



UNIVERSITY *of the*
WESTERN CAPE

FACULTY OF ECONOMIC AND MANAGEMENT SCIENCES
DEPARTMENT OF ECONOMICS

Exchange Rate Pass-Through to Domestic Prices in South Africa

Francis Chiparawasha
(3076379)

A mini-thesis submitted in partial fulfilment of the requirements for the degree of Master of Commerce (Economics) in the Department of Economics, University of the Western Cape.

Supervisor: Mr. Dawie van Lill

7 October 2015

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

ABSTRACT

This mini-thesis examines the speed and magnitude of exchange rate pass-through to domestic prices in South Africa. The shift from fixed exchange rate regimes to a system of floating exchange rates by many countries after the collapse of the Bretton Woods system increased the role of the exchange rate in the determination of inflation. In theory, exchange rate depreciation causes inflation via a process called exchange rate pass-through (ERPT). The effect of exchange rate variations on inflation is of special interest to policy makers especially for countries under inflation targeting regimes. The knowledge of the speed and magnitude of ERPT to domestic inflation (import, producer and consumer inflation) is important in the designing of an optimal monetary policy mix which is needed to ensure price stability.

South Africa is one of the countries that moved to an inflation targeting regime under a system of a floating exchange rate. This study therefore aims to empirically determine the speed and magnitude of ERPT to domestic prices in the short run and long run using VAR and VEC models.

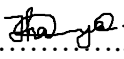
The empirical results show that ERPT to import prices is immediate and moderately high reaching a peak of about 45% and 47% within three quarters for the VAR and VEC models respectively. In contrast, ERPT to producer and consumer prices is gradual and low. For instance, long-run ERPT is below 30% for producer prices and around 20% for consumer prices. Moreover, the results indicate a high pass-through (above 75%) of producer price shocks to consumer prices. In sharp contrast, the extent of pass-through of import price shocks to consumer prices as reported in the VECM is low at approximately 10% in the short run and declining to approximately 2% in the long run.

KEYWORDS

Exchange rate, Pass-through, Depreciation, Monetary policy, Import prices, Producer prices, Consumer prices, South Africa.

DECLARATION

I, Francis Chiparawasha, hereby declare that this mini-thesis entitled '*Exchange Rate Pass-Through to Domestic Prices in South Africa*' is an end product of my own work under the supervision of Mr. Dawie van Lill, and that it has not been previously submitted in part or in its entirety for any degree or examination in any other university. All the sources I have used or quoted have been indicated and acknowledged by means of complete references.

Signature: 

Date: 7 October 2015



ACKNOWLEDGEMENTS

I am exceedingly grateful to the Lord Almighty for His guidance and all those who assisted me in different ways to complete this mini-thesis.

I am highly grateful for the valuable insights and the diligent support of my supervisor, Mr. Dawie van Lill, in the writing process of this work.

I am also appreciative to the entire staff of the Economics Department, former HOD Prof Lieb Loots and Dr. Carol Puhl-Snyman for their constant encouragement and support during the course of my studies.

I am especially grateful to my family – my mother and siblings for their endless encouragement, support, love and prayers.

Lastly, I owe a special gratitude to my friends and colleagues who have offered me unwavering support during the course of my studies, especially Fadwah, Faez, Eunice and Takunda.

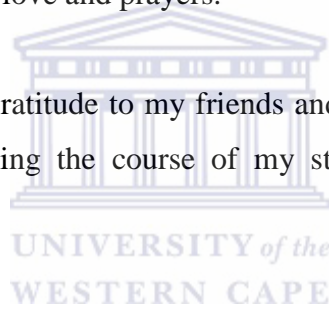


TABLE OF CONTENTS

ABSTRACT	ii
KEYWORDS	ii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF ABBREVIATIONS	x
CHAPTER 1	1
1. INTRODUCTION	1
1.1 Background	1
1.2 Objectives of the Study	2
1.3 Rationale and Significance of the Study	3
1.4 Methodology and Data	4
1.5 Structure of the Study	5
CHAPTER 2	7
2 THEORETICAL AND EMPIRICAL LITERATURE	7
2.1 Introduction	7
2.2 Theoretical Overview	7
2.2.1 Definition of Key Concepts	7
2.2.1.1 Exchange Rate	8
2.2.1.2 Exchange Rate Pass-Through (ERPT)	9
2.2.1.3 Incomplete ERPT	10
2.2.1.4 ERPT Asymmetry	10
2.2.2 The Implications of ERPT on Monetary Policy	11
2.2.3 The Channels of Exchange Rate Pass-Through	15
2.2.3.1 Distribution Chain Channel	16
2.2.3.2 Direct versus Indirect Channel	16
2.2.4 The Determinants of Exchange Rate Pass-Through	22
2.2.4.1 Exchange Rate Volatility	23
2.2.4.2 Monetary Policy and Inflationary Environment	24
2.2.4.3 Market Structure and Pricing Behaviour of Firms	25
2.2.4.4 Pricing Policies	26
2.2.4.5 Product Substitutability	27
2.2.4.6 Trade Openness and Cross-Border Production Sharing	27

2.3	Empirical Literature Overview	28
2.3.1	Empirical Evidence on Developed Economies.....	28
2.3.2	Empirical Evidence on Developing Economies	32
2.3.3	Empirical Evidence on South Africa	36
2.4	Concluding Remarks	39
CHAPTER 3		41
3	METHODOLOGY AND DATA.....	41
3.1	Introduction	41
3.2	Approaches to Estimate ERPT	41
3.2.1	Ordinary Least Squares (OLS) Models	42
3.2.2	Vector Autoregressive (VAR) Models	43
3.2.3	Vector Error Correction Models (VECM).....	46
3.2.4	Bayesian Vector Autoregressive (BVAR) Models.....	47
3.2.5	Dynamic Stochastic General Equilibrium (DSGE) Models	49
3.3	ERPT Data Measurement Challenges	51
3.4	Model Estimation Techniques	54
3.4.1	Stationarity and Non-Stationarity	54
3.4.1.1	Graphical Analysis	56
3.4.1.2	Unit Root Tests.....	56
3.4.2	Cointegration	59
3.4.2.1	Engle-Granger Approach	61
3.4.2.2	Johansen Cointegration Approach.....	62
3.4.3	Model Adequacy (Diagnostic Checks) Tests.....	63
3.4.3.1	Testing for Serial Autocorrelation.....	64
3.4.3.2	Testing for Heteroscedasticity.....	64
3.4.3.3	Testing for Normality	65
3.4.4	Structural Analysis.....	65
3.4.4.1	Impulse Response Functions	66
3.4.4.2	Variance Decompositions.....	66
3.5	Data and Description of Variables	67
3.6	Concluding Remarks	70
CHAPTER 4		72
4	ECONOMETRIC MODEL AND RESULTS.....	72
4.1	Introduction	72
4.2	Model Specification	72
4.2.1	Recursive VAR Model.....	73

4.2.1.1	Model Restrictions	76
4.2.1.2	Shortcomings of the Model	79
4.2.2	Vector Error Correction Model (VECM)	80
4.3	Main Findings – Econometric Results	81
4.3.1	Non-Stationarity and Stationarity Tests.....	81
4.3.2	Cointegration Test Results.....	82
4.3.2.1	VAR Lag Order Choice.....	83
4.3.2.2	Johansen Cointegration Tests.....	84
4.3.3	Residuals Diagnostic Check Results.....	85
4.3.4	Structural Analysis of VAR Model Results.....	87
4.3.4.1	Impulse Response Analysis.....	87
4.3.4.2	Variance Decompositions.....	94
4.3.5	Structural Analysis of VEC Model Results	95
4.3.5.1	Impulse Response Analysis.....	96
4.3.5.2	Variance Decompositions.....	98
4.3.6	Robustness Check Results	99
4.4	Concluding Remarks	101
CHAPTER 5	103
5	GENERAL CONCLUSION	103
5.1	Introduction	103
5.2	Main Findings.....	105
5.2.1	ERPT to Domestic Prices	105
5.2.2	Import and Producer Price Shocks PT to Consumer Prices.....	107
5.2.3	Limitations of the study	107
5.3	Areas for Further Research.....	108
REFERENCES.....		109
APPENDIX.....		123
TURNITIN REPORT		126

LIST OF TABLES

Table 3.1: Description of Variables and Data Sources	67
Table 4.1: Unit Root Test Results	82
Table 4.2: VAR Lag Order Selection.....	83
Table 4.3: Johansen Trace and Maximum Eigenvalue Likelihood Tests	85
Table 4.4: VAR Time Profile of ERPT Elasticity for Domestic Prices.....	89
Table 4.5: Comparison of Short-run ERPT to Prices in South Africa.....	91
Table 4.6: Comparison of Long-run Pass-Through in South Africa.....	93
Table 4.7: VAR Model - Variance Decomposition of Import Prices	94
Table 4.8: VAR Model - Variance Decomposition of Producer Prices.....	95
Table 4.9: VAR Model - Variance Decomposition of Consumer Prices.....	95
Table 4.10: VECM Time Profile of ERPT Elasticity for Domestic Prices.....	96
Table 4.11: Comparison of Long Run Pass-Through across Models	98
Table 4.12: VECM - Variance Decomposition of Import Prices.....	98
Table 4.13: VECM - Variance Decomposition of Producer Prices	99
Table 4.14: VECM - Variance Decomposition of Consumer Prices	99
Table 4.15: VAR Model ERPT Elasticities for the Different Models	100
Table 4.16: VEC Model ERPT Elasticities for the Different Models	101

LIST OF FIGURES

Figure 2:1: Share of Exchange Rate Regimes at the End of 2007	8
Figure 2:2: Share of World Exports across Different Economies.....	12
Figure 2:3: ERPT from Currency Depreciation to Consumer Prices.....	21
Figure 2:4: Short-term Variability of Nominal Effective Exchange (DLNEER) in South Africa, 1980M1 – 2015M7	24
Figure 2:5: Inflation Rates at the Time of Adoption of Inflation Targeting Framework across Countries	34
Figure 4:1: Response of Domestic Prices to 1% Appreciation in the Rand.....	88
Figure 4:2: ERPT Elasticities for Import, Producer and Consumer Prices.....	89
Figure 4:3: Pass-Through Elasticities from Import and Producer Price Shocks to Consumer Prices	92
Figure 4:4: Consumer Inflation and Producer Inflation, 1980 – 2014.....	93
Figure 4:5: ERPT Elasticities for Import, Producer and Consumer Prices.....	96

LIST OF ABBREVIATIONS

ADF	Augmented Dickey Fuller
AIC	Akaike Information Criterion
ARDL	Auto Regressive Distributed Lag
BLUE	Best Linear Unbiased Estimator
BVAR	Bayesian Vector Autoregressive
CIS	Commonwealth of Independent States
DGP	Data Generating Process
DF	Dickey Fuller
DL	Distributed Lag
DLNEER	Differenced Log of Nominal Effective Exchange Rate
DSGE	Dynamic Stochastic General Equilibrium
DW	Durban-Watson
ERPT	Exchange Rate Pass-Through
FPE	Final Prediction Error
GDP	Gross Domestic Product
HICP	Harmonised Index of Consumer Prices
HP	Hodrick Prescott Filter
HQ	Hannan-Quinn Information Criterion
IFS	International Financial Statistics
IMF	International Monetary Fund
KPSS	Kwiatkowski, Phillips, Schmidt & Shin
LCP	Local Currency Pricing
LCPI	Log of Headline Consumer Price Index
LIMP	Log of Import Price Index
LM	Langrage Multiplier
LNEER	Log of Nominal Effective Exchange Rate
LOIL	Log of Price of Crude Oil
LPPI	Log of Producer Price Index
LR	Sequential Modified LR test
OECD	Organisation for Economic Co-operative Development

OLS	Ordinary Least Squares
NEER	Nominal Effective Exchange Rate
PCP	Producer Currency Pricing
PP	Phillips-Peron
PT	Pass-Through
REER	Real Effective Exchange Rate
SARB	South African Reserve Bank
SIC	Schwarz Information Criterion
StatsSA	Statistics South Africa
SVAR	Structured Vector Autoregressive
UK	United Kingdom
UNCTAD	United Nations Conference on Trade and Development
USA	United States of America
VAR	Vector Autoregressive
VEC	Vector Error Correction



CHAPTER 1

1. INTRODUCTION

1.1 Background

After the fall of the Bretton Woods system of exchange rate management, many advanced economies moved to the floating exchange rate regime. Over the years, emerging economies have also followed suit by abandoning fixed exchange rate regimes in favour of the floating exchange rate framework. Like other emerging economies, South Africa undertook trade liberalisation measures in early 1995 (Aron, Farrell, Muellbauer & Sinclair 2012: 12) and later adopted a unitary floating exchange rate regime under an inflation targeting framework in 2000 (Du Plessis & Smit 2007: 675; Mtonga 2011: 4).

