 0.001 and 0.63 and global commodity prices (fuel and non-fuel).

Table 7. Granger causality for TSE

Source of causation	Δ lnTSE	Δ lnFuel	Δ lnNFuel	Δ lnEGDP	$ECT_{(t-1)}$
Δ lnTSE		0.053	0.028	2.12	-0.03
Δ lnFuel			0.56		-0.06
Δ lnNFuel	0.69	0.04			-0.03
Δ lnEGDP					

Table 8. Granger causality for TASI

Source of causation	Δ lnTASI	Δ lnFuel	Δ lnNFuel	Δ lnIGDP	$ECT_{(t-1)}$
Δ lnTASI		0.001	0.63		-0.03
Δ lnFuel	0.58		0.95		-0.06
Δ lnFuel	0.05	0.56			-0.03
Δ lnIGDP					

Effect of Global Commodity Prices on Stock Market Returns

The need to investigate the effect of the global commodity prices index (fuel and nonfuel) on stock market returns is principally to determine the degree of responsiveness of stock market returns to movement in the global commodity prices index. Also, it presents an opportunity to determine the relative importance of the global commodity prices index of fuel and global commodity prices of nonfuel on stock market returns. To this effect, Table 9 shows the results of the estimated ARDL model stated in equations one and two for TSE and TASI markets respectively. The results in Table 9 show that in the Saudi market, global commodity prices have a statistically significant effect on stock market returns at 5.4 and 0.12 significant levels in the short-run and long-run respectively. This implies that global commodity prices have a weak effect on stock market returns in the short run but the effect is much stronger in the long run. In the short term, unit fluctuations in the global fuel commodity price index will contribute 0.26 to stock market return performance, and similar fluctuations in the global non-fuel commodity price index will contribute 0.42 to TSE. Long-term contributions will increase to 0.46 and 0.61 in the Global Fuel and Non-Fuel Commodity Price Index, respectively. Contrary to expectations in this market, the global non-fuel commodity price index has a significant impact on NSE stock market returns, both short-term and long-term. The results in Table 9 show that in the TASI market: Global commodity prices have a statistically significant impact on short-term and long-term stock market returns at significance levels of 0.34 and 0.23, respectively. This means that global commodity prices have a weak impact on stock market returns in the short term, but much more in the long term. In the short term, a single move in the global fuel commodity price index will contribute 0.12% to stock market return performance, while a similar move in the global non-fuel commodity price index will contribute 0.35% to TASI. To do. Long-term contributions will increase to 0.09 and 0.23 in the Global Fuel and Non-Fuel Commodity Price Index, respectively. As expected in this market, the global non-fuel commodity price index will have a significant impact on TSE stock market returns, both short-term and long-term.

Table 9. Short–run and Long-run Co-efficient of ARDL Model

	dlnFuel	dlnNfuel	dlnEGDP	dlnIGDP	CointEq (-1)	lnFuel	lnNfuel	lnEGDP	lnIGDP
TSE-INDEX	0.26	0.42	0.54		-0.12	0.46	0.61	0.59	
TASI-INDEX	0.12	0.35		0.34	-0.23	0.09	0.23		0.46

Conclusion

Consequently, upon the thorough econometric investigation of the nexus between global commodity prices and stock market performances in the Middle East, the following conclusions can be inevitably arrived at. There is a long-run relationship between the global commodity prices index (fuel and nonfuel) and stock market returns in the Middle East. Also, the global commodity prices index (fuel and nonfuel) has both short-run and long-run effects on stock market returns in TSE and TASI. Thus, it is safe to conclude that the global commodity prices index affects stock market performance in the Middle East. The most important conclusion from this study is that there is a bidirectional causal relationship between global commodity prices and stock market returns in TSE and TASI. This conclusion confirms that the Middle East stock market is integrated into the global market and is part of the global interdependence and commodity market monetization process. Therefore, individual investors in the region need to take this established connection into account when making investment decisions, especially when it comes to portfolio diversification. Governments in the region can also use this relationship to design mechanisms to drive growth and mitigate the global impact.

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Original Research

Foreign Exchange Reserves and Import Demand in a Developing Economy: New Evidence from Nigeria

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Abstract

The attempt in this study has been to detect the influence of foreign exchange reserves on import demand in Nigeria. With data spanning from 2000 to 2020, we estimated the long-run and short-run import demand function using 'fully modified ordinary least squares' and 'error correction model' respectively after we established that our variables were integrated of the first order and that cointegration exists. The long-run import demand function pointed out that the effect of foreign exchange reserves on import demand is positive but insignificant but such effect turned negative and significant in the short-run. Import price was also noted to put forth a negative sway on import demand with its effect being significant. Income was observed to wield a positive long-run influence on import demand while the effect of exchange rate was positive and significant in the long-run but became negative and significant in the short-run. By the elasticity coefficients, income elasticity put forth a greater influence on import demand compared to every other variable with the coefficient being greater than unity. It therefore becomes pertinent for actions toward reducing the income coefficient to less than or equal to one to be instituted. It is critical that import demand management be regarded as an aspect of an inclusive stabilization strategy. Imports should be targeted as part of this effort to compensate for shortfalls in domestic production. Furthermore, strategies that reduce government spending or raise taxes (contractionary fiscal policy) could reduce income growth which is a chief driver of import demand.

Keywords: Exchange Rate, Trade Balance, J-Curve, Marshall-Learner Condition, Elasticity.

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Introduction

The decision to import is influenced by diverse economic factors which ranges from the domestic income, import prices, the available foreign reserves (or external reserves) to back the import demand, the exchange rate, and an array of other variables that defines the volume of import into an economy. Importation stems from the rising globalization and international interdependence among nations (Fatukasi & Awomuse, 2010). This rising interdependence is an outcome of adherence to the rules of the World Trade Organization's (WTO) coupled with reduced protectionism in international trade, which culminates to rising import in developing economies.

The pattern of international trade could have some implications on the domestic economy. Lessons from emerging economies like China and India showcases that with trade liberalization, the countries enjoyed the benefits associated with globalization (Englama, *et al*., 2013). However, the case of developing countries such as Nigeria is different. With globalization, industrialization would be accelerated in developing countries through the importation of capital and raw materials which could promote future exports to gain from trade.

The reasons why a nation imports products and services differ from one nation to the next: to address the needs of the populace for goods and services, to fill the production gap for things that can be produced locally but not in big quantities, and to offer raw materials for industrial use (Vacu & Odhiambo, 2020). Most notably, in accordance with the comparative advantage, nations frequently import products that cannot be produced effectively, while others are imported for financial reasons to increase tax income for government spending on development. However, excessive importation of goods and services through imported inflation has negative effects on macroeconomic stability. Additionally, it may lead to an unstable balance of payments and have an effect on a nation's credit rating. A drain on foreign exchange reserves and a worsening of the 'balance of payments' situation can also result from excessive importing. However, if import is investment-induced, growth is often anticipated to be boosted by import.

