FORECASTING DIESEL CONSUMPTION IN SRI LANKA USING MULTIVARIATE TIME SERIES MODELS

Thusitha Tharindu Weerawardhana

(168849E)

Master of Science in Business Statistics

Department of Mathematics

University of Moratuwa
Sri Lanka

July 2020

FORECASTING DIESEL CONSUMPTION IN SRI LANKA USING MULTIVARIATE TIME SERIES MODELS

Thusitha Tharindu Weerawardhana

(168849E)

Dissertation submitted in partial fulfillment of the requirements for the
Master of Science in Business Statistics

Department of Mathematics

University of Moratuwa
Sri Lanka

July 2020

DECLARATION OF THE CANDIDATE

"I declare that this is my own work and this thesis/dissertation2 does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis/dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books)."

……. ……..

Signature of Candidate Date

(T. T. Weerawardhana)

The above candidate has carried out research for the Masters dissertation under my supervision.

Senior Prof. T. S. G. Peiris
Senior Professor in Applied Statistics,
Department of Mathematics
Faculty of Engineering
University of Moratuwa

ABSTRACT

In the modern trends of industrialization and development, energy has become one of the most important aspects of every economy in the world. Among the energy sources that are available today, diesel has a considerable consumption for various activities such as production of goods and transportation in many countries including Sri Lanka. Using monthly data of ten explanatory variables (January 1998 to July 2018) vector error correction model of order 2: VECM (2) was developed to model monthly consumption of diesel in Sri Lanka. The diesel consumption has been increasing due to various activities. The most significant influential variables are Exchange rates of USD to LKR, Merchandize Imports, Number of Tourists Arrivals, National Consumer Price Index, and Electricity Power Generated. The errors of the model were found to be white noise. The percentage errors of the fitted data using the VECM (2) model for both trained and validated set vary from -8.4 to +8.5%. Further it was found that Exchange rates of USD to LKR, Merchandize Imports, and Number of Tourists Arrivals show significant long run positive association with diesel consumption while National Consumer Price Index and Electricity Power Generated indicate significant long run negative relationship with diesel consumption in Sri Lanka. This model is suitable only short term prediction and it is recommended to develop the model so that it can be used for long run prediction. Nevertheless, the model provides the analyst with the ability to make decisions using various predicted intervals with different membership values by controlling the explanatory variables.

Keywords: Vector Error Correction Model, Multivariate Time Series, Correlation, Consumption of Diesel,

ACKNOWLEDGEMENT

The author wishes to extend his sincere gratitude to the following people, for their generous support guidance, views and comments, which paved the way to the successful completion of this project:

Senior Prof. T.S.G. Peiris, Senior Professor in Applied Statistics and former Head of Department of Mathematics, Faculty of Engineering, University of Moratuwa and the Course Coordinator of M. Sc. / Post Graduate Diploma in Business Statistics, for being a visionary throughout the lifetime of this research project. His valuable insights and continuous comments helped me to complete this project successfully.

To the academic and non-academic staff at the Department of Mathematics for the all wishes and good will.

To my family and loved ones whom have offered their fullest support and strength of mind throughout my academic life.

TABLE OF CONTENTS

ABSTRACT i

ACKNOWLEDGEMENT i

LIST OF FIGURES x

LIST OF TABLES v

LIST OF ABBREVIATIONS viii

CHAPTER 1 1

INTORDUCTION 1

1.1 Background 1

1.2 World Energy Consumption 2

1.3 Energy Consumption in Sri Lanka 3

1.4 Problems in Fossil Fuel 4

1.5 Present Situation in Sri Lanka 5

1.6 Importance of Forecasting 5

1.7 Objectives of the Study 7

1.8 Outline of the Dissertation 7

CHAPTER 2 9

LITERATURE REVIEW 9

2.1 Introduction 9

2.2 Use of VEC Model 9

2.3 Use of ARIMA Models 10

2.4 Use of Other Models 11

2.5 Summary of Chapter 2 12

CHAPTER 3 13

MATERIAL AND METHODS 13
3.1 Secondary Data 13
3.2 Description of Ten Explanatory Variables 14
3.2.1 Consumption of Diesel (DC) 14
3.2.2 National Consumer Price Index (NCPI) 14
3.2.3 Wage Rate of the Employees (WR) 14
3.2.4 Distance Operated in Public Road Transport (PT) 15
3.2.5 Distance Operated in Rail Transport (RT) 15
3.2.6 Number of Vehicle Registered (VR) 15
3.2.7 Merchandise Imports (MI) 15
3.2.8 Merchandise Exports (ME) 15
3.2.9 Total Tourist Arrivals (TA) 15
3.2.10 Monthly Average Exchange Rate (EX) 15
3.2.11 Electricity Power Generation (EP) 16
3.3 Abbreviations of the Variables 16
3.4 Time Series 16
3.4.1 Stationary Time Series 17
3.4.2 Strictly Stationary Time Series 17
3.4.3 Weekly Stationary Time Series 17
3.4.4 Augmented Dickey-Fuller test 17
3.4.5 Autocorrelation 18
3.4.6 Autocorrelation Function (ACF) 18
3.4.7 Partial Autocorrelation Functions (PACF) 18
3.4.8 Use of ACF and PACF 19
3.4.9 Ljung-Box Portmanteau test (Q-Statistic) 19