The demise of the coordinated system of fixed exchange rates beginning in the 1970s in favour of neoliberal markets resulted in many countries facing challenges under the existing fixed exchange rate system at that time. All the countries that had fixed exchange rate regimes and with open trade policies were trapped in a monetary policy dilemma popularly known as the *impossibility trinity* (Edwards 2006: 15). It became difficult to concurrently pursue three objectives of exchange rate stability (through foreign exchange management), free capital mobility and monetary policy autonomy (Yagci 2001: 17). Thus, when a country adopts a floating exchange rate and an open trade policy, it loses the power to insulate its own economy from external economic shocks. One of the possible transmitters of these shocks is the exchange rate. Exchange rate volatility creates uncertainty and increases the trading cost for firms (Palley 2004: 65).

Exchange rate fluctuations affect an economy through various channels such as its impact on imports, exports and capital flows (Parsley 2010: 1). According to economic theory, exchange rate depreciation is one of the determinants of inflation (Karoro, Aziakpono & Cattaneo 2009: 380). The need to understand the role of each determinant of inflation is of special interest to monetary policy makers. A better

understanding of how exchange rate fluctuations affect domestic prices (exchange rate pass-through) helps in determining the optimal monetary policy mix in order to ensure price stability (Choudhri & Hakura 2006: 617). The designing of optimal policy is crucial because countries that experience high exchange rate volatility are also likely to experience unstable domestic inflation (Devereux & Yetman 2010: 182).

The objective of attaining price stability is important especially for economies that adopted inflation targeting regimes such as South Africa. Generally, unstable domestic inflation usually complicates the primary objective of inflation targeting, that is, maintaining inflation within a pre-determined range or target. Usually, an unanticipated change in the exchange rate weakens the role of demand management policies by compromising the conduct of monetary policy and creating uncertainty regarding its impact on domestic prices (McCarthy 2006: 4). Therefore, this study aims to empirically estimate the speed and degree of exchange rate pass-through (ERPT) in South Africa. The results drawn from this study help to explain the role of exchange rate variations on domestic inflation.

1.2 Objectives of the Study

As discussed above, exchange rate movements have the potential to complicate the goal of achieving price stability. Once a country decides to let its currency be determined by market outcomes, it loses the autonomy to control the effect of exchange rate variations on domestic inflation. As a consequence, exchange rate variations become one of the determinants of inflation. Therefore, the aim of this study is to determine the impact of exchange rate fluctuations on domestic inflation (import, producer and consumer inflation) in South Africa. In particular, the study aims to address the following objectives:

- Analyse the theoretical and empirical literature on how exchange rate affects domestic prices across countries;
- Estimate the short-run and long-run speed (how fast) of exchange rate pass-through to domestic prices in South Africa;

- Examine the short-run and long-run magnitude (extent) of exchange rate pass-through to domestic prices in South Africa;
- Estimate the impact of import and producer price shocks on consumer prices in South Africa.

1.3 Rationale and Significance of the Study

The shift in international monetary system post the Bretton Woods agreement necessitated that countries had to change their approach with regard to international trade. Similarly, Kardasz & Stollery (2001: 719) argue that many scholars started to develop international trade models with imperfect competition as compared to prior models which were heavily based on the assumption of perfect competition. This shift in research was also followed by researchers developing an interest in examining the impact of exchange rate variations on product prices.

The fluctuations in exchange rate affect not only import prices but also producer prices and consumer prices (Kardasz & Stollery 2001: 720). Under an open trade policy and floating exchange rate framework, a country becomes susceptible to different volatilities in the global economy. For instance, the 2008 global financial crisis caused high variations in commodity prices, oil prices and grain prices (Shakeri & Gray 2013: 15). The global economy will continue to struggle in managing these volatilities which destabilise economic growth and complicate policy planning especially in the face of increasing world economic integration. Similarly, this volatility in the global economy is likely to cause fluctuations in exchange rates for the foreseeable future. The persistent variations in exchange rate justify the importance of analysing the effect of exchange rate movements on domestic prices. Domestic inflation has a direct effect on people's standards of living especially where nominal wages do not rise at par with inflation.

The analysis of ERPT is important in determining a country's optimal monetary policy mix (Choudhri & Hakura 2006: 614). Exchange rate movements have a strong bearing on the monetary policy that a country should adopt. The choice of an optimal monetary policy is more important especially where the country is under an inflation targeting framework, for example South Africa. Low pass-through credits the

implementation of inflation targeting and provides more autonomy to pursue independent monetary policy (McCarthy 2006: 5). Even though the advantages of low pass-through seem obvious, there is no consensus in literature as to what either causes low pass-through or how a country can achieve such an environment (Nogueira 2007: 191).

To succeed in designing optimal monetary policy to address the challenges of inflation, policy makers must have a better understanding of the drivers of inflation. Understanding the behavior of the determinants of inflation helps in efficiently executing monetary policy decisions in order to maintain price stability. Given the hypothesis that exchange rate depreciation causes inflation, it is important to understand the speed and magnitude of ERPT to domestic inflation. This study aims to add to the existing literature by analysing how changes in the exchange rate affect domestic prices. The results help in understanding the role of exchange rate fluctuations on inflation especially given the increase in volatility of currencies for emerging markets post the 2008 global financial crisis.

1.4 Methodology and Data

This study uses quantitative methods to estimate the impact of exchange rate variations on domestic prices in South Africa. Due to their wide use, the study uses a Vector Autoregressive (VAR) model to estimate the speed and degree of ERPT. The popularity of VAR models is in their ability to treat all variables as endogenous. VARs are also preferred to Ordinary Least Squares (OLS) regressions or simultaneous equations because they can accommodate the non-stationarity of most macroeconomic time series (Yaffee & McGee 2000: 421). However, in the presence of cointegration between variables, VARs are usually used for short-run analysis thus; the model is extended to a Vector Error Correction Model¹ (VECM) to provide long-run inferences from the data (Ca' Zorzi, Hahn & Sanchez 2007: 11).

¹ This is the correct model to estimate exchange rate pass-through if there is at least one cointegration relationship between the variables.

The main sources of data are the South African Reserve Bank (SARB), Statistics South Africa (StatsSA) and the International Financial Statistics (IFS) from the International Monetary Fund (IMF) website. The study uses seven variables which are Import price index, Producer price index, Consumer price index, Crude oil prices, Nominal effective exchange rate, Short-term interest rate and Output gap. The Output gap is derived from the Gross Domestic Product (GDP) using a relevant econometric smoothing technique. The analysis of short-run and long-run pass-through is based on quarterly² data covering the period 1980Q1 to 2014Q4.

1.5 Structure of the Study

The study is divided into five chapters. As above, Chapter One presents a general introduction to the study and motivates the importance of this research. Chapter Two reviews the theoretical and empirical framework underpinning the study. Then, Chapter Three provides the description of data and methodology. Chapter Four specifies the model and provide an analysis of the empirical results. Finally, Chapter Five concludes the study.

Chapter Two of the study provides a discussion on the definition of terms, an analysis of the channels of ERPT and its determinants. The determinants of pass-through also play a role in influencing the speed at which exchange rate fluctuations feed into domestic prices. Empirical literature reviews the evidence of ERPT in advanced and developing countries.

Chapter Three analyses the most commonly used methodologies in estimating ERPT, their respective strengths and weaknesses. The discussion follows a historical approach, which is, starting with the OLS models to the most recent Dynamic Stochastic General Equilibrium (DSGE) models. Also covered in the chapter is a review of the various data measurement challenges in pass-through studies. Lastly, Chapter Three provides an outline and the sources of the data.

² The choice of using quarterly data is due to the unavailability of monthly import price index data covering the entire study period but the variable is available quarterly.

Chapter Four begins with the specification of the VAR model and the VECM utilised in this study. The specification of the model is followed by an analysis of the short-run and long-run pass-through empirical results in South Africa using impulse response functions and variance decompositions.

Chapter Five concludes the study by reflecting on the analysed literature, main empirical findings and how these results address the research objective outlined in Section 1.2 above. The chapter also discusses the limitations of the study and possible areas of future research that can be conducted to enhance knowledge on the impact of exchange rate variations on domestic inflation.



CHAPTER 2

2 THEORETICAL AND EMPIRICAL LITERATURE

2.1 Introduction

This chapter is divided into two main sections: the theoretical approach to the questions and the empirical literature review on exchange rate pass-through (ERPT). The first section provides a theoretical discussion on the definition of ERPT followed by an analysis of channels and determinants of pass-through. The channels of ERPT refer to the transmission mechanisms through which exchange rate variations affect domestic prices. These mechanisms can be divided into two: either the direct channel or the indirect channel. Authors such as McCarthy (2000; 2006) also propose analysing the transmission of exchange rate variations along the distribution chain. The section on determinants of pass-through covers the factors that affect the speed and magnitude of transmission of exchange rate variations. These factors include but are not limited to exchange rate volatility, inflation environment, market structure, monetary policy and pricing behaviour of firms.

The second section on the overview of empirical literature is divided into three categories: a discussion of empirical evidence on advanced economies; developing economies; and a specific section about empirical evidence on ERPT in South Africa.

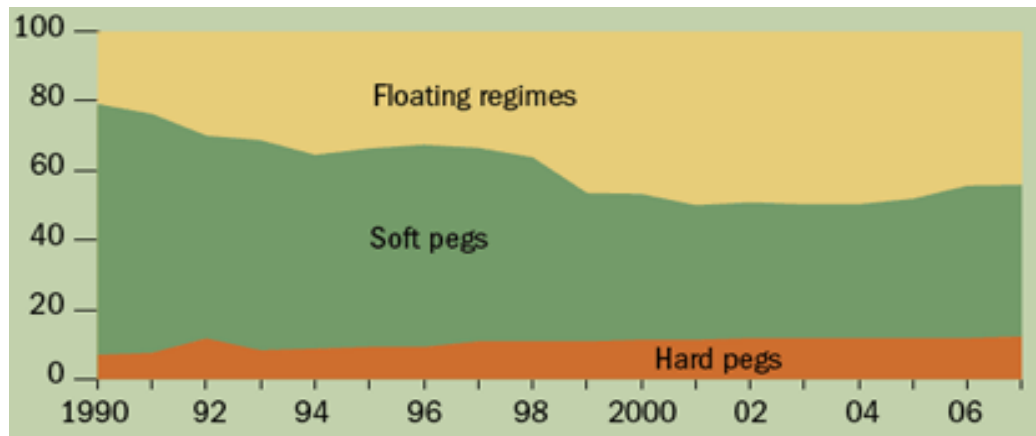
2.2 Theoretical Overview

2.2.1 Definition of Key Concepts

The failure of the Bretton Woods framework of fixed exchange rate led to many economies moving from fixed exchange rate systems to floating exchange rate frameworks. This trend has created an interest in identifying the role of exchange rate in determining a country's policies, especially in the face of economies increasingly opening up their borders to international trade (Ozcelebi & Yildirim 2011: 180).