Imports are the source of raw resources that are unavailable locally, as well as the supply of capital goods and technology, which are essential for increasing the economy's productive capacity (Vacu & Odhiambo, 2020). Additionally, imports are a component of cross-border trade, which gives nations – particularly impoverished ones and those with limited production capacity – access to capital goods produced in wealthier nations, expanding prospects for people by raising their standard of living (Mutreja and Ravikumar, 2014; cited in (Vacu & Odhiambo, 2020). Still, there is a disparate viewpoint that contends that a nation's balance of payments is negatively impacted by excessive import demand. They support import substitution and fair trade because they think that free trade, particularly in developing nations, may be detrimental to economic progress (Chani *et al*., 2011; cited in (Vacu & Odhiambo, 2020).

The situation in Nigeria is a case of rising importation which is not balanced with rising exports, causing balance of payments anomalies. Imports in Nigeria rose from N985,022.39 million in 2000 to N10,186,684.82 million in 2010 before reaching N14,893,334.49 million and N21,905,499.46 million in 2018 and 2020 respectively. This lead to recent unfavourable balance of payments of N2,219,548.48 million naira in 2015; N895,232.74 million in 2016; N636,849.97 million in 2019; and N8,168,415.84 million in 2020 (Central Bank of Nigeria, 2020). Given this scenario, the need to determine the import demand function for Nigeria as a result of the rising import bills becomes pertinent in order to coin policies that will aid in addressing the balance of payments issues.

The import demand of a nation depends strategically on the level of external reserves which is a crucial policy variable for maintenance of exchange rate stability in an economy operating fixed or somewhat flexible exchange rates. Therefore, the formulation and assessment of present and future macro policies targeted at attaining the trade balance heavily relies on external reserves. External reserves have an impact on trade policies from a policy standpoint. Policies that are not much restraining are linked to strong external reserves. Foreign currency is sometimes a crucial necessity in international trade to fund imports of products and services. Hearsay evidence shows that external reserves operate as a global liquidity restriction in this respect, and any rise in reserves should likely pose a favourable effect on import demand (Arize & Malindretos, 2012).

Aside from exchange rate stability, foreign reserves are widely regarded as an indicator of an economy's vigour, predominantly its exporting industries. In global trade, foreign currency is frequently required to finance imports of commodities. In this sense, foreign reserves serve as an international liquidity constraint, and any increase in reserves should boost import demand (Arize & Osang, 2007). This position is one of the hypotheses that will be empirically tested using recent Nigerian data.

The foreign exchange reserves in Nigeria has been showcasing series of fluctuations which could also affect its adequacy in financing imports, and also points to the deteriorating foreign exchange earnings from exports. As at 2002, the foreign exchange reserves grew by 13.19% as it rose from US$7,590.77 million in 2000 to US$8,592.01 million in 2002; though this is far below the 35.39% recorded in 2001 where the foreign exchange reserves were valued at US$10,277.49 million. The rising trend in foreign exchange reserves was steadily maintained that the value was more than doubled as it rose from US$24,320.78 million in 2005 to US$58,472.88 million in 2008 representing a 140.43% growth. Subsequent years were marked with drastic decline in the foreign exchange reserves as it plunged to US$32,580.28 million in 2011 or 44.28% decline. Though an improvement was later recorded as at 2013 where it was valued at US$45,612.95 million or 40% increase, such was followed by declining trend to the tune of US$26,054.37 million in 2016. Within 2017 and 2019, foreign exchange reserves rose substantially to US$ 42,249.06 or 31.10% growth before it plummets by 15.29% to US$35,791.14 in 2020 (Central Bank of Nigeria, 2020).

The classic import demand theory is grounded on the consumer theory of demand, which holds that “the customer's goal is to maximize satisfaction” (Alam & Ahmed, 2010). This argument is expanded to include consumer demand for imports, showing that consumer demand for imports is impacted by income, import prices, and the prices of other goods (Englama, et al., 2013). The economy's total import demand is the sum of each individual consumer's desire for imports (Harrod & Hague, 1963). Along with the ‘imperfect substitution’ theory, which is in line with standard demand theory, the customer is predicated to maximize utility while under financial constraints. In other

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words, the price of the imported item, the price of locally produced goods, and the income of the importing country are all represented by the import demand function (Goldstein & Khan, 1985).

The amount of imports has typically been correlated with real domestic income and relative import prices according to empirical assessment of the import-demand function (see (Thursby & Thursby, 1984); (Arize & Afifi, 1987); (Gafar, 1995) (Masih & Masih, 2000); and (Chen, 2008)). In accordance with the literature, we thus incorporate a measure of domestic income as well as the relative cost of imports to our empirical model along with our foreign exchange reserve holdings. External reserves have been noted as an additional factor affecting 'import demand' in some studies (see (Arize, Malindretos, & Grivoyannis, 2004); (Arize & Osang, 2007); (Sultan, 2011); (Butts & Mitchell, 2012); (Englama, et al., 2013)). Therefore, leaving out exchange reserves might cause a model's empirical results to overstate the sway of the variables that are included, especially income and import prices (Arize & Malindretos, 2012). Our concern is therefore to examine the sway of income, import prices, foreign exchange reserves, and exchange rate as it affects import demand in Nigeria.

Review of Related Literature and Stylized Facts

Literature Review

The neoclassical comparative advantage theory (Heckscher-Ohlin), the Keynesian trade multiplier, and the new trade theory are some of the several models of international trade that are discussed in contemporary trade theories (imperfect competition theory). The Heckscher Ohlin (H-O) framework, a neoclassical 'comparative advantage' theory, was based on the writings of David Ricardo (Ricardo, 1817). The hypothesis is predicated on the idea that since nations differ in their endowments of production components, they have a propensity to import items with low factor endowments. Thus, changes in the relative pricing of these endowed elements have an impact on global commerce (Englama, *et al*., 2013). In other words, the idea contends that import demand is also influenced by how much more expensive a certain item is produced in the importing nation than in its trading partner. The impact of relative import prices on the volume and direction of international commerce are the comparative advantage's main concern ((Shuaibu & Fatai, 2014) cited in (Vacu & Odhiambo, 2020)).

The Keynesian trade multiplier hypothesis assumes employment to be a variable and that global capital flows would adapt as needed by the trade balance, while seeing import demand as a function of production and price (Englama, *et al*., 2013). The marginal income inclination to import should be one, according to the Keynesian paradigm, which focuses on the aggregate short-run link between income and import demand. The theory of 'comparative advantage' does not adequately explain intra-industry trade by taking into account market imperfections, hence the new trade theory (imperfect competition) concentrates on this area. "The implications of 'economies of scale', 'product differentiation', and 'imperfect competition' on global commerce are explained by the new trade theory" (Hong, 1999).

Empirical studies on the import demand function has been reported by different scholars in different regions. (Arize, Malindretos, & Grivoyannis, 2004) took the case of a developing economy to estimate the import demand for Pakistan with the aid of a cointegration technique. A linear connection was reported to bind import demand, foreign reserves, income, and exchange rate. The short-run estimates portrayed that while income, domestic prices, and foreign reserves put forth a positive weight on Pakistan's import demand, the import prices wielded a positive influence which is also significant.