3.5 Vector Auto Regressive Model (VAR) 20
3.5.1 Johansen cointegration test 21
3.5.2 Phillips–Perron test 22
3.5.3 Test for Normality 22
3.6 Vector Error Correction Model (VECM) 23
3.6.1 The Optimum Lag Length 24
CHAPTER 4 25
TEMPORAL VARIABILITY OF TIME SERIES 25
4.1 Temporal Variability of the Monthly Consumption of Diesel (DC) 25
4.1.1 Monthly Consumption of Diesel in Sri Lanka 25
4.1.2 Distribution of Monthly Consumption of Diesel 26
4.2 The Total Annual Diesel Consumption in Sri Lanka 27
4.3 Temporal Variability of the 10 Explanatory Variables 28
4.3.1 Temporal Variability of NCPI 28
4.3.2 Temporal Variability of EP 29
4.3.3 Temporal Variability of EX 31
4.3.4 Temporal Variability of ME 32
4.3.5 Temporal Variability of MI 34
4.3.6 Temporal Variability of PT 35
4.3.7 Temporal Variability of RT 37
4.3.8 Temporal Variability of TA 39
4.3.9 Temporal Variability of Monthly VR 40
4.3.10 Temporal Variability of WR 42
4.4 Stabilize the Variations of the Observed Time Series 43
4.5 Distribution of Each Log Time Series 46

4.6 Correlation between the Observed Series 50
4.7 Summary of Chapter 4 51
CHAPTER 5 53
DEVELOPMENT OF VECTOR ERROR CORRECTION MODEL USING ALL EXPLANATORY VARIABLES 53
5.1 Stationary of the Original Log Series 53
5.2 Stationary of the First Difference Series 57
5.3 Existence of Cointegration 61
5.4 Optimal Lag Length 64
5.5 VEC Model 65
5.6 Diagnostics Tests for Residuals of the VECM(5) Model 69
5.6.1 Randomness 69
5.6.2 ARCH Effect 70
5.6.3 Normality 71
5.6.4 Serial Correlation 72
5.6.5 Heteroskedasticity 73
5.6.6 Errors of the Fitted Model 73
5.7 VECM(5) Model 74
5.8 Validation of the VEC Model 75
5.9 Summary of Chapter 5 76
CHAPTER 6 77
ALTERNATIVE VECTOR ERROR CORRECTION MODEL: SCREENING VARAIBLES 77
6.1 Selecting Variables for the VEC Model 77
6.2 Stationary of Each Time Series 77

6.3 Existence of Cointegration 78
6.4 Optimal Lag Length 80
6.5 VEC Model 81
6.6 Diagnostics Tests for Residuals of the VECM(2) Model 84
6.6.1 Randomness 84
6.6.2 ARCH Effect 85
6.6.3 Normality 86
6.6.4 Serial Correlation 86
6.6.5 Heteroskedasticity 87
6.6.6 Errors of the Fitted Model 87
6.7 VECM(2) Model 88
6.8 Validation of the VEC Model 89
6.9 Summary of Chapter 6 89
CHAPTER 7 91
COMPARISON OF VECM(5) AND VECM(2) 91
7.1 Similarities of the Two Models 91
7.2 Model Comparison 91
7.3 Discussion 92
7.4 Summary of Chapter 7 93
CHAPTER 8 94
CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS 94
8.1 Conclusion 94
8.2 Recommendation 95
8.3 Suggestions 95
REFERENCE 96

LIST OF FIGURES

Figure 1. 1 The Distribution of Energy Consumption in the World.....2

Figure 1. 2 Energy Consumption in Sri Lanka.....3

Figure 1. 3 Comparison of Consumption of Petroleum Products.....4

Figure 4.1 Temporal Variability of the Monthly Diesel Consumption in Sri Lanka 25

Figure 4.2 Distribution of Diesel Consumption.....26

Figure 4.3 Temporal Variability of monthly NCPI.....28

Figure 4.4 Temporal Variability of EP.....30

Figure 4.5 Temporal Variability of EX.....31

Figure 4.6 Temporal Variability of ME.....33

Figure 4.7 Temporal Variability of MI.....34

Figure 4.8 Temporal Variability of PT.....36

Figure 4.9 Temporal Variability of RT.....38

Figure 4.10 Temporal Variability of TA.....39

Figure 4.11 Temporal Variability of VR.....41

Figure 4.12 Temporal Variability of WR.....42

Figure 4. 13 Time Plot of LNDC.....44

Figure 4. 14 Time Plots of 10 Explanatory Variables (After Log Transformation)...45