Figure 2.1 illustrates the increasing proportion of countries adopting floating exchange rate regimes.

Figure 2:1: Share of Exchange Rate Regimes at the End of 2007



Source: Stone, Anderson & Veyrune (2008)

The opening up of borders has major implications in terms of capital flows especially for the emerging economies. Ahmed and Zlate (2013: 1) note that even though free capital flows can improve allocation of resources, enhance productivity and promote economic growth, large capital movements can cause macroeconomic policy challenges. These capital flows can also have a significant effect on a country's exchange rate.

In recent years, the progression towards strong economic integration among world economies has made changes in exchange rate a determinant of domestic inflation, trade and the debt burden of countries. Before providing an overview of the theoretical literature, it is important to provide a discussion of the different concepts to be constantly used in this study.

2.2.1.1 Exchange Rate

A nominal exchange rate refers to the domestic currency price of a foreign currency (Montiel 2009: 47). Similarly, Engel (2009: 182) defines nominal exchange rate as the relative price of two currencies. In other words, exchange rate refers to the units of domestic currency which are needed to acquire a unit of foreign currency or vice

versa. This definition means that the nominal exchange rate deals with the value of a domestic currency in relation to foreign currencies (Asari, Baharuddin, Jusoh, Mohamad, Shamsudin & Jusoff 2011: 49). In the modern era in which most economies are open to trade, exchange rates play an important role in influencing a country's level of trade (Asari *et al.* 2011: 49). Many scholars have developed an interest in analysing the underlying relationship between variations in exchange rate and domestic prices, especially of tradable goods. This is referred to as exchange rate pass-through (ERPT) or in short pass-through. The analysis of pass-through is of particular interest under a system of floating exchange rate where the behaviour of the exchange rate is determined by market forces (Ocran 2010: 293).

2.2.1.2 Exchange Rate Pass-Through (ERPT)

ERPT can be analysed along a distribution chain. It can either be pass-through to import, export, producer or consumer prices. Bhattacharya, Karayalcin and Thomakos (2008: 1135) define ERPT to import prices as the proportional change in local currency import prices as a consequence of a one percentage change in the nominal exchange rate. Also referring to pass-through to import prices, Menon (1996: 434) defines pass-through as the magnitude by which exchange rate fluctuations are transmitted to the destination country's prices of tradable goods. Similarly, Ocran (2010: 292) and Aron *et al.* (2012: 1) define ERPT to domestic prices as the elasticity of import, producer or consumer prices to variations in the exchange rate. In short, ERPT to domestic prices refers to the response of import, export, producer and consumer prices to a given change in the exchange rate. The above definitions illustrate that it is important to differentiate whether the pass-through is to import, export, producer or consumer prices. This study focuses only on determining ERPT to import, producer and consumer prices henceforth domestic prices.

The definition of ERPT from the different authors shows that the study of ERPT aims to examine the responsiveness of domestic prices to a given change in exchange rate (Tandrayen-Ragoobur & Chicooree 2013: 2). This is reflected in many studies (Menon 1996; Bhundia 2002; Devereux & Yetman 2002; McCarthy 2006; Karoro *et*

al. 2009; Aron *et al.* 2012; Choudhri & Hakura 2012) which analyse pass-through to different price levels. In this study, the definition of ERPT refers to a change in domestic prices given a change in the exchange rate. The focus is also on pass-through at aggregate price level since aggregate prices are more relevant for monetary policy (Hüfner & Schröder 2002: 1).

2.2.1.3 Incomplete ERPT

Assuming an open economy which is under the purchasing power parity assumption, traditional macroeconomic models predict that ERPT to import, producer and consumer prices is always immediate and complete (Khundrakpam 2007: 2). Purchasing power parity hypothesises that national price levels across nations should be the same once converted to a common currency (Rogoff 1996: 647). Rogoff (1996: 647) highlights that empirical evidence show that ERPT to domestic prices is usually incomplete in the short run and only complete in the very long run. An incomplete pass-through occurs when a change in the exchange rate causes a less than proportionate change in domestic prices (Aron *et al.* 2012: 1). Shakeri and Gray (2013: 16) define incomplete ERPT as a less than one-to-one response of domestic prices to a given change in exchange rate.

The deviation of market structures from perfect competition is one of the factors cited as the cause of incomplete pass-through of exchange rates (Menon 1996: 435). Understanding the magnitude of pass-through is also important for policy implications. For instance, partial pass-through raises less concern over inflationary pressures induced by variations in exchange rates (Ghosh & Rajan 2007: 13). However, if the magnitude of pass-through is high, policy makers need to factor in the possibility of inflationary pressures when a currency changes especially with regard to currency depreciation.

2.2.1.4 ERPT Asymmetry

Asymmetric pass-through refers to a case where depreciation in a currency induces a different degree or speed of pass-through as compared to the appreciation of the same currency (Aron *et al.* 2012: 1). For a same degree of change in exchange rate,

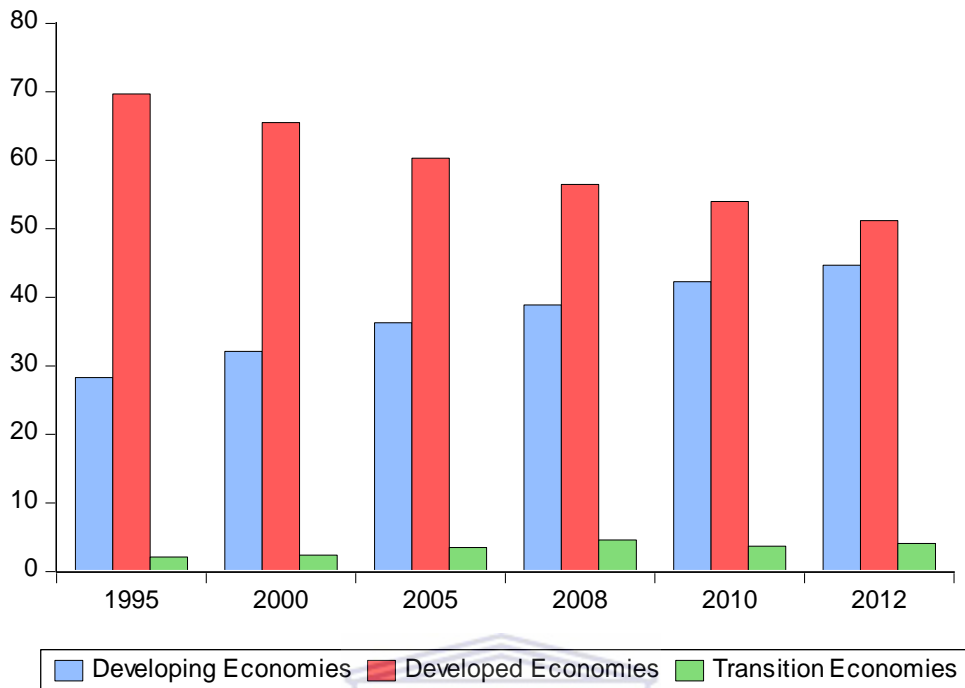
depreciation leads to a higher impact on domestic prices than currency appreciation. Alternatively, this asymmetric pass-through can be where smaller changes in exchange rate result in a different magnitude of ERPT as compared to a magnitude caused by larger changes in the exchange rate. In other words, asymmetry can be analysed both from directional (appreciation versus depreciation) or size (large versus small exchange rate changes) perspectives. Karoro *et al.* (2009: 381) provide possible causes of asymmetry in adjustment of prices. These include menu costs, production switching, quantity constraints and market share. These factors are covered under the determinants of ERPT in Section 2.2.4. This study does not make an attempt to investigate the presence of asymmetric pass-through in South Africa.

2.2.2 The Implications of ERPT on Monetary Policy

The last few decades have been characterised by an increase in economic integration among developed and developing economies. This strengthening economic integration has exposed these economies, particularly the small and open economies, to speculative pressures, easy capital flow reversals and contagions (Aron *et al.* (2012: 1). Besides these exposures, developing economies have also increased their share of world trade. For instance, by 2008 they accounted for 40% of world exports in comparison to less than 30% in 1990 (Bussière & Peltonen 2008: 7).

Figure 2.2 shows the change in the proportional share of exports between transitional, developing and developed economies. The share of developed economies' exports has declined from approximately 70% in 1995 to about 51% by 2012. In exchange, transitional and developing economies have consistently expanded their share of world exports over the same period.

Figure 2:2: Share of World Exports across Different Economies



Source: Own computations using data from UNCTAD Report (2013)

After experiencing exchange rate crises in the mid-1990s, many emerging economies changed their monetary policy regimes from targeting exchange rates and monetary aggregates in favour of targeting inflation (Nogueira 2007: 190). This change was complemented by many emerging economies moving from fixed exchange rate regimes to floating exchange rate frameworks. Countries that maintain a free floating exchange rate regime expose themselves to exchange rate movements due to external shocks such as foreign trade and international capital flow shocks. Therefore, understanding the dynamics of exchange rate movements with particular interest on its effect on domestic prices is important for various reasons.

According to Bussière and Peltonen (2008: 7) the understanding of ERPT in emerging economies is of importance for mainly three reasons. Firstly, the global adjustment of current account balances or imbalances is partially determined by exchange rate changes via the response of trade prices after an exchange rate shock. Secondly, the degree of pass-through and pricing to market among these emerging economies is important in analysing their role in global inflation. Lastly,

understanding the elasticity of both export and import prices to exchange rate variations is a significant factor in macroeconomic monitoring and forecasting. Generally, exchange rate changes are a major concern for domestic macroeconomic policies (Parsley 2010: 1). Ito and Sato (2006: 3) concur with this view. They highlight that exchange rate variations have major implications for macroeconomic policy design across countries. In this regard, exchange rate movements play an important role in the determination of domestic inflation, the international transmission of business cycles, the movements in both the current and financial accounts and the conduct of monetary policy.

Ocran (2010) complements the arguments by Bussière and Peltonen (2008) on the importance of understanding ERPT. The author adds that more knowledge on the relationship between domestic prices and exchange rate movements helps in the formulation of trade and monetary policy (Ocran 2010: 292). Arguing the same points but differently, Omisakin (2009: 38) notes that the extent by which exchange rate changes affect domestic prices is of major concern for monetary policy. In general, this concern emanates from the fact that ensuring a stable currency is one of the goals of monetary policy in many countries. For example, Section 224 of the Constitution of the Republic of South Africa (1996) mandates that the central bank's primary objective is the protection of the value of the rand. This primary objective is to be pursued in the interest of balanced and sustainable economic growth. Specifically, the desire to ensure stable currency and inflation is driven by the need to ensure a healthy financial and monetary environment that is conducive for economic growth (Omisakin 2009: 38).

The analysis of the effect of exchange rate variations on domestic prices is important in ensuring that central banks are conducting monetary and foreign exchange policy optimally (Ponomarev, Trunin & Uluykaev 2014: 16). Similarly, Choudhri and Hakura (2006: 614) argue that the degree of pass-through of exchange rate to domestic prices is a vital factor in debates of determining optimal monetary and exchange rate policies. The author further mentions that low pass-through is conducive for pursuit of an independent monetary policy and the adoption of an

inflation targeting regime. In short, a low degree of ERPT provides a wider room for monetary policy autonomy (Razafimahefa 2012: 3). This autonomy implies that monetary authorities will have more space to pursue countercyclical policies during the downward phases of the business cycles such as exchange-rate-induced inflation. In support, Taylor (2000: 1394) argues that understanding the degree of pass-through is essential to policy makers when deciding by how much to tighten monetary policy after an increase in inflation. This understanding of pass-through is specifically important if the change in inflation is driven by changes in the exchange rate.

To illustrate the importance of policy autonomy, McCarthy (2006: 2) cites the tightening of monetary policy in 2000 by the European Central Bank as a result of inflationary effects due to a weakening euro. Subsequently, this tightening was followed by the loosening of monetary policy in 2003 during a period in which the euro was appreciating against other major currencies.