(Arize & Osang, 2007) in estimating the import demand for countries in Latin America (Trinidad, Brazil, Costa Rica, Colombia, Ecuador, Venezuela, and Argentina) in the short-run and long-run put to use, the error correction model and fully modified OLS approaches. Findings of the study portrayed that for all the countries, a significant weight of real income, domestic prices, and foreign exchange reserves were reported in the long-run; where the influence of real income and foreign exchange reserves were positive, while that of relative prices was negative. In the short-run, foreign exchange reserves put forth a positive but insignificant weigh on import demand in all the countries; while the influence of income was positive though insignificant in some of the countries.

From 1960 to 2006, (Agbola, 2009) evaluated short-run cum long-run Philippines' import demand functions. As explanatory variables in the calculated model, private consumption, investment, government spending, export of goods and services, and import price index were included. The study used Johansen's co-integration technique to investigate this, and the outcomes showed a long-term cointegrating rapport concerning import demand and these variables.

Using a bounds testing technique, (Babatunde & Egwaikhide, 2010) examined the import demand function for Nigeria for 1980 through 2006. Aggregate imports, domestic income, and comparative prices were demonstrated to be cointegrated, and the predicted import demand long-run elasticities pertaining to domestic income and comparative prices were respectively 2.48 and -0.133. The findings indicated that, given Nigeria's import price elasticity being lower-than-unity, the 'Marshall-Lerner' requirements were not met.

(Fatukasi & Awomuse, 2010) attempted to explore the determinants of import demand from 1970 through 2008 for Nigeria. With the use of the error correction model, it was realized that core short-run determinant of import demand is the real GDP (income). The long-run result also pointed that income remains the core determinant of import demand as it put forth a positive sway on import demand, of which such effect was significant. For the short-run result, foreign exchange reserves put forth a negative effect while the influence of income remained positive, with the effect remaining significant in both cases.

(Zhou & Dube, 2011) calculated the import demand function for Brazil, China, India, and South Africa from 1970 to 2007 using the bounds test for co-integration technique and four distinct models. The findings exposed that, in the long term, import demand is extremely sensitive and elastic to vicissitudes in income for all four nations and specified models. Furthermore, a positive but inconsequential rapport concerning import demand and relative import price was discovered. This means that import demand in these nations is not very sensitive to vagaries in relative import prices. The findings on import demand

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contradicted traditional theory, which states that there is an inverse link concerning relative import prices and import demand.

Using data from the years 1970 to 2008, (Awomuse & Fatukasi, 2011) evaluated the factors inducing Nigeria's import demand functions. The investigation, which used an error correction model technique, showed that real income was the main short-term predictor of import demand in Nigeria. The considerable functioning of the error correction model further demonstrated the presence of a long-term link concerning the variables.

(Butts & Mitchell, 2012) differ from other studies by incorporating official development assistance and exports as- capacity to import ratio on the import demand function for Guyana within the framework of VAR. With income growth and growth in foreign reserves exerting a positive though insignificant influence, the exports as-capacity to import ratio and official development assistance wielded a positive and significant weight on import demand; while the effect of exchange rate was negative and insignificant.

(Fukumoto, 2012) calculated China's disaggregated 'import demand' functions for 'capital goods', 'intermediate goods', and 'final consumer products' from 1988 through 2005. The bounds test was put forth to estimate this, and the study identified 'import demand' for these groupings of commodities as a function of GDP, income after tax, total consumption, total investment, and total exports. The data revealed that GDP and total investment impact 'import demand' for capital goods, whereas exports influence 'import demand' for intermediate products and GDP influences 'import demand' for consumer items.

For (Arize & Malindretos, 2012), the need to study how foreign exchange reserve affects import demand was conduction for Asian countries of India, Japan, Korea, Singapore and Thailand. The cointegration, error correction mechanism, and fully modified OLS along with the Dynamic OLS was utilized basing the major analysis of the ARDL framework. The study reported an existence of cointegrating relationship concerning the variables, while it was also uncovered that for all the countries, real income and foreign exchange reserves wielded a positive weight on import demand while relative prices put forth a negative influence. In all cases, the variables wielded a significant weight on the demand for import in the Asian countries.

(Englama, *et al*., 2013) put to use the ARDL approach in the estimation of import demand for Nigeria by using data that covers 1970 through 2011. The outcome of the analysis revealed that the identified determinants (foreign reserves, domestic consumer prices, income and exchange rate) all wielded a significant weight on import demand. The short-run result pointed out that import demand in Nigeria is both income and price elastic, revealing the possibility of an upsurge in import if the income and domestic prices surges. While foreign reserves, income and domestic prices wielded a positive influence, exchange rate put forth a negative weight in the short-run, all of which were significant.

(Jiranyakul, 2013) used the bounds test to probe the sway of 'real exchange rate uncertainty' on Thailand's 'import demand' from 1997(July) to 2011(December). Real income and real exchange uncertainty were the 'independent variables' in the model. The findings demonstrated that income and 'exchange rate uncertainty' had an effect on 'import demand', with 'exchange rate uncertainty' posing a detrimental impact on Thailand's imports.

(Budha, 2014) investigated the impact of spending components on Nepal's Indian imports. The research also used the bounds test on yearly data from 1975 through 2011. As possible factors of 'import demand', the estimated model comprised private spending, government spending, investment spending, and export spending, plus relative import price and trade liberalisation policy. Private consumption was shown to be a primary predictor of Nepal's 'import demand' from India, whereas public spending had no significant sway. Surprisingly, investment and export spending were discovered to have a negative inspiration on Nepal's imports from India, although relative import price and trade liberalisation appear to be favourably associated to 'import demand'.

(Baek, 2015) used the bounds test to examine Korea's import demand behaviour from 1989(first quarter) to 2014(second quarter). The findings supported a long-run link concerning imports and income, plus relative import prices. Furthermore, income was discovered to be the most vital element for Korea's imports in both the short and long term, whilst prices only had a major short-run influence.

It is clear from the literature reviewed that recent studies have not been conducted to ascertain the import demand; and majority of the studies has been conducted in other countries, thus creating a paucity of empirical studies in the case of Nigeria. It is within this angle that this study tries to fill this gap by contributing to the existing body of knowledge using recent data.

Stylized Facts on Import Demand and Exchange Rate Utilization

Import Demand in Nigeria

The import demand is being segmented into the oil import and the non-oil imports (Table 1). The oil import volume of Nigeria has maintained a tremendous rising trend in the 21st century with an increase from N220,817.69 million in 2000 to N237,106.83 million in 2001 or 7.38%. A further increase of 10.29% between 2002 and 2003 where oil import demand rose from N361,710.00 million to N398,922.31 million in the respective two periods; but plummet by20.26 % between 2003 and 2004 as oil import demand declined from N398,922.31 to N318,114.72 for the two era respectively. A momentous improvement was recorded between 2004 and 2005 after the decline as oil import demand rose by 150.63% from N318,114.72 million to N797,298.94 million for the respective years. The rising trend kept rolling throughout 2006 to 2012 where oil import demand was valued at N3,049,352.59 million representing a 99.83% upsurge between 2010 and 2012. This was accompanied by a drastic decline to the tune of 78.22% as oil import demand declined to N1,711,002.84 as at 2015. Meanwhile, a substantial 45.37% increase was recorded thereafter as at 2017 before a substantial decline to 28.49% was recorded as at 2020 due to the Covid-19 pandemic.