Figure 4. 15 Distribution of LNDC.....46

Figure 4. 16 Distribution of LNNCPI.....46

Figure 4. 17 Distribution of LNEP.....47

Figure 4. 18 Distribution of LNEX.....47

Figure 4. 19 Distribution of LNME.....47

Figure 4. 20 Distribution of LNMI 48
Figure 4. 21 Distribution of LNPT 48
Figure 4. 22 Distribution of LNRT 48
Figure 4. 23 Distribution of LNTA 49
Figure 4. 24 Distribution of LNVR 49
Figure 4. 25 Distribution of LNWR 49
Figure 5. 1 Correlogram of the Residual with (Q Statistic) of VEC Model……...70
Figure 5. 2 Correlogram of Squared Residuals in VEC model 71
Figure 5. 3 Normality Test for the Residuals 72
Figure 5. 4 Error of VECM(5) model 73
Figure 6. 1 Correlogram of the Residual with (Q Statistic) of VECM (2) Model…..84
Figure 6. 2 Correlogram of Squared Residuals in VEC model 85
Figure 6. 3 Normality Test for the Residuals 86
Figure 6. 4 Error of VECM(2) model 88

LIST OF TABLES

Table 3. 1 Breakdown of the Data Collected 14

Table 3. 2 Abbreviations of the Variables..... 16

Table 4.1 Annual Total Diesel Consumption (DC)..... 27

Table 4. 2 Basic Statistics of NCPI..... 29

Table 4. 3 Basic Statistics of EP..... 30

Table 4. 4 Basic Statistics of EX 32

Table 4. 5 Basic Statistics of ME..... 33

Table 4. 6 Basic Statistics of MI..... 35

Table 4. 7 Basic Statistics of PT..... 37

Table 4. 8 Basic Statistics of RT 38

Table 4. 9 Basic Statistics of TA 40

Table 4. 10 Basic Statistics of VR 41

Table 4. 11 Basic Statistics of WR 43

Table 4. 12 Correlations the Log-Transformed Time Series..... 50

Table 4. 13 The p-values of the Corresponding Correlations in Table 4.12 51

Table 5. 1 Test for Stationarity of LNDC (Level)..... 53

Table 5. 2 Test for Stationarity of LNEP (Level)..... 54

Table 5. 3 Test for Stationarity of LNEX (Level) 54

Table 5. 4 Test for Stationarity of LNME (Level)..... 54

Table 5. 5 Test for Stationarity of LNMI (Level)..... 55

Table 5. 6 Test for Stationarity of LNCPI (Level) 55

Table 5. 7 Test for Stationarity of LNPT (Level)..... 55

Table 5. 8 Test for Stationarity of LNRT (Level) 56

Table 5. 9 Test for Stationarity of LNTA (Level) 56
Table 5. 10 Test for Stationarity of LNVR (Level) 56
Table 5. 11 Test for Stationarity of LNWR (Level) 57
Table 5. 12 Test for Stationarity of LNDC (First Difference) 57
Table 5. 13 Test for Stationarity of LNEP (First Difference) 58
Table 5. 14 Test for Stationarity of LNEX (First Difference)..... 58
Table 5. 15 Test for Stationarity of LNME (First Difference) 58
Table 5. 16 Test for Stationarity of LNMI (First Difference) 59
Table 5. 17 Test for Stationarity of LNCPI (First Difference)..... 59
Table 5. 18 Test for Stationarity of LNPT (First Difference) 59
Table 5. 19Test for Stationarity of LNRT (First Difference)..... 60
Table 5. 20 Test for Stationarity of LNTA (First Difference)..... 60
Table 5. 21 Test for Stationarity of LNVR (First Difference) 60
Table 5. 22 Test for Stationarity of LNWR (First Difference)..... 61
Table 5. 23 Unrestricted Cointegration Rank Test (Maximum Eigen value) 62
Table 5. 24 Unrestricted Cointegration Rank Test (Trace)..... 63
Table 5. 25 VAR Lag Order Selection Criteria 64
Table 5. 26 Vector Error Correction Model Estimates 65
Table 5. 27 Description of the Coefficients of the above VECM(5) Model..... 68
Table 5. 28 Test for Serial Correlation 72
Table 5. 29 Test for Heteroskedasticity 73
Table 5. 30 Validation of the VECM(5) Model 75
Table 6. 1 Unrestricted Cointegration Rank Test (Maximum Eigen value)……...78
Table 6. 2 Unrestricted Cointegration Rank Test (Trace)..... 79
Table 6. 3 VAR Lag Order Selection Criteria..... 80

Table 6. 4 Vector Error Correction Model VECM (2) Estimates 81

Table 6. 5 Description of the Coefficients of the model VECM (2) 83

Table 6. 6 Test for Serial Correlation 86

Table 6. 7 Test for Heteroskedasticity 87

Table 6. 8 Validation of the VECM (2) Model 89

Table 7. 1 Comparison of the Models 91

LIST OF ABBREVIATIONS

Abbreviation	Description
AR	Autoregressive Model
ARCH	Autoregressive Conditional Heteroskedasticity
ARMA	Autoregressive–moving-average Model
ARIMA	Autoregressive–Integrated Moving-Average Model
IID	Independent and Identically Distributed
OLS	Ordinary Least Square
MT	Metric Ton
VAR	Vector Autoregressive Model
VECM	Vector Error Correction Model