Under a more financially integrated world, the behaviour of policymakers especially in small and open economies is constrained by external shocks such as imported inflationary pressures and exchange rate volatility (Aron *et al.* 2012: 1). These challenges mean the knowledge of how domestic prices react to exchange rate changes is crucial in anticipating inflationary developments and the optimal policy response. The knowledge becomes even more important for forward-looking central banks that need to forecast the possible trajectory of domestic inflation.

Mohanty and Klau (2001: 1) note that non-monetary factors (e.g. exchange rate changes) only affect the short-run path of inflation. On the other hand, only monetary variables influence the long-run path of inflation. Nevertheless, the degree of short-run pass-through is crucial in interpreting the short-run inflation dynamics (Engel 2009: 179). For instance, an increase in import prices of intermediate goods in response to a currency depreciation is likely to affect other sectors of the economy thereby raising the production costs and possibly igniting an inflation spiral (Razafimahefa 2012: 3). The possibility of an inflation spiral means that even short-run inflation has an important implication for people's welfare. The interpretation

from this possible negative consequence of short-run inflation is that monetary policy designed to control inflation should not allow exchange rate fluctuations to cause an inflationary spiral (Laflèche 1997: 22).

Unexpected supply side shocks such as unexpected changes in exchange rate also complicate the conduct of monetary policy (Mohanty & Klau 2001:2). These shocks weaken the impact of demand management policy which in turn creates uncertainty on their effect on domestic prices. Unanticipated shocks also make the process of inflation forecasting more complex. The prediction of the possible future path of inflation is essential for forward-looking central banks as discussed above. In this respect, Taylor (2000: 1394) highlights that understanding the degree of ERPT is crucial for forecasting inflation. A more accurate forecast of inflation will in turn lead to appropriate policy response to mitigate the potential negative inflationary outcomes.

Even though the understanding of the relationship between exchange rate movements and domestic prices as well as the implication of this relationship to monetary policy is important, it is still essential to closely analyse the channels through which exchange rate movements influence domestic prices. The next section covers the transmission mechanisms of exchange rate fluctuations to domestic prices.

2.2.3 The Channels of Exchange Rate Pass-Through

McCarthy (2000; 2006) groups the transmission stages of ERPT along a distribution chain. The distribution chain is divided into three stages: at the point of importation, production and consumption (Choudhri & Hakura 2006: 617). Under this classification, the transmission of exchange rate changes to domestic prices is then analysed at each stage of the distribution chain. Conversely, some studies (Hüfner & Schröder 2002; Wimalasuriya 2006; Hyder & Shah 2004) prefer classifying the transmission mechanisms of exchange rate movements to domestic prices into direct and indirect channels of pass-through.

2.2.3.1 Distribution Chain Channel

The analysis of pass-through along the distribution chain is divided into two main stages. The first stage relates to the impact of changes in exchange rate on the import and export prices, widely known as the impact of exchange rate fluctuations at the dock (McCarthy 2000: 5). The second stage involves analysing the subsequent impact of changes in import prices due to variations in the exchange rate on other aggregate prices, meaning producer and consumer prices.

The theoretical hypothesis is that any change in import prices whether of finished goods, capital goods, raw materials or intermediate goods should eventually lead to changes in both or one of the producer prices and/or consumer prices. In general, the degree of ERPT on the second stage is lower than the first stage of pass-through. This difference is because the price indices on the second stage of pass-through include prices on non-tradable goods which are not directly affected by movements in exchange rates (Ghosh & Rajan 2007: 14). Moreover, the producer and consumer prices are affected by other factors such as domestic taxes. The wholesalers and retailers of goods may absorb some of the exchange rate changes. In literature, some scholars only analyse pass-through at the first stage while others analyse both the first and second stage of pass-through.

2.2.3.2 Direct versus Indirect Channel

According to Hübner and Schröder (2002: 2) the **direct channel** of ERPT (see Figure 2.3 on page 21) refers to the situation in which an appreciation or depreciation results in a change in import prices. As a result of the change in import prices, production and consumer prices will also change. The subsequent change in producer and consumer prices will materialise if producers decide to change their prices in order to match the changing cost of production from the increase in import prices. In the same way, An and Wang (2012: 363) define the direct channel as the transmission of exchange rate movements to import, producer and consumer prices via its effect on prices of imported intermediate goods. This transmission implies that the primary

effect of exchange rate changes in domestic prices is through changing the domestic currency price of tradable goods.

Similar to Hüfner and Schröder (2002), Hyder and Shah (2004: 3) highlight that the direct channel of pass-through can be observed when exchange rate movements affect domestic inflation via its effect on imported inputs and finished goods. In general, the depreciation of a currency leads to higher import prices for either finished goods or intermediate goods and vice versa for currency appreciation. This reaction of import prices to fluctuations in the exchange rate is likely to hold in the case of small and open economies which are price takers (Hyder & Shah 2004: 3). To illustrate, an increase in the cost of imported raw materials and capital goods due to exchange rate depreciation will push up the marginal cost of production (Omisakin 2009: 38). Consequently, most producers will also increase prices of their products hence; nominal depreciations have the potential to trigger depreciation-inflation spirals (Herr 2007: 36).

Karoro (2007: 8) further divides the direct channel into two sub-channels; either through the change in price on import inputs or through the change of tradable imported finished goods. The first sub-channel works through the effect of exchange rate changes on production cost. For instance, depreciation in a currency will lead to an increase in the price of imported capital goods, raw materials or intermediate goods which consequently affect production costs. *Ceteris paribus*, firms are likely to respond by increasing the prices of their products. The increase in production costs will in turn result in higher consumer prices. This sub-channel is in line with the proposition made by McCarthy (2006) of analysing ERPT along the distribution chain.

The second sub-channel relates to the effect of fluctuations of the exchange rate on prices of imported finished goods (Karoro 2007: 8). This is likely to be the case if firms importing tradable finished goods decide to accordingly increase prices in local currency to avoid absorbing the higher purchasing cost of the imported goods. The

factors that determine whether firms will decide to absorb or pass on the burden to consumers are covered in Section 2.2.4.

The further division of the direct channel into effects through imported finished goods or import inputs by Karoro (2007) is of importance in determining the speed and magnitude of pass-through. The degree and magnitude may differ depending on whether the imported products are final goods, intermediate goods, capital goods, raw materials or imported components that are assembled in the domestic market and then exported to other countries.

The magnitude of ERPT is most likely to be complete for imported final goods depending on the market structure and currency of pricing being used by the importing firm. Capital goods and raw materials are likely to have low pass-through especially at the consumption level. Moreover, the ERPT of capital goods may also be low because these goods are used in the production of other goods for a long time. Components which are imported for assembling and then exported are likely not to have a big impact on the local market. However, they may have an effect on the potential income that can be generated through the export sector. Similarly, pass-through is likely to be more on tradable goods than non-tradable goods.

The **indirect channel** (see Figure 2.3 on page 21) operates via the effect of exchange rate variations on the competitiveness of a country's goods and services relative to foreign markets (Hüfner & Schröder 2002: 2). Any changes in the competitiveness of a country which influence aggregate demand will also have an impact on the net exports (Hyder & Shah 2004: 3). The change in relative prices in favour of the domestic country makes locally produced goods cheaper to the foreign market, thus increasing foreign demand (Karoro 2007: 8). The increase in foreign demand will increase exports (Hüfner & Schröder 2002: 2). As a consequence, the increase in aggregate demand due to the increase in foreign demand will exert an upward pressure on domestic prices (Hyder & Shah 2004: 3). Herr (2007: 36) also argues that currency appreciation can cause deflationary effects by reducing import prices.

Commenting on the indirect channel, Ponomarev *et al.* (2014: 3) state that this channel depends on the degree of cross-substitution of trade partners between domestic products and imported products in both the domestic and foreign market. For instance, the depreciation of a currency will increase domestic demand of local goods whilst also boosting foreign demand of local goods. The increase in domestic demand is driven by the fact that imported tradable goods which are denominated in domestic currency become relatively expensive (domestic substitution). This is also referred to as the expenditure switching effect of exchange rate depreciation. In contrast, the increase in foreign demand for domestic goods is as a result of the goods becoming relatively cheaper in the foreign market (foreign substitution) (Ponomarev *et al.* 2014: 3). The resultant effect of these two substitution effects will be an upward pressure on domestic production of tradable goods which in turn leads to increase in wages and domestic prices (producer and consumer prices).

Like the direct channel, the indirect channel can also be further divided into two sub-channels; with regard to whether the goods are finished goods or inputs. If the goods which are facing an increase in foreign demand are locally produced tradable finished goods, local firms may increase prices with the objective of maintaining their profit margins (Karoro 2007: 8). In comparison, if the demanded goods are mostly intermediate goods, producer prices are likely to increase; then eventually consumer prices will also rise. Tandrayen-Ragoobur and Chicooree (2013: 3) prefer to rather divide the indirect channel into the wage inflation effect and the competition effect.

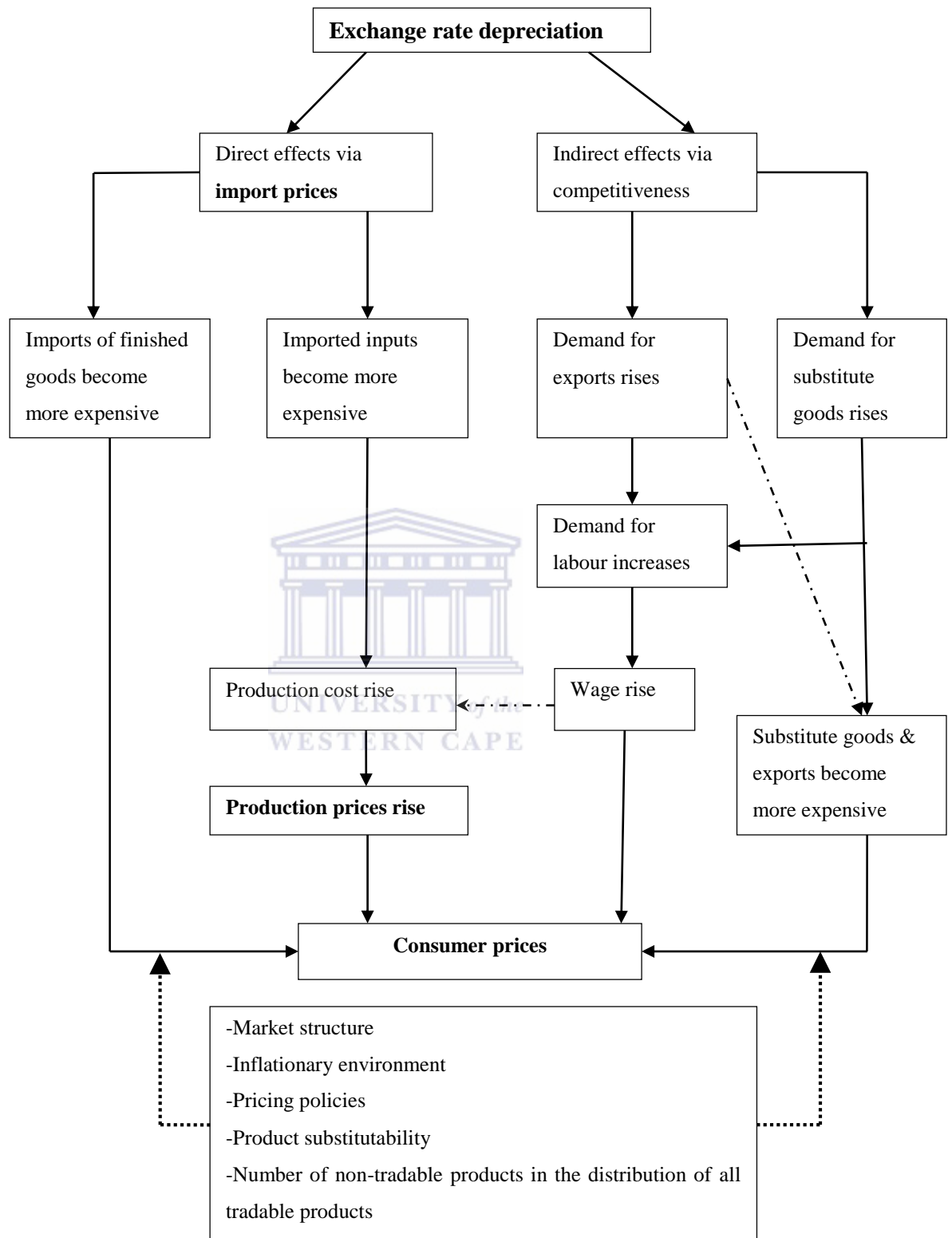
The wage inflation effect is determined by the correlation between changes in wages and the cost of production. As an illustration, if the exchange rate depreciates, it will lead to an increase in price of imported consumption goods and concurrently the purchasing power of workers' wages will fall (Tandrayen-Ragoobur & Chicooree 2013: 3). In the short run, nominal wage contracts are usually fixed. Therefore, after an increase in domestic prices, real wages are likely to decline whilst output increases (Hüfner & Schröder 2002: 2). However, over time employers will be forced to increase nominal wages in order to compensate for the fall in purchasing power,

but this will lead to an increase in production cost and domestic inflation. Alternatively, the lower wages are usually followed by wage inflation which in turn reduces the quality of a currency causing capital outflows thus further currency depreciation (Herr 2007: 36). It is important to note that due to nominal rigidities, the final pressure of domestic demand on prices and wages is generally only applicable in the medium to long run (Laflèche 1997: 24).