Non-oil imports portray a substantial increase more than that of the oil component as it increased from N764,204.70 million in 2000 to N2,003,557.39 million in 2005. Such trend permeates through 2011 where non-oil import demand was valued at N7,159,084.19 million and grew by 22.82% before declining by 16.32% as its value declined to N5,990,406.37 million in 2012. Subsequent years were marked by rapid increase in non-oil imports up to N8,558,499.88 million in 2015 before declining to N6,640,556.92 million in 2016 or a 22.41% decrease. The periods 2017 through 2020 was marked with a significant upsurge in non-oil import demand up to the tune of N19,077,608.60 million in 2019 or % growth before a 0.83% decline to a tune of N18,920,076.09 million in 2020.

Table 1: Import Trade: Oil and Non-Oil (₦' Million)

Year	Oil Import	Non-Oil Import	Total Import	% of Total Trade	% of GDP
2000	220,817.69	764,204.70	985,022.39	33.61	11.64
2001	237,106.83	1,121,073.50	1,358,180.33	42.1	12.1
2002	361,710.00	1,150,985.33	1,512,695.33	46.45	10.59
2003	398,922.31	1,681,312.96	2,080,235.27	40.25	15.66
2004	318,114.72	1,668,930.55	1,987,045.27	30.15	18.28
2005	797,298.94	2,003,557.39	2,800,856.33	27.88	26.18
2006	710,683.00	2,397,836.32	3,108,519.32	29.79	25.63
2007	768,226.84	3,143,725.79	3,911,952.63	32.01	28.17
2008	1,319,460.97	3,929,095.19	5,248,556.16	32.71	34.64
2009	1,063,557.89	4,039,040.16	5,102,598.05	36.36	28.04
2010	1,748,062.20	5,828,831.34	7,576,893.54	37.74	36.76
2011	3,027,600.63	7,159,084.19	10,186,684.82	39.02	45.4
2012	3,049,352.59	5,990,406.37	9,039,758.96	36.48	41.35
2013	2,417,368.14	6,347,245.93	8,764,614.07	35.66	38.88
2014	2,213,233.95	7,540,618.93	9,753,852.88	41.65	34.87
2015	1,711,002.84	8,558,499.88	10,269,502.72	51.81	28.72
2016	2,384,694.07	6,640,556.92	9,025,250.99	48.89	27.18
2017	3,132,106.08	8,938,307.67	12,070,413.75	40.66	43.35
2018	4,368,200.30	10,525,134.19	14,893,334.49	39.1	54.58
2019	4,174,867.38	19,077,608.60	23,252,475.98	48.78	66.78
2020	2,985,423.37	18,920,076.09	21,905,499.46	61.46	50.91

Source: (Central Bank of Nigeria, 2020)

Total import demand exhibited similar behaviours that were put forth by the oil and non-oil components over the years. The import demand rose from N985,022.39 million in 2000 or 33.61% of total trade and 11.64% of GDP to 2,800,856.33 million or 27.88% of total trade and 26.18% of GDP as at 2005; with a further increase to N5,248,556.16 million or 32.71% of total trade and 34.64% of GDP in 2008. This rising trend continued till 2011 where the value of import was put at N10,186,684.82 million with a 34.45% year-on-year growth rate, and accounting for 39.02% of total trade and 45.4% of GDP,

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before it plummets to N9,025,250.99 million or -12.12% in 2016 with a 48.89% of total trade and 27.18% of GDP. Import demand in subsequent three consecutive years was marked by a momentous increase to a tune of N23,252,475.98 million and being 48.78% of total trade and 66.78% of GDP, before it reached a low turn-out as at 2020 where it was valued at N21,905,499.46 million (a 5.79% decline) and accounting for 61.46% of total trade and 50.91% of GDP in 2020.

With the rising import demand discussed above with some periods of declining import demand, the import value and import volume index has been moving in similar direction as portrayed in Figure 1.

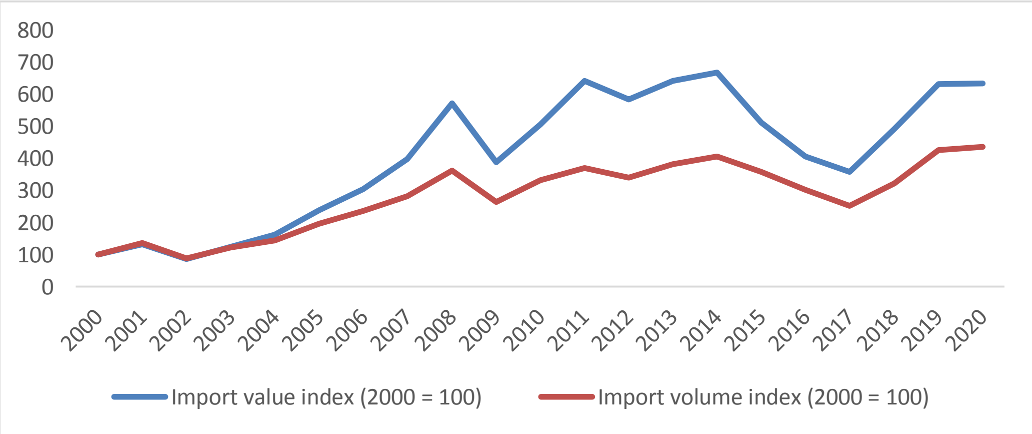

Figure 1: Import value and import volume index, 2000 to 2020.

With 2000 being the base year, the import value index rose from 132.85 in 2001237.97 in 2005; while the import volume index was 136.33 in 2001 before clicking 197.20 in 2005, thus showing the rising value and volume of import in Nigeria. This was followed by a continuous increase up to 572.74 for import value index and 362.86 for import volume index in 2008 before it dropped to 388.78 and 264.67 for the respective indices in 2009. An amplification in the import demand subsequently caused the import value and import price indices to surge further reaching 668.48 and 406.10 respectively as at 2014 before a declining was prevailing up to 358.58 and 253.54 respectively as at 2017. The two indices recovered substantially throughout the remaining periods as it reached 635.11 for import value index and 437.51 for import volume index as at.

Sectoral Utilization of Foreign Exchange in Nigeria

The utilization of foreign exchange in Nigeria is categorized into the import and invisible components (Central Bank of Nigeria, 2020). The import components include utilization in agricultural sector, industrial sector, finished goods, transport, personal effects, oil sector, and the mineral sector; while the invisible components include education services, business service, communication services, construction and related engineering services, distribution services, environmental services, financial services, health related and social services, recreational, cultural, and sporting services, transport services, and other services. Table 2 captures the sectorial utilization for 2000 to 2007 while Table 3 captures for 2008 to 2020.