The explanation for the competition effect is the same as in Hyder and Shah (2004); a depreciation of a currency changes relative prices between trading countries and boosts domestic demand which in turn leads to higher domestic prices. Figure 2.3 summarises the distinction between the direct and the indirect channel.



Figure 2:3: ERPT from Currency Depreciation to Consumer Prices



Source: Adapted from Laflèche (1997); Hüfner & Schröder (2002) and Hyder & Shah (2004)

The figure illustrates both the direct and indirect channels of ERPT and succinctly shows how a given change in exchange rate feeds into domestic prices. At the bottom of the figure are the factors that determine the speed and degree of ERPT.

The analysis of the transmission mechanisms of exchange rate changes to domestic prices discussed above might create an impression that ERPT is always complete. In other words, the discussion creates an impression that any change in exchange rate leads to a proportional change in domestic prices. In spite of the basic economic theory of purchasing power parity supporting the idea of complete pass-through, ERPT is rarely complete in reality (Ponomarev *et al.* 2014: 4). Rowland (2004: 108) emphasises that the incomplete ERPT is particularly a short-run phenomenon. In addition, empirical research has shown that the speed and degree of ERPT to domestic prices is gradual and incomplete respectively, that is, changes in exchange rate are only partially transmitted to prices often with a delay (Beckmann & Fidrmuc 2013: 707). Hüfner and Schröder (2002) also support this argument by citing several studies which found pass-through to be incomplete.

The speed and degree of pass-through depend on the nature of the product as well as the channel through which the exchange rate changes are transmitted to domestic prices. The degree of ERPT within each channel is also further affected by various determinants such as the market structure, inflationary environment, exchange rate volatility and monetary policy. These factors as outlined in Figure 2.3 affect the speed and magnitude of ERPT. Therefore they are the focus of the following section.

2.2.4 The Determinants of Exchange Rate Pass-Through

Tandrayen-Ragoobur and Chicooree (2013: 4) group the factors which affect the speed and magnitude of ERPT to domestic prices into macroeconomic and microeconomic factors. These factors either weaken or strengthen the impact of exchange rate fluctuations on domestic prices. Some of the factors discussed in the literature include exchange rate volatility, monetary policy and inflationary environment, the pricing behaviour of firms, the size and openness of a country and

the persistence of exchange rate shocks (Mann 1986; Taylor 2000 as cited in An & Wang 2012: 362).

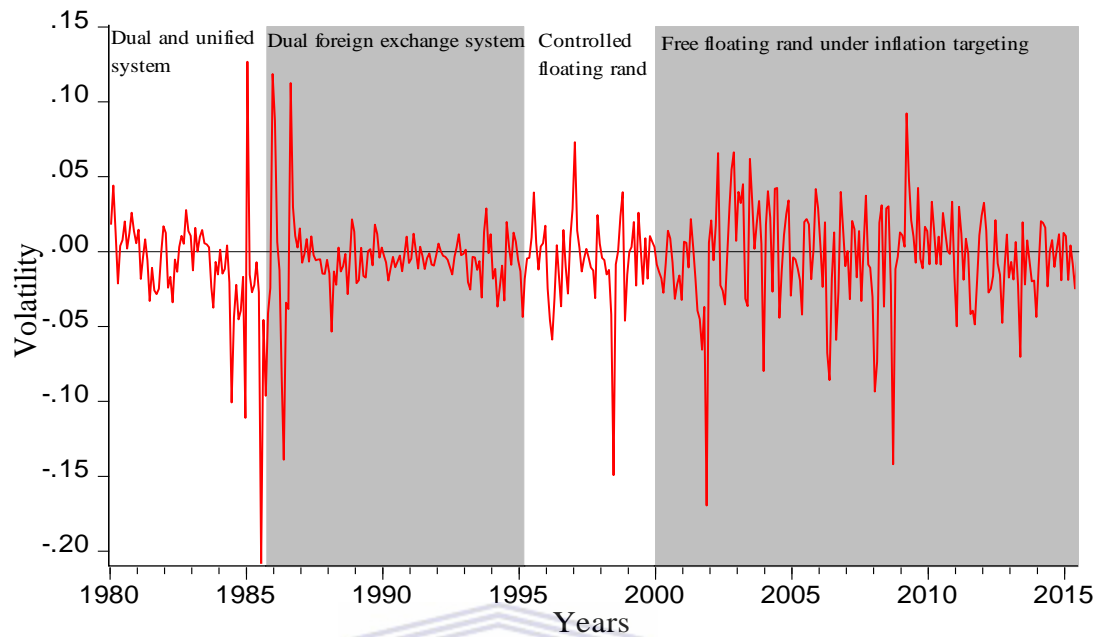
2.2.4.1 Exchange Rate Volatility

There are various factors that cause exchange rate to fluctuate. Factors such as a country's exchange rate regime, the independence of the central bank, the degree of openness of an economy, inflation and any other unanticipated shocks play an important role on the direction of the exchange rate (Stančík 2006: 3). Mishkin (2008: 2) believes that in the past, excessive money creation by central banks was the main source of exchange rate and price instability in countries. The deduction from this observation is that there must be a correlation between movements in exchange rate and domestic inflation in response to monetary shocks.

There are many macroeconomic variables that affect the degree of pass-through. One of them is exchange rate volatility (McCarthy 2006: 5). For example, a high degree of volatility means a more frequent change in exchange rate. This frequent change may force importers to adjust their profit margins rather than constantly changing prices. In that case, ERPT is likely to be low. This reaction also links to how firms perceive the change in exchange rate. Firms may decide to absorb the effect of the exchange rate through cutting down on their profit margins if they perceive the movement in exchange rate to be temporary (Ghosh & Rajan 2007: 15). However, where the change in exchange rate is perceived to be permanent, firms are likely to pass the entire burden of increased prices to consumers thus leading to complete ERPT.

Figure 2.4 shows the volatility of the South African rand over the period 1980 – 2015. The main focus of this study is to estimate how fast and how much of the variations in the figure will eventually feed into domestic prices. The graph clearly shows high volatility of the rand against other major trading partner currencies especially under the period of the floating rand (after the year 2000).

Figure 2:4: Short-term Variability of Nominal Effective Exchange (DLNEER) in South Africa, 1980M1 – 2015M7



Source: Own calculations using data from IMF, 1980 – 2015

Huang (2010: 136) highlights that the effect of exchange rate volatility on ERPT also depends on the degree of hedging by firms. The author posits that importing firms with a high hedging engagement via forward markets or other means should have lower degree of ERPT. In other words, hedging can help importing firms to insulate themselves from exchange rate risks through locking in the exchange rate in financial markets.

2.2.4.2 Monetary Policy and Inflationary Environment

One of the trends being observed by many scholars (Taylor 2000; Goldfan & Werlang 2000; Mishkin 2008) is that the inflation rate especially among developed economies has declined over the last two decades. The general consensus in the literature is that the degree of ERPT has also declined over the past two decades (Beckmann & Fidrmuc, 2013: 707). Taylor (2000: 1390) credits this decline in inflation across the globe to the changes in monetary policy stance over the years. A country with a more stable monetary policy and low inflation is more likely to have low pass-through (Goldfajn & Werlang 2000: 6). In support, Mishkin (2008: 2) observes that nominal shocks can cause more volatile exchange rates and inflation in

an environment where monetary policy is unstable. An unstable monetary policy may even lead to a strong correlation between nominal exchange rate fluctuations and domestic inflation.

Using a staggered price setting model Taylor (2000) proves that low inflation environments are positively correlated with low degree of ERPT. The low degree of ERPT seems that the change in monetary policy stance by central banks which led to the decline in inflation in the last few decades has contributed to the declining speed and degree of ERPT. In support, McCarthy (2000) highlights that countries with stable inflation environments are most likely to also have low ERPT. The argument raised by Taylor (2000) that pass-through is endogenous to a country's monetary stability and monetary policy is also supported by Gagnon and Ihrig (2004). Ghosh and Rajan (2009: 70) also note that higher inflation environment is closely associated with higher degree of ERPT.

2.2.4.3 Market Structure and Pricing Behaviour of Firms

According to Laflèche (1997: 25) the speed and magnitude of ERPT depends on three factors, namely: price elasticity of demand, price elasticity of supply and the sensitivity of the exchange rate to firms' cost structure. If a firm's products face inelastic demand in the market, it becomes easier to increase its prices after exchange rate depreciation. Production firms are unlikely to change their prices if the cost of their inputs is less responsive to changes in exchange rate. In this instance, firms may prefer to absorb the small changes in cost by adjusting their mark-ups in order to maintain market share.

The reaction of firms to changes in exchange rate is also influenced by the extent to which they value market share over profits (Laflèche 1997: 27). Froot and Klemperer (1989) designed a model in which firms prioritise market share conditional on the variations of the exchange rate. The main assumption is that the decision to change prices by firms mainly depends on how they perceive the path of exchange rate in the future. If exchange rate changes are perceived to be prolonged, firms will change their prices. However, where they believe the change in exchange rate is temporary

they do not change their prices or they change prices by small margins (Froot & Klemperer 1989: 651).

The pricing behaviour of firms and market structure can also be used to explain the reasons why ERPT is predominantly incomplete (Rowland 2004: 110). Importing firms may decide to hold prices constant but change their mark-ups on prices when the exchange rate changes. The adjustment of mark-ups instead of prices has also strong support from the Post-Keynesian price theory of the firm (Shapiro & Sawyer 2003: 356).

The Post-Keynesian price theory of the firm postulates that a firm does not always change its prices when production cost changes due to menu cost (Shapiro & Sawyer 2003: 356). The cost of changing the menu prices may be higher than the potential gain from the higher prices (Rowland 2004: 110). Rowland (2004) highlights that many firms may prefer to incur losses in the short run in order to maintain their market share. The process of holding prices constant and adjusting mark-ups when the exchange rate changes is called *pricing to market*. This behaviour by firms is common in competitive industries where maintaining market share is a high priority for firms (Rowland 2004: 110). The adoption of pricing to market behaviour by firms is also associated with a low speed and degree of ERPT.