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Table 2: Sectoral Utilization of Foreign Exchange for Transactions Valid for Foreign Exchange (US$' Million), 2000 – 2007

Year	Industrial Sector	Agricultural Sector	Finished Goods	Transport	Personal Effects	Total Visible Imports	% of Total	Invisibles	% of Total
2000	3,078.96	194.21	2,442.25	356.12	0.48	6,072.02	77.49	1,764.22	22.51
2001	4,388.22	185.00	2,818.15	533.29	0.02	7,924.67	69.81	3,426.81	30.19
2002	4,149.12	178.30	3,334.66	456.28	0.00	8,118.35	79.35	2,112.67	20.65
2003	4,836.84	106.80	3,920.17	876.30	0.45	9,740.56	80.46	2,364.87	19.54
2004	4,841.19	121.29	4,270.50	948.01	14.25	10,195.24	83.92	1,953.23	16.08
2005	6,928.11	116.24	4,218.40	1,503.96	2.20	12,768.90	85.90	2,096.23	14.10
2006	7,814.93	169.79	5,704.03	828.76	1.88	14,519.39	77.73	4,159.54	22.27
2007	9,454.97	209.37	7,720.97	1,288.80	0.13	18,674.24	68.99	8,394.01	31.01

Source: (Central Bank of Nigeria, 2020)

As indicated in Table 2, the industrial sector account for a huge proportion of foreign exchange utilization as it accounts for 50.71% of the total foreign exchange utilization for import as at 2000 and this is followed by the finished goods components with 40.22% in the same year. Both components seem to exhibit a rising trend in the utilization of foreign exchange up to 50.63% for industrial sector and 41.35% for the finished goods categories. The utilization of foreign exchange for the visible import component has showcased a declining trend as the percentage of foreign exchange utilization for total visible import declined from 77.49% in 2000 to 68.99% in 2007.

The invisible component seems to oscillate for some periods as it rose from 22.51% in 2000 to 30.19% in 2001 before declining sharply to 19.54% and 14.10% in 2003 and 2005 respectively; but a significant upsurge to 31.01% was recorded in 2007. The foreign exchange utilization for visible imports thus rose form US$6,072.02 million in 2000 to US$9,740.56 million in 2003 before reaching a substantial value of US$18,674.24 million in 2007. The utilization for the invisible components also tend rose form US$1,764.22 million in 2000 to US$3,426.81 in 2001 before declining substantially to US$1,953.23 million in 2004. Thereof, a substantial increase was recorded from US$2,096.23 million in 2005 to US$8,394.01 in 2007.

The rising trend in the foreign exchange utilization for imports still point to the fact that the industrial sector and food and manufactured products accounts for a greater chunk of the foreign exchange utilization with some inspirations from minerals/oil sectors in some periods. While the industrial sector accounts for 34.90% which is a decline from previous periods, the contribution of food and manufactured products accounted for 35.77% while the minerals/oil sectors accounted for 22.47% as at 2008. A common trend that can be observed is that the industrial sector utilization kept on declining from US$10,155.33 million in 2014 to US$6,972.14 million in 2017 before it plummets to US$5,224.90 million in 2020. This similar trend is observed in both the food and manufactured products as well as for the minerals/oil sectors. The reason behind this is the rising utilization of foreign exchange for the invisible components of imports.

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Table 3: Sectoral Utilization of Foreign Exchange for Transactions Valid for Foreign Exchange (US$' Million), 2008 – 2020

Year	Industrial Sector	Food and Manufactured Products	Transport Sector	Agricultural Sector	Minerals/Oil Sectors	Total Visible Imports	% of Total	Invisibles	% of Total
2008	10,552.51	10,784.92	1,672.06	364.04	6,775.28	30,148.79	62.39	18,176.66	37.61
2009	7,378.09	9,461.31	1,564.06	271.72	5,085.86	23,761.04	72.89	8,835.37	27.11
2010	6,174.06	9,662.24	1,471.88	314.23	6,202.56	23,824.98	71.39	9,545.88	28.61
2011	7,586.89	9,880.84	1,768.58	353.21	12,323.23	31,912.75	67.59	15,304.30	32.41
2012	7,576.75	10,152.67	1,818.97	241.84	8,989.47	28,779.71	68.4	13,294.99	31.6
2013	8,447.38	9,264.10	1,539.04	297.76	8,550.78	28,099.06	51.84	26,106.13	48.16
2014	10,155.33	10,465.18	1,988.44	513.63	11,079.41	34,201.99	51.83	31,788.39	48.17
2015	7,850.70	7,314.78	912.45	270.53	8,369.84	24,718.30	57.52	18,251.93	42.48
2016	5,876.39	4,588.45	530.38	254.45	5,904.50	17,154.17	68.5	7,888.63	31.5
2017	6,972.14	3,739.52	406.76	298.97	3,744.12	15,161.51	54.85	12,480.96	45.15
2018	7,383.44	5,626.88	472.59	296.32	2,102.34	15,881.57	38.4	25,479.94	61.6
2019	7,918.24	5,741.68	679.84	300.00	2,553.10	17,192.86	36.03	30,524.73	63.97
2020	5,224.90	4,468.84	512.98	188.14	1,475.58	11,870.44	42.61	15,991.16	57.39

Source: (Central Bank of Nigeria, 2020)

The percentage of foreign exchange utilization for imports declined continuously from 62.39% in 2008 to 51.84% in 2013 and then plummet to 38.40% in 2018 before recording mild improvement to 42.61% in 2020. The invisible component is gaining momentum as it declined from 37.61% in 2008 to 31.60% in 2012 before improvements to a tune of 48.17% was recorded in 2014. A decline to 31.50% was recorded in 2016 before a massive recovery was recorded to a tune of 63.97% in 2019 before it plummet to 57.39% in 2020. A unique trend that can be observed is that the utilization of foreign reserves for visible imports has declined significantly in recent times while the invisible components gained momentum.

The relationship between the movements in the external reserves and import demand is displayed in Figure 2. The foreign exchange reserve was put at US$7,590.77 million in 2000 but rose by 58.91% to US$12,062.75 million in 2004; while triple to US$37,355.70 million in 2010. Though it declined by 12.78% to US$32,580.28 million in 2011, subsequent periods were marked by a rising trend up to US$45,612.95 million in 2013. Between 2014 and 2016, the foreign exchange reserve decline massively up to US$26,054.37 million in 2017 before surging to US$44,525.07 million in 2018 which was followed by a declining trend to a tune of US$35,791.14 million in 2020.