2.2.4.4 Pricing Policies

The speed and degree of ERPT also depends on the pricing policies of firms. There are mainly two strategies that firms can follow; local currency pricing (LCP) or producer currency pricing (Sweidan 2013: 113). Local currency pricing refers to the circumstances where exporting firms choose to price their products in the currency of the destination market (Sweidan 2013: 113). In this regard, these firms face competition from domestic firms and are forced to set prices equal to domestic competitors' prices. The constraint that these firms have to charge the same prices as destination market competitors implies that they have to absorb the effects of exchange rate changes in their mark-ups in order to remain competitive. In order to fully absorb variations in exchange rate and still remain competitive, producers'

mark-ups have to be adjusted on a one-to-one negative proportion to variations in nominal exchange rate (Sweidan 2013: 113).

On the other hand, producer currency pricing (PCP) occurs where the prices of exports are set in the home currency of the firm exporting the products (Sweidan 2013: 113). In this case, an exporting firm's mark-up is independent of the exchange rate and ERPT tends to be complete.

2.2.4.5 Product Substitutability

The nature of the goods under trade matters. In a situation where exporting firms face low competition in the destination market, they not only maintain market share but also pass the whole burden of the fluctuating exchange rate to the consumers (Ghosh & Rajan 2007: 15). However, where firms face strong competition, they may protect their market share by absorbing the effects of the exchange rate. The presence of competition in the domestic market also implies that there are close substitute goods to the goods being imported. This presence of substitutes forces firms to change prices less frequently as they face possibility of losing market share to other competing goods. Menon (1996: 443) argues that the substitutability between domestically produced and imported goods is positively related to the speed and degree of ERPT.

2.2.4.6 Trade Openness and Cross-Border Production Sharing

According to Goldfajn and Werlang (2000: 6) the degree of economic integration of a country has implications for the speed and magnitude of ERPT. A country which is more open to trade with a high volume of exports and imports is likely to experience a more pronounced effect of a given currency depreciation as compared to closed economies.

Lan, Lin, Lin and Chuang (2013) analyse the impact of cross-border production sharing on pass-through. The increase in economic integration (multilateral trade liberalisations & technological advances) among countries has encouraged cross-border production sharing between countries (Arndt 2005: 13). Cross-border production sharing promotes firms to adopt pricing to market strategies. Lan *et al.*

(2013: 299) argue that the degree of pass-through when there is pricing to market for intermediate goods will be less than in the absence of pricing to market. Therefore, the presence of cross-border sharing plays a role in determining the speed and magnitude of ERPT.

2.3 Empirical Literature Overview

Although some studies conducted an analysis of pass-through on the same or on similar countries, their results tend to differ. Rowland (2004: 111) and Menon (1995: 225) argue that the difference in results is due to differences in variable constructions, methodologies and model specifications. Therefore, this section aims to analyse the results from various studies taking cognisance of their methodologies. The empirical literature on ERPT can be classified into three categories (Hyder & Shah 2004: 5). The first category consists of studies examining ERPT to import prices at a disaggregated price level. Similarly, the second category is on ERPT to import prices but at aggregate price level. Lastly, the third category comprises studies on ERPT to producer and consumer price indices (aggregate price level).

Despite the growing literature on ERPT in developing economies, Hyder and Shah (2004: 5) argue that literature is still dominated by studies on ERPT in developed economies. In support, Karoro (2007: 20) also notes that the majority of the studies are on pass-through in developed economies such as the United Kingdom (UK) and the United States of America (USA). This section reviews empirical evidence from developed and developing economies and a specific section on empirical evidence of pass-through in South Africa.

2.3.1 Empirical Evidence on Developed Economies

There is an extensive literature on ERPT in developed countries. Some of the earlier literature is surveyed in Menon (1995). The study by Menon (1995) provides a comprehensive survey of forty three studies on ERPT. More than 50 percent of these studies were on pass-through in developed economies specifically on the USA, Germany and Japan. Moreover, most of the studies in the survey (Spitaeller 1980; Freinberg 1986; Lattimore 1988; Khosla & Teranishi 1989; Froot & Klemperer

1989; Marston 1990; Athukorala 1991; Menon 1992; as cited in Menon 1995: 210 – 221) use Ordinary Least Squares (OLS) to estimate ERPT. However, Menon (1995: 224) notes that OLS estimates are less accurate due to their inability to take into account the non-stationarity of most time series data.

Menon (1995: 224) groups the findings from the survey into five categories. These categories are the magnitude and dynamics of ERPT, the nature of ERPT across countries and products, differences in ERPT estimates for the same country and the stability of ERPT over time. With the exception of six studies, all the other studies show that pass-through is incomplete across countries (Menon 1995: 224). Across countries, the results are mixed. For instance, Kreinin (1977) (as cited in Menon 1995: 224), finds that ERPT ranges from 50 percent for the USA to complete in Italy. In contrast, other studies such as Spitaeller (1980), and Khosla and Teranishi (1989) which were also cited in Menon (1995) find that ERPT is complete for small economies and low for large economies.

The results at disaggregated price level in the survey show that there is a significant difference across product categories and industries. The findings within countries also show different results. For instance, the USA which is the most studied country shows differing results; from a low of 48.7 percent to a high of 91 percent. Menon (1995) attributes this difference for same-country studies to differences in methodology. Lastly, most studies conclude that pass-through has remained fairly stable over the period 1970s – 1995.

Using an OLS model, Menon (1996) conducted another study on pass-through in Australia. Unlike the Menon (1995) survey, the Menon (1996) study focuses on ERPT at disaggregate price level of forty product categories of consumer goods. The findings were similar to most of the results in Menon's (1995) survey; ERPT is incomplete but high. Almost all the product categories show a pass-through of above 70 percent within twelve months (Menon 1996: 434 – 444). However, even though all the product categories show a high degree of ERPT, there is a significant variation in pass-through within different product categories. Some of the author's observations are that substitutability between imported and domestically produced products is positively linked to pass-through. Moreover, the difference is also caused

by the presence of foreign controls, product differentiation, import share of domestic market and quantitative restrictions such as quotas. According to Menon (1996) these four factors are negatively related to the degree and magnitude of pass-through.

Goldfajn and Werlang (2000) analyse the correlation between inflation and exchange rate depreciation using a panel of 71 countries between 1980 and 1998. These countries consist of both developed and developing countries. Their study show that the magnitude of ERPT depends on the time horizon under analysis. The magnitude increases from a low of about 17 percent in the third month to a high of 73.2 percent by the twelfth month. The overall results indicate that pass-through is lower in OECD countries in comparison to developing economies. The authors point out that the degree and speed of ERPT is a product of the inflation environment, deviation of GDP from potential output, the degree of openness to trade and business cycles.

McCarthy (2000) uses a vector autoregressive (VAR) model which incorporates a distribution chain to examine the impact of exchange rate and imported prices on local producer and consumer prices. The study is on pass-through in industrialised economies which are the USA, the UK, Germany, Japan, France, Belgium, Sweden, Switzerland and the Netherlands. The results from the study show that pass-through from exchange rate changes and import prices to producer and consumer prices at aggregate level are modest for most of the economies. Similar results are in McCarthy (2006) which is an update of the same study. The author also argues that exchange rates and import prices played an important role in the disinflationary effect experienced by these economies (except the USA) during the 1990s. For instance, the degree of ERPT declines by approximately 50 percent in the UK, France and Japan. However, McCarthy (2000; 2006) attributes the weak impact of exchange rate and import prices on producer and consumer inflation in comparison to other studies to differences in methodology. Unlike the previous studies, the author's model includes a central bank reaction function. In addition, import prices and exchange rates are treated as endogenous variables in the author's model rather than exogenous variables as in other models.

In estimating pass-through within the euro zone (Germany, Spain, France, Netherlands and Italy) Hufner and Schröder (2002) use a Vector Error Correction

Model (VECM) for the period 1987 – 2007. They argue that a VECM is the most ideal model because of its ability to account for the non-stationarity of data and provide analysis of ERPT both in the short and long run. Based on findings from individual countries, ERPT is fastest in the short run for the Netherlands and faster in the long run for Italy and France. Hüfner and Schröder (2002) also computed a Harmonised Index of Consumer Prices³ (HICP) to measure the average ERPT in the euro area. The results indicate that a 10 percent depreciation of the euro leads to a 0.4 percent rise in the inflation rate after twelve months.

Similar to Hüfner and Schröder (2002), Campa, Goldberg and González-Mínguez (2005) also analysed short-run and long-run pass-through in the euro zone. The difference between the two studies is that Campa *et al.* (2005) analyse ERPT to import prices at disaggregate price level. The results indicate that pass-through is incomplete in the short run but relatively high. In the long run, the degree of ERPT is even higher and almost complete. The degree and speed of ERPT is also different across industries and countries. Even though not significant, their findings also indicate that the degree of ERPT is declining in two-thirds of the industries particularly in the manufacturing industry. These results support Taylor's (2000) argument that the degree of pass-through has been declining over the years especially in developed economies.

Stulz (2007) uses monthly data over the period 1976 – 2004 under a Vector Autoregressive (VAR) model to examine ERPT to domestic prices in Switzerland. Stulz (2007) concludes that the degree of pass-through to import prices is high but moderate for consumer prices. The author finds an ERPT to import prices of 35 percent in three months as compared to 9 percent for pass-through to consumer prices. Evidence also suggests that the degree of pass-through has been declining over the years. Similar to Taylor (2000), Stulz (2007) credits the fall in pass-through over the years to the low level of inflation in Switzerland.

Bhattacharya *et al.* (2008) analyses the short-run and long-run speed and degree of pass-through at the industry level in the USA, the UK and Japan. Their results show

³ HICP is an aggregate of euro area inflation rates.

that pass-through is between 30 percent and 50 percent for industries in the USA. However, the results show an insignificant ERPT to iron and steel industries in the UK. Similarly, pass-through in food, metal and textile industries is almost insignificant in Japan. Their results also indicate a different degree of pass-through across industries and countries as expressed in Campa *et al.* (2005).

Przystupa and Wróbel (2011) find pass-through to be incomplete both in the short and long run for Poland. Their evidence also rejects the presence of ERPT asymmetry between depreciation and appreciation of the currency. However, the results show asymmetry to consumer prices with respect to the degree of volatility in the exchange rate. This difference in the size implies that high fluctuations in exchange rate cause a different degree of pass-through as compared to small variations.

Cheikh and Louhichi (2014) analyse ERPT to consumer prices in 12 euro zone countries using quarterly data over the period 1980 – 2010. The results show different degrees of pass-through across countries. For instance, 10 percent depreciation in currency in Portugal causes an 8.4 percent change in consumer prices and 5.8 percent in Greece. However, the same 10 percent change leads to only 2% change in consumer prices in Finland, France and Germany.

2.3.2 Empirical Evidence on Developing Economies

Unlike developed economies, the investigation of ERPT in developing economies has only started to attract interest in recent years. Aron, Creamer, Muellbauer and Rankin (2014) observe the growing of empirical literature on ERPT in developing countries in recent years. These studies (Mihaljek & Klau 2001; Rowland 2004; Nogueira 2007; Bussière & Peltonen 2008; Karoro *et al.* 2009; Omisakin 2009; Parsley 2010; Ocran 2010; Aron *et al.* 2012; Masha & Park 2012; Aron *et al.* 2014; Ellyne & Hearn 2014) cover various issues. Others are on ERPT to import, producer or consumer prices. There is also a mixture of analysis at both disaggregate and aggregate price level.

Mihaljek and Klau (2001) analyse the degree of ERPT in 13 emerging economies including South Africa. They use an OLS model to estimate pass-through to import and consumer prices. The authors find that fluctuations in exchange rate are highly and contemporaneously correlated with domestic inflation rather than with changes in import prices (Mihaljek & Klau 2001: 69). The results indicate that domestic inflation is highly correlated with import price variations in the same quarter for Mexico, Turkey and South Africa. This compares with Poland and Hungary where inflation is highly correlated with previous quarter import price changes. The findings also show that import price and exchange rate changes have almost the same effect on consumer prices in Chile, Malaysia, South Africa and Turkey. However, Hüfner and Schröder (2002) criticised the use of an OLS model by Mihaljek & Klau (2001). The authors note that an OLS model does not adequately account for the non-stationarity of data which is usually the case for macroeconomic variables.