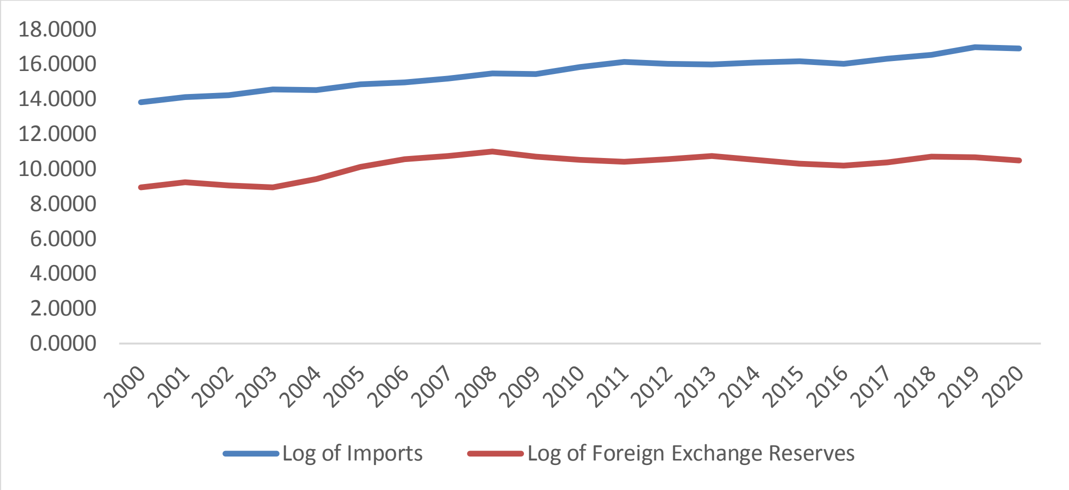

Figure 2: Trend of log of imports and log of foreign exchange reserves

With imports rising over the years, the foreign exchange reserves have also been on the rise though with some fluctuations being prevalent in some years. This calls for examining if indeed, such movements have a significant influence on the demand for imports in Nigeria.

Model Specification and Theoretical Backings

The Model

Our modelling of the relationship concerning import demand and exchange rate follows an adapted version of the model utilized by (Thursby & Thursby, 1984), (Khalid & Al-Yousef, 2002), (Arize, Malindretos, & Grivoyannis, 2004), (Arize & Osang, 2007), and (Englama, *et al.*, 2013). In specifying the import demand function, they considered key variables like aggregate output (income), relative prices, exchange rate, and foreign exchange reserves. In that angle and building on their works, the model for this study is specified thus;

$$impt_t^* = (rgdp_t, mcpi_t, fxrs_t, excr_t) \tag{1}$$

In which $impt_t^*$ is the natural log imports, *rgdp* is the natural log of real aggregate income, *mcpi* is the import commodity price index, *fxrs* is the natural log of foreign exchange reserves, and *excr* is naira-dollar exchange rate. It follows that Equation (1) can be fine-tuned to suit estimation as follows;

$$impt_t^* = \delta_0 + \delta_1 rgdp_t + \delta_2 mcpi_t + \delta_3 fxrs_t + \delta_4 excr_t + \varepsilon_t \tag{2}$$

Where is the ε_t error term and δ_i are the parameters to be estimated. Data on each of the variables were sorted out form the 2020 version of CBN statistical bulletin, and the data span from 2000 through 2020.

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Theoretical Backings of the Functional Form and Sign of the Parameters Estimate

The specification of the import demand function in a log-linear format is in line with best practices as enunciated in (Arize & Osang, 2007), which could otherwise be tested for using Box-Cox (B-C) procedure (Zarembka, 1974), Bera and McAleer (BM) procedure (McAleer, 1987), and MacKinnon, White and Davidson (MWD) procedure (Gujarati, 2002).

Further, the above model captures that the import demand function follows a long-run equilibrium state, pointing to a cointegrating association. The fundamental principle of cointegration is that if a linear combination of the model's variables is stationary, two or more non-stationary time series may be taken to define a long-run equilibrium relationship (converges to an equilibrium over time). “The ‘stochastic trends’ in real imports are therefore related to the ‘stochastic trends’ in aggregate income, foreign exchange reserves, import commodity price index, and exchange rate if the import demand function designates a stationary long-run bond among the variables in the equation” (Arize & Malindretos, 2012). The variable will eventually return to its (long-term) equilibrium level even if deviations from the equilibrium do occur because they are mean reverting, as the previous sentence explained.

The $\partial impt/\partial rdgp > 0$ in accordance with the theory of demand. For two reasons, it would be expected that *impt* would upsurge as *rgdp* escalates. First off, with an unchanged income distribution, more foreign goods will be bought if an upturn in real income causes an upsurge in real consumption. Second, if a proliferation in income also results in an intensification in real investment, then imported goods must be purchased for investment purposes (Arinze and Osang, 2007). Contrariwise, it is anticipated that $\partial impt/\partial mcpi < 0$ and $\partial impt/\partial excr < 0$ because, as import prices rise and domestic currency depreciates, consumers will turn to domestic goods instead. An upsurge in foreign exchange reserves is anticipated to have a favourable effect on the demand for imports because foreign reserves serve as a ceiling on the size of excess import demand hence, $\partial impt/\partial fxrs > 0$.

Technique of Analysis

Following the work of (Arize & Osang, 2007), this study utilized the ‘Fully Modified Ordinary Least Squares’ (FMOLS) to estimate the long-run estimates of the model to detect the direction of effect of the variables as predicted, and to detect whether they offer any significant weight on import demand. Apart from detecting the long-run influence, it is also pertinent to check if we could also obtain a similar result if the analysis is conducted in a short-run model. To this, the ‘error correction model’ (ECM) under the Representation theorem as put forth by Engel and Granger (Engle & Granger, 1987) becomes a potent vehicle. The model for the estimation is specified thus,

$$\Delta impt_t^* = \sum_{i=1}^{n} (\gamma_{1i}\Delta rgdp_{t-i} + \gamma_{2i}\Delta mcpi_{t-i} + \gamma_{3i}\Delta fxrs_{t-i} + \gamma_{4i}\Delta excr_{t-i}) + \sum_{i=1}^{m} \Delta impt_{t-i} + \emptyset + \theta ecm_{t-1} + \mu_t \quad (3)$$

Where ecm_{t-1} is the error correction term and the coefficient, θ, is the error correction coefficient which measures how import demand respond to per period deviation from equilibrium as reflected in Equation (1); with an assurance of a convergence conditional upon if $1 \geq \theta \geq -1$. The dependent and explanatory variables inclusive are expressed in first difference as revealed by the utilization of the difference symbol, Δ. The error-correction term (ecm_{t-1}) is present in equation (3) because it is assumed that actual imports do not instantly adapt to their long-run determining factors. So, the equation provides the short-run factors that affect import demand and captures both the short and long-term dynamics of the series. Any imbalances in the long-term import demand are adjusted for in the short run.

Empirical Result

Establishing the Cointegrating Rapport

In establishing the prevalence of long-run equilibrium association, it is pertinent to first test if stochastic trends exist in the 'autoregressive representation'. To this, the Augmented Dickey-Fuller (ADF) unit root test becomes the potent tool to deploy. Table 4 reflects on the result, where the 5% critical value is -3.6908. It is pertinent to note that the null hypothesis states that "the variables are non-stationary. To overrule the null hypothesis, the value of the test statistic should be less than the critical value at 5%.

Table 4: ADF Unit Root Test

Variables	Levels	First Difference	Order of Integration
IMPT	-2.3384	-5.1462	I(1)
RGDP	-2.812	-4.8471	I(1)
MCPI	-2.9893	-4.0896	I(1)
FXRS	-2.5949	-3.8523	I(1)
EXCR	-0.835	-4.2292	I(1)

Note: The 5% critical value of the ADF is given to be -3.6908.