Using an unrestricted VAR model to analyse the degree of ERPT to domestic inflation in Colombia (monthly data, 1983 – 2002), Rowland (2004) finds a strong pass-through to import prices. Within a year, 80 percent of the change in exchange rate would have been transmitted to import prices with only 28 and 20 percent of the change passed to producer and consumer prices respectively.

The high degree of ERPT in Rowland's (2004) study is also supported by Choudhri and Hakura (2006). Their study on emerging and developed economies shows that the degree of pass-through is generally higher in developing economies than in developed economies. Choudhri and Hakura (2006) argue that this disparity is caused by differences in the inflation environment, that is, developing economies seem to be experiencing higher levels of inflation than developed economies. Bussière and Peltonen (2008) highlight the role of the inflation environment but from a different perspective. They argue that once problems of currency crises and high inflation are controlled for in emerging economies, the degree of ERPT in emerging and developed economies is closely comparable. Their study is based on 28 emerging economies which were compared to 13 developed economies.

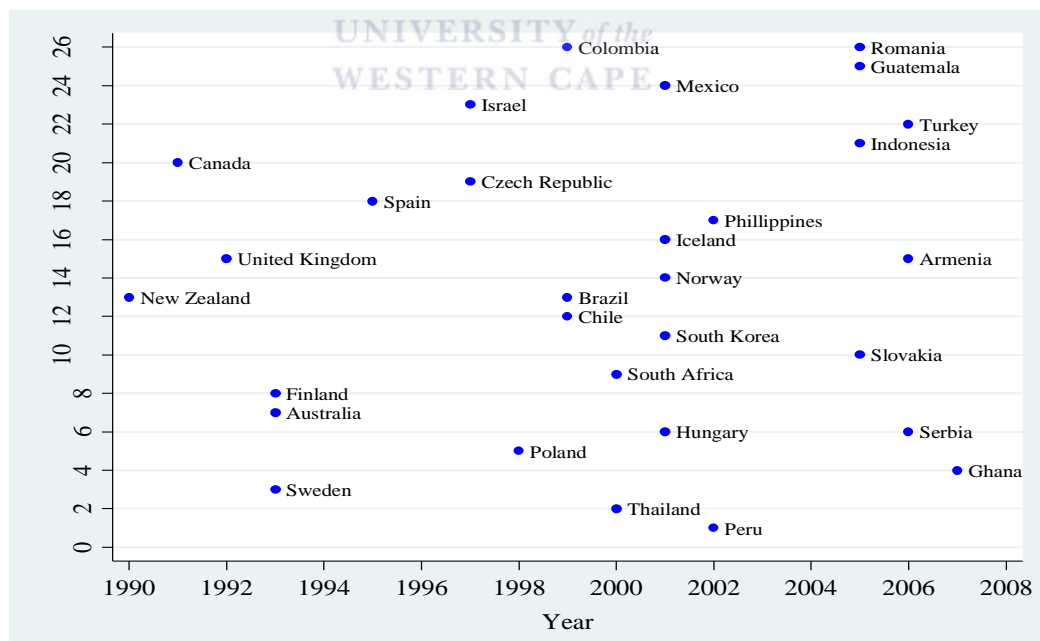
Wimalasuriya (2006) uses two models to estimate the degree of ERPT in Sri Lanka, a log-linear regression model and a VAR model. The results from the log-linear

model indicate that approximately 50 percent of all changes in exchange rate are transmitted to import prices. Using the VAR model, Wimalasuriya (2006) finds that the degree of pass-through to producer prices (input, trade and wholesale producer prices) is complete. However, the degree of pass-through to consumer prices is only 30 percent.

Ito and Sato (2006) analyse the effect of exchange rate changes on import, producer and consumer prices in East Asia⁴. The findings indicate that pass-through is largest in import prices and smallest for consumer prices. In Indonesia, producer and consumer prices experience the highest responsiveness to exchange rate shocks.

Nogueira (2007) uses an Autoregressive Distributed Lag (ARDL) model to examine the impact on pass-through of shifting to an inflation targeting framework. The study is a cross-country analysis of emerging or developing economies that adopted inflation targeting (inclusive of South Africa).

Figure 2:5: Inflation Rates at the Time of Adoption of Inflation Targeting Framework across Countries



Own computations using data from Roger (2009; 2010)

⁴ South Korea, Thailand, Indonesia, Malaysia, Singapore

Besides showing a decline in pass-through to both producer and consumer prices, the results indicate that the degree of pass-through to producer prices is higher than to consumer prices. Figure 2.5 above provides an overview of the different inflation rates across countries at the time they shifted to inflation targeting regimes.

Omisakin (2009) follows a similar methodology as McCarthy (2000) to estimate the magnitude of pass-through to domestic prices and output in Nigeria. The variance decomposition results show that exchange rate shocks have an insignificant effect on consumer prices. The author establishes that monetary shocks explain changes in domestic inflation better than exchange rate shocks. Another study in Africa is by Mwase (2006). Mwase's (2006) study is on pass-through in Tanzania over the period 1990 – 2005. The VAR estimates show that inflation rate declined during the 1990s despite the country experiencing depreciation of its currency. The author attributes this nonconventional result to structural and macroeconomic reforms implemented in Tanzania during the same period. Measures such as increased competition, tighter monetary policy and increased productivity helped to reduce the speed and magnitude of ERPT.

Razafimahefa (2012) provides a comprehensive study of ERPT in sub-Saharan Africa. The results show that the average degree of ERPT in sub-Saharan Africa is 40 percent. However, the magnitude is reported to be lower in countries maintaining flexible exchange rate regimes. Similar to observations in other studies (Taylor 2000; Choudhri & Hakura 2012; McCarthy 2000; McCarthy 2006) the degree of pass-through in sub-Saharan Africa has declined in the last two decades. Razafimahefa (2012) establishes that pass-through has declined by approximately 50 percent since the mid-1990s. The author credits the decline in pass-through to transformations in political and macroeconomic environments in sub-Saharan Africa.

Similar to Omisakin (2009), Masha and Park (2012) use McCarthy's (2000) methodology (VAR with pricing along the distribution chain) to estimate the degree of ERPT to consumer prices in Maldives. The results show that pass-through to consumer prices is 79 percent within a year. This high degree of ERPT is expected since Maldives is a small and open economy which heavily relies on imports. The findings in Masha and Park (2012) contradict Sweidan's (2013) results in Jordan,

another small and open economy. Even though Sweidan (2013) concludes that fluctuations in exchange rate and oil prices are the main determinants of domestic inflation, ERPT is still moderately low. In the short run, oil price shocks have a higher effect (29%) on import prices than exchange rate shocks (13%). However, in the long run, both exchange rate and oil price shocks have an effect on import prices of 13 percent.

Beckmann and Fidrmuc (2013) estimate the degree of pass-through in 7 Commonwealth of Independent States (CIS)⁵ using monthly data during the period 1999 – 2010. The results show that pass-through is relatively high especially for small and open economies which are more reliant on imports or have a high level of dollarisation. In Kyrgyzstan, Ukraine and Moldova, the degree of short run ERPT is between 50 and 70 percent by the twelfth month. The authors note that changes in the USA dollar seem to have a more pronounced effect on consumer prices than changes in the euro. In the long run, pass-through is about 60 percent.

2.3.3 Empirical Evidence on South Africa

Literature on ERPT with a specific focus on South Africa only started in the last 15 years with the first study by Nell (2000). However, since then many studies have been done both at disaggregate price level (Swanepoel & Rangasamy 2004; Parsley 2010) and aggregate price level (South African Reserve Bank (SARB) 2002; Bhundia 2002; Karoro *et al.* 2009; Ocran 2010; Ellyne & Hearn 2014). There are studies also on pass-through to import prices (Aron *et al.* 2012) or all the domestic prices (Ocran 2010; Karoro 2007; Aron *et al.* 2014; Ellyne & Hearn 2014).

Using Distributed Lag (DL) and ARDL models, Nell (2000) examines the impact of exchange rate depreciation on inflation in South Africa during the period 1973 – 1998. The author finds a pass-through in the long run of 82 percent and 72 percent in levels and rates of change respectively (Nell 2000: 20). The study also analyses whether the drivers of inflation in South Africa have changed over the years. This is motivated by the fact that the country adopted a more market-oriented exchange rate

⁵ These states include Armenia, Belarus, Azerbaijan, Moldova, Kazakhstan, Kyrgyzstan, Tajikistan, Russia and Uzbekistan. Also included are Turkmenistan, Ukraine and Georgia even though they are not members of CIS

system along with structural, political and institutional changes during this period. Nell (2000) finds that the long-run causes of inflation have changed. The long-run path of inflation was mainly driven by demand-pull factors during the period 1973 – 1983 as compared to cost-push factors over the period 1987 – 1998.

SARB (2002) uses a VECM to estimate pass-through of exchange rate to import prices in South Africa. The results indicate that changes in exchange rate have a gradual impact on import prices. For instance, 10 percent depreciation in the rand led to a 0.46 percent increase in import prices within a month of the shock. However, in the long run 78 percent of the exchange rate shock is transmitted to import prices with 50 percent of the adjustment occurring in less than twelve months.

Another study which was done in the same year is that by Bhundia (2002). The author uses a six variable recursive VAR model to estimate the degree of ERPT to import, producer and consumer prices. The magnitude of ERPT to import prices was moderate at about 40 percent. For consumer prices, the focus was on CPIX inflation especially between the period 2000 and 2001. The findings show that the degree of pass-through from import price shocks (due to exchange rate changes) to producer prices is high, almost complete within eight quarters. Moreover, the results indicate that a 10 percent increase in producer prices lead to a 7.5 percent increase in consumer prices. This degree increases to 8.5 percent in the long run (Bhundia 2002: 9).

In comparison, the degree of pass-through from import price shocks to consumer prices is very low; only 3.5 percent in the long run. The possible causes cited in the study for the low transmission of import price shocks to consumer prices are that consumers may be substituting imported goods with local products. Another conclusion from the study was that the degree of ERPT seems to decline along the distribution chain. The degree is highest in descending order to import prices, then producer prices and then consumer prices. Ghosh and Rajan (2009: 61) note that ERPT to consumer prices is lower than to import and producer prices because consumer prices include non-tradable goods which are affected by other factors such as market structure and the distribution channels.

Karoro *et al.* (2009) use a Johansen maximum likelihood approach based on a VAR model to estimate pass-through. The authors use different proxies to represent an exporting firm's production costs. The findings indicate that the long run ERPT to import prices is between 75 percent and 82 percent depending on the exporter's production costs. Karoro *et al.* (2009) also rejected the null hypothesis of no asymmetry in South Africa. The results reveal that depreciation of the rand causes a higher pass-through (72%) than for appreciation (64%). However, Aron *et al.* (2012: 10) criticise the methodology that the two lags used in their VAR model are too short for monthly data and the results may be biased because they did not control for structural breaks.

Ocran (2010) uses an unrestricted VAR model to estimate ERPT to domestic prices using monthly data over the period 2000 – 2009. The author finds that the speed of ERPT is highest for import prices (40.4 % after 7 months), followed by producer prices (26.5%) and then consumer prices (9.8%). The findings of a declining pass-through along the distribution chain are consistent with Bhundia's (2002) findings.

Parsley (2010) argues that studying ERPT at aggregate price level is likely to lead to biased results. The weights and composition of price indices (import, producer and consumer price indices) usually change over time and these indices fail to control for this demerit. Therefore, the author selected a panel of products which are analysed over time concentrating on South Africa's major trading partners⁶. The results reveal that ERPT to import prices is between 38 percent for imports from Japan and 75 percent from Brasil and the USA. However, ERPT to consumer prices is very low (14% - 27%). China has the lowest degree of ERPT to goods but the degree of pass-through is higher for services than other countries.