At levels, all the variables are reported to have a test statistic greater than -3.6908 confirming the non-rejection of the null hypothesis of non-stationarity at levels. Meanwhile, the variables, though not stationary, are reported to be integrated of order one as the first differencing revealed that their test statistic are less than 3.6908 at 5% critical value.

With the establishment of the non-stationarity of the variables at level, it is pertinent to proceed into determining if there is a cointegrating relationship concerning them. This is conveniently done using the Johansen cointegration test as put forward by (Johansen, 1988) since our variables are all integrated of order one. Table 5 captures the test result where we compare the Trace statistic with the 5% critical value. For cointegration to exist, it is mandatory that the Trace statistic must be greater than the 5% critical value, and this will be captured by $p < .005$.

Table 5: Test for Cointegration among Import Demand, Income, Import Commodity Price Index, Foreign Exchange Reserves, and Exchange Rate

Hypothesized Number of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Probability
H_0: r = 0; H_1: r =1	0.97406	138.603	69.8189	0.0000**
H_0: r ≤ 1; H_1: r = 2	0.77093	69.2159	47.8561	0.0002**
H_0: r ≤ 2; H_1: r = 3	0.72273	41.2152	29.7971	0.0016**
H_0: r ≤3; H_1: r = 4	0.53822	16.8427	15.4947	0.0312**
H_0: r ≤ 4; H_1: r = 5	0.10755	2.16195	3.84147	0.1415

Note: The ** captures significance at 5% level

Table 5 gives us the cointegration test result where r captures the number of cointegrating vectors. It is observable from Table 5 that the Trace statistic is greater than the 5% critical value up to when r = 4. The implication of this is that the model has four cointegrating equations. This clearly validates that a long-run relationship exist among import demand, aggregate income, import commodity price index, foreign exchange reserves, and exchange rate.

Long-Run Dynamics

In the specified log-linear long-run model, it is pertinent to note that our estimated coefficients are simply long-run elasticities. The result of the long-run dynamics is therefore captured in Table 6 where the FMOLS is utilized to estimate the size and magnitude of the elasticities in influencing import demand.

Table 6: Phillips-Hansen Estimator (FMOLS) Long-Run Estimates

Variable	Coefficient	Standard Error	t-Statistic	Probability
RGDP	2.1489	0.26797	8.01906	0.0000***
MCPI	-0.0014	0.00042	-3.4308	0.0037***
FXRS	0.1237	0.0966	1.28052	0.2198
EXCR	0.0025	0.00068	3.70767	0.0021***
C	-9.1994	2.05694	-4.4724	0.0004***

Note: The *** captures significance at 1% level

It is clear from Table 6 that our result showcases that import demand rapport is positive for aggregate income (*rgdp*), foreign exchange reserves (*fxrs*), and exchange rate (*excr*) but negative for import commodity price index (*mcpi*). Also, the estimated coefficients are significant at 1%, except for exchange rate which wields an inconsequential effect. This insignificant effect from exchange rate is of reality since irrespective of the exchange rate if a country, the demand for import will still be positive. The insignificant effect of exchange rate on import demand conflicts with earlier findings reported by (Inyang & Effiong, 2021) where it was observed that the long-run effect of exchange rate on import demand is negative and significant. The findings offer a robust theoretical forecasts concerning the bearing of income, import prices and foreign exchange reserves on imports demand, as it pertains to Nigeria.

Taking the relative strength of the identified determinants into consideration, aggregate income seems to have a higher effect as indicated by the magnitude of the coefficient (2.1489) compared to the import price (-0.0014). The magnitude of the coefficient of foreign exchange reserves also outweighs that of import prices but not up to that of income. The implication here is that the economic importance of income and foreign exchange reserves far exceeds the importance of import price variation on import demand. This is a clear scenario where it can be adduced that with income and adequate foreign exchange reserves, the price of import will not pose a greater influence on import demand in Nigeria.

Linking our findings with earlier studies, the income elasticity coefficient of 2.24 so estimated for Venezuela as reported in (Arize & Osang, 2007) is consistent with the income elasticity of 2.15 reported in Table 6 in our study. With our positive income elasticity, our findings differ from that of (Sinha, 1997) where a negative income elasticity of -1.032 was being reported for Thailand. The magnitude of our income elasticity also outweighs those reported by (Arize & Osang, 2007) for Argentina (0.54), Brazil (0.52), Colombia (1.73), Costa Rica (1.33), Ecuador (0.63), and Trinidad (0.66); plus, that reported by (Arize & Malindretos, 2012) for India (1.45), Japan (0.74), Korea (1.20), Singapore (0.73), and Thailand (1.02); and 0.09 reported by (Butts & Mitchell, 2012) for Guyana.

The import price elasticity estimate of -0.0014 is in tandem with the negative coefficient reported by (Sinha, 1997), (Arize & Osang, 2007) and (Arize & Malindretos, 2012), but the difference is that the absolute value of our estimated elasticity coefficient is far less than theirs. Meanwhile, it elasticity coefficient is similar to the findings of (Inyang & Effiong, 2021) where they obtained an elasticity coefficient of -0.0020 for Nigeria. For foreign exchange reserves, the estimated coefficient of 0.1237 is also less than 0.3 in the study conducted by (Arize & Osang, 2007) where all the countries considered, except Colombia with 0.65, had the elasticity coefficient of foreign exchange reserves to be less than 0.3. A similar less than 0.3 coefficient was reported by (Arize & Malindretos, 2012) for India (0.09), Japan (0.19), Korea (0.05), Singapore (0.22), and Thailand (0.21). One similar thing here is that our study reported a positive effect which was also being reported by the above studies.

Short-Run Dynamics

Having established the long-run rapport amid import demand and the set of identified determinants, it is also pertinent to examine the possibility of such long-run rapport being noticeable in the short-run given the non-stationarity of the variables. In this, the short-run result is estimated and the result is presented in Table 7, where we utilized the ECM approach.

Table 7: Short-Run Dynamic Error Correction Model

Variable	Coefficient	Standard Error	t-Statistic	Probability
Δ(RGDP)	6.9300	1.105044	6.27125	0.0002**
Δ(RGDP(-1))	10.4904	1.177174	8.911507	0.0000**
Δ(MCPI)	0.1407	0.078322	1.795802	0.1103
Δ(FXRS)	-0.2643	0.111959	-2.360426	0.0399**
Δ(EXCR)	-0.0012	0.000735	-1.577767	0.1533
Δ(EXCR(-1))	-0.0047	0.001446	-3.226316	0.0121**
$ECM_{(t-1)}$	-0.7921	0.127923	-6.191854	0.0001**
R-squared	0.8662		Log likelihood	25.0118
Adjusted R-squared	0.8148		Durbin-Watson stat	2.0089

Note: The ** captures significance at 5% level

The short-run effect of income (current and lag) exercises a positive and significant sway on import demand in line with the long-run prediction. Import price index now wields a positive (though insignificant) short-run waves on import demand against the negative effect established in the long-run. The positive influence aligns with the findings of (Zhou & Dube, 2011), (Budha, 2014) and such arises from the lack of substitutes in imported commodities (Vacu & Odhiambo, 2020). Foreign exchange reserves now put forth a deleterious sway on import demand, where such effect is significant and this is against the positive long-run effect earlier established. The finding agrees with that of (Fatukasi & Awomuse, 2010) where they also reported a negative weight of foreign exchange reserve on import demand in Nigeria. The exchange rate now put forth the expected negative weight on import demand in the short run, where the effect is also significant. As it can be observed, the elasticity coefficient of income (both current and lag) is far greater than that of import price index, pointing to the fact that import demand respond faster to income changes compared to price changes. Also, import demand respond faster to price income changes that to changes in foreign exchange reserves and exchange rate.