In terms of methodology, Aron *et al.* (2012) use two models to estimate ERPT to import prices: single equations and Johansen maximum likelihood approach based on a structural VAR (SVAR) model (multiple equations). The study is based on monthly data over the period 1980 – 2009. The findings reveal that short-run pass-through within six months is 21 percent and 31 percent for the SVAR and single equation

⁶ The countries considered as major trading partners are the United States, India, China, Sweden, Germany, Great Britain, Japan, Switzerland, and Taiwan.

estimates respectively. However, the long-run ERPT is 55 percent from the multiple equations as compared to 75 percent for the single equation. Aron *et al.* (2012: 28) highlight that the difference between the estimates of the two models is because SVAR treats exchange rate and labour costs as endogenous variables. Under the single equation, these variables are treated as exogenous variables, thus failing to account for the feedback effect of changes in prices on exchange rate.

More recently, Ellyne and Hearn (2014) and Aron *et al.* (2014) estimate ERPT in South Africa. Ellyne and Hearn (2014) use a SVAR model to estimate ERPT to import, producer and consumer prices over the period 2000 to 2013. The results from the study indicate that 46 percent of the shock in exchange rate is transmitted to import prices but only 10 percent of the same shock is passed directly to consumer prices. However, the pass-through of import price changes to producer prices is high (89%), but only 18 percent of the subsequent change in producer prices is transmitted to consumer prices. In contrast to Ellyne and Hearn (2014), Aron *et al.* (2014) estimate pass-through to consumer prices at disaggregate price level covering about 63 percent of the Consumer Price Index (CPI) weights over the period 2002 to 2007. The OLS estimates show that pass-through to the food category as a whole is about 46 percent after two years.

2.4 Concluding Remarks

ERPT refers to the responsiveness of domestic prices to exchange rate shocks. A shock to the exchange rate can be passed to domestic prices either entirely or partially (incomplete ERPT). It is also possible that different magnitudes of exchange rate shocks can lead to different degrees of pass-through. Similarly, currency depreciation may have a different impact on domestic inflation as compared to a currency appreciation of the same magnitude (ERPT asymmetry). It is important for policy makers to understand the impact of exchange rate on domestic inflation because fluctuations in exchange rate are one of the determinants of inflation.

A high degree of ERPT may complicate the conduct of monetary policy by weakening the demand management policies. It can also complicate inflation forecasting which is important for ensuring price stability especially for inflation-

targeting countries such as South Africa. Understanding the process of ERPT is important for policy making decisions as well as assessing the potential burden on the macro economy.

From a review of the literature, there are two transmission mechanisms of ERPT. The channels can be classified as along the distribution chain in that exchange rate shocks affect import prices, then import prices affect producer prices which in turn affect consumer prices or direct versus indirect channels of pass-through. The direct channel is similar to transmission of exchange rate shocks along the distribution chain but the indirect channel is the effect of changes in exchange rate on domestic inflation via its effect of demand. The speed and magnitude of ERPT via these channels is influenced by various factors such as the volatility of the exchange rate, pricing behaviour of firms, product substitutability, inflation environment and market structure.

There is a general consensus from empirical evidence that ERPT is mostly incomplete regardless of the level of advancement of the country. However, most studies find that ERPT is higher in developing economies than in developed economies. Also most countries have experienced a decline in pass-through over the years. The degree of pass-through differs significantly across countries. Some countries are experiencing an ERPT as high as 85 percent (a 10% variation in the exchange rate leads to 8.5% change in a given domestic prices) whilst other countries are experiencing as low as 20 percent.

The results on pass-through in South Africa are fairly mixed. Besides being fairly mixed, the results also depend on whether the study is on aggregate or disaggregate price level or which stage of the distribution is being analysed. In general, all the studies reviewed in this study report that the degree of pass-through in South Africa is incomplete. The majority of the studies establish an ERPT to import prices between 40 percent and 55 percent, with ERPT to producer and consumer prices below 30 percent and 20 percent respectively.

CHAPTER 3

3 METHODOLOGY AND DATA

3.1 Introduction

The next section covers a discussion of the approaches which are commonly used in the estimation of the speed and degree of exchange rate pass-through (ERPT). These approaches include the Ordinary Least Squares (OLS), Vector Autoregressive (VAR), Vector Error Correction (VEC), Bayesian VAR (BVAR) and Dynamic Stochastic General Equilibrium (DSGE) models. After discussing these approaches, Section 3.3 reviews the data measurement challenges that are encountered in estimating ERPT. This is followed by a general discussion on data. Lastly, Section 3.5 provides concluding remarks.

3.2 Approaches to Estimate ERPT

Over the years, the preferred technique to estimate ERPT has been changing constantly. As noted in Chapter 2, OLS regressions were the dominant methodology prior to the 1980s. However, various criticisms of the OLS method led to the development of new techniques such as the VAR (Sims, 1980s), BVAR and DSGE models. The development of these models was made possible by new developments in econometric modelling such as improvements in computational abilities due to the technological revolution. However, these new methods have their own weaknesses.

In recent years, DSGE modelling has become the preferred macroeconomic tool. Mwase (2006: 9) identifies the single equation econometric models, VARs, Vector Error Correction Models (VECMs), structural macroeconomic models and DSGE models as the economic techniques which are being broadly used to estimate ERPT.

Some scholars (Devereux, Engel & Storgaard 2004; Bouakez & Rebei 2008; Marmolejo 2011; Choudhri & Hakura 2012) have also used DSGE models to estimate ERPT to domestic prices, that is, import prices, producer prices and consumer prices. Amongst all the above methods, there is no consensus between the

scholars as to the most ideal approach to estimate ERPT since all the methods have different strengths and weaknesses. In the context of ERPT, this section aims to review the commonly used models and also discuss their respective strengths and weaknesses.

3.2.1 Ordinary Least Squares (OLS) Models

A regression analysis is an econometric tool that is used to explain deviations of a variable under investigation from its mean using other variables (Andren 2007: 33). In the case of ERPT, movements in domestic prices can be explained by variations in exchange rate and other variables. Before the 1980s, the common approach to estimate these regressions was through a method called ‘Ordinary Least Squares’ (OLS)⁷. This method is one of the most popular and dominant regression estimation techniques due to its attractive statistical properties and relative simplicity (Gujarati 2004: 58).

It is often impractical to analyse population regression thus the use of sample regressions to estimate the population parameters. Using a sample, the OLS aims to estimate a curve that represents the average relationship of the observation data (Andren 2007: 38). The aim is to minimise the residual sum of squares of the vertical distance between the regression curve and the observed data (Maddala 1992: 69).

According to Hill, Griffiths and Lim (2011: 51) the reason for the squaring of residuals is to avoid large positive residuals cancelling the large negative residuals. In other words, the squaring of the residuals makes sure that all the residuals (deviations) which are used in the computation of the parameters are positive and thus negative residuals do not cancel out positive residuals (Brooks 2008: 33). The OLS parameter estimates must satisfy the Gauss Markov Theorem, in that they must be Best Linear Unbiased Estimators (BLUE).

Menon (1995: 222) observes that the majority of the previous scholars used OLS to estimate ERPT. The author highlights that many of these scholars failed to take cognisance of the nature of time series data. For instance, Nelson & Plosser (1982:

⁷ The method of OLS is credited to a German mathematician, Carl Friedrich Gauss.

140) observe that many macroeconomic time series and asset prices are non-stationary. Similarly, Hüfner and Schröder (2002: 6) criticise the failure to take into account the non-stationarity of data under OLS regressions by some studies. These criticisms are considered important because the prerequisite for using OLS regressions is that the model must be linear in parameters and the residuals should show no signs of serial correlation (Brook 2008: 38). Unfortunately, non-stationary time series data often lead to non-linear parameters thus making OLS regressions unsuitable as methods of analysis.

Using non-stationary data in estimating an OLS regression might create a problem of spurious regressions⁸ (Menon 1995: 223). A spurious regression is usually identified by a high R^2 and significant t -statistics when in reality the results have no economic meaning (Enders 1995: 216). In support, Murray (1994: 38) argues that regressing two unrelated and non-stationary variables mostly leads to rejection of the null hypothesis of no relationship between the variables. This rejection is mainly because the regression coefficients are usually small compared to their standard errors (Murray 1994: 38). Moreover, estimating simultaneous equations using OLS often leads to biased estimates except in the case of recursive system of equations (Maddala 1992: 387).

Menon (1995: 223) points out that due to the non-stationarity of data, many of these previous studies are likely to be biased. The evidence cited by Menon (1995) to substantiate this problem is the presence of high R^2 and low Durbin-Watson (DW) statistics in the majority of the studies. Hendry (1986: 203) notes that R^2 which is greater than the DW statistic shows a likelihood of the relationship under analysis to be spurious. The problem of non-stationarity of data has forced many scholars to move away from the use of OLS especially in time series analysis.

3.2.2 Vector Autoregressive (VAR) Models

The VAR models were pioneered by Sims (1980) as a step to overcome some of the econometric challenges of the models of that time especially OLS models. According

⁸ The term “spurious regression” refers to a regression which shows significant relationship between variables when there is no economic relationship in reality. This term was proposed by Granger and Newbold (1974).

to Watson (1994: 2844) Sims (1980) showed that a VAR model provides a more tractable and flexible framework to handle economic time series analysis. Moreover, Sims (1980: 2) criticises the fact that simultaneous equations were based on exogeneity assumptions on some of the variables in the model. It is important to treat variables on equal footing especially where there is real simultaneity among the given variables (Gujarati 2004: 848). Therefore, one of the aims of VAR models is to solve the simultaneity bias challenge in many models.

Mirdala (2014: 12) defines a VAR model as a dynamic system of equations. In this system, the current level of variables depends on their past movements as well as all the other variables in the dynamic system. In other words, all variables are endogenous and are explained by their own past values and the lagged values of other endogenous variables in the system (Gujarati 2004: 837). Stock and Watson (2001: 101) precisely define a VAR model as an:

n-equation, n-variable linear model in which each variable is in turn explained by its own lagged values, plus current and past values of the remaining $n - 1$ variables.

The VAR model helps to describe the dynamic structure of variables in the system (Lütkepohl 2011: 2). In addition, Rebucci (2010: 1183) also highlights that VARs are useful in analysing and summarising dynamic correlations among variables of interest, particularly in macroeconomics.

As mentioned above, one of the advantages of VAR models is that there is no need to distinguish between endogenous and exogenous variables since all the variables are treated as endogenous (Davidson & MacKinnon 1993: 684). The categorisation of variables into endogenous and exogenous often brings a challenge. Sometimes theory is vague thus making the process of classifying variables into endogenous and exogenous challenging (Brooks 2008: 291). Moreover, VAR models are more flexible since the value of variables in the model depends not only on their own lagged variables but a combination of white noise terms and other lagged variables (Brooks 2008: 291). This characteristic of VAR models makes it possible to analyse ERPT into a set of domestic prices such as along the distribution chain (Ito & Sato 2006: 9).

A VAR model also allows the identification of structural shocks through a Cholesky decomposition of the innovations in the model (Ocran 2010: 296). This approach helps to analyse the elasticity of domestic prices to the exchange rate orthogonalised VAR innovations (Choudhri & Hakura 2012: 5). The orthogonalised VAR innovations focus on the response of domestic prices to various exogenous shocks. The robust structure of these models makes them ideal for capturing more features of the data. According to Gujarati (2004: 853) the estimation of VAR models is simple since the OLS method can be used to estimate each equation in the model separately (e.g. Stulz, 2007). However, Brooks (2008: 291) argues that the OLS technique can only be used in the absence of contemporaneous terms on the right hand side of the equations. The VAR models also generate better forecasts than many traditional structure models or complex simultaneous-equation models (Brooks 2008: 292; Gujarati 2004: 853).

Irrespective of their superiority over the OLS models and some simultaneous equations, VAR models have their own identification, estimation and statistical inference challenges (Watson 1994: 2844). VAR models are criticised for