Going to the $ECM_{(t-1)}$ it is clear that the coefficient is negative (as required) along with being statistically significant at 5%. With the coefficient being -0.7921, it means that suffice import exceeds its long-run rapport with income, import price index, foreign exchange reserves, and exchange rate, the adjustment will be in a downward manner at a rate of 79.21% on a yearly basis. Given this scenario, the findings imply that (i) that disregarding the cointegration of the variables would have resulted in a misspecification of the core dynamic structure; (ii) that market forces exist in the imports market sector that function to re-establish long-run equilibrium after a short-run deviation; (iii) that it takes less than a year to correct 70% of the deviations from long-run equilibrium; and (iv) that the full adjustment of real imports to changes in the independent variables may take about one year and seven months. Our estimated R-squared points to the fact that our short-run model is capable to explain 86.62% of the overall short-run changes import demand, and the model is stable since our Durbin-Watson statistic is 2 pointing the total non-existence of serial correlation in the model.

Our estimated income elasticity coefficient of 6.93 and 10.49 for current and lag income changes respectively for the case of Nigeria is far greater than that obtained in the findings of (Arize & Osang, 2007) where it was reported for Argentina (0.209), Colombia (2.615), Brazil (0.820), Costa Rica (0.370), Ecuador (0.757), Trinidad (1.149), and Venezuela (1.149). The higher income elasticity coefficient also exceed those estimated by (Arize & Malindretos, 2012) for India (0.346 to 0.401 including the lags), Japan (0.126), Korea (0.254 to 0.482 including lags effect), Singapore (-0.243 to 0.895 lag inclusive), and Thailand (-0.623 to 0.775); and the 0.88 obtained by (Englama, *et al.*, 2013) for Nigeria. With our study reporting a positive influence of foreign exchange reserves on import demand, our findings conflict with that of (Arize & Osang, 2007), (Arize & Malindretos, 2012), and (Englama, *et al*., 2013) where they reported a short-run positive influence for all the countries they examined.

Conclusion and Recommendation

The aim of the paper has been to ascertain the potency of income, import prices, foreign exchange reserves, and exchange rate in influencing import demand in Nigeria. Such an analysis is conducted for both the short-run and long-run situations using data that captures 2000 through 2020. By first ascertaining the stationarity properties of the series using the ADF technique and uncovering that the series are non-stationary at level, we test for cointegration where the series were reported to have an element of cointegrating bond. With that the FMOLS was utilized to estimate the long-run effect while the error correction model (ECM) served as a tool for analysis in the short-run. The introduction of foreign exchange reserves is the core point of concern in the import demand function. In theory, an increase in foreign reserves may have a positive effect on import demand because it relaxes the excess demand liquidity constraint (Arize & Osang, 2007).

Going by the analysis, our result revealed certain strands of result:

(i) With the reported non-stationarity of the variables, the need to treat such becomes pertinent to drive at a tangible result. The need for the cointegration analysis pointed out that imports, income, import prices, foreign exchange reserves, and exchange rates are cointegrated; implying that they exhibit some level of long-run rapport. Foreign exchange reserve is a potent variable that influences import demand in the short-run and in the long-run. Meanwhile, the recorded short-run influence is negative and consequential while that of the long-run is positive and but insignificant. With the statistical impact of foreign exchange reserves being significant, the economic consequence on the contrary is weak as given by the elasticity coefficient when compared to the income elasticity coefficient.

(ii) That income and import prices play a crucial role in influencing import demand, with income wielding a positive and substantial sway while import prices put forth a negative and substantial influence. Income is also noted to wield a greater economic influence on import demand than import prices given their elasticity coefficient. With the elasticity coefficient for income being greater than one, import demand is thus income elastic, pointing to the fact that import demand increase in a significant manner as income increases. This implies that increases in real income are likely to exacerbate Nigeria' trade deficits. To the extent that governments are apprehensive about the trade balance, they may be forced to reduce income growth (for example, by contractionary fiscal measures). Furthermore, because the timing of import responses to income changes, strong domestic growth in these countries will stimulate the export activities of their corresponding trading allies.

(iii) For import prices, the long-run elasticity is far away from unity pointing out that import demand is price inelastic. This has implications on the efficacy of monetary and fiscal policy actions in curtailing excessive demand for import if there is a rise in income. This also points out that an expansionary policy accompanied with a depreciating exchange rate policy will not yield the desired result rather, a contractionary policy stance will work out. In short, petite price elasticity does not tend to mitigate negative J-curve effects on the Nigeria's balance of payments position. The petite price elasticity demonstrates that the Nigeria has made little progress in manufacturing that can substitute for imports.

(iv) Exchange rate has a significant statistical short-run influence on import demand in the short-run though the long-run influence was positive and significant as well. It is clear from the elasticity coefficient that both the short-run and long-run estimates were far below unity, pointing to the exchange rate inelasticity for import demand in Nigeria. Thus, it is clear from this that policies that is geared towards exchange rate depreciation (as earlier pointed out in the case of import price index) will not influence the level of import demand in Nigeria.

With the foregoing observations, policies aimed at snowballing foreign exchange reserves should be followed, as they have the potential to impact import behaviour. Policies aimed at growing foreign exchange reserves, for example, should be followed because they are probable to stimulate import behaviour. Policies, for example, would have to be geared toward export promotion. As identified by (Esfahani, 1991) cited in (Arize & Malindretos, 2012), exports are likely to increase reserves, allowing for greater access to international markets. Given the availability of reserves, trade policy should discourage efforts to borrow.

Action is also required in Nigeria to reduce the income coefficient to less than or equal to one. It is critical that import demand management be regarded as an aspect of an inclusive stabilization strategy. Imports should be targeted as part of this effort to compensate for shortfalls in domestic production or to change its quality and structure. Furthermore, strategies that reduce government spending or raise taxes (contractionary fiscal policy) could reduce income growth.

Lastly, the importance of import prices and exchange rates in our long-run import demand function has a significant impact on the efficacy of exchange rate policy or commercial policy aimed at correcting trade imbalances and encouraging growth of export. The diminution in import volume will more than compensate for the upsurge in import prices. If the demand price elasticity for exports is significant, the 'Marshall-Lerner' condition is very likely to be met.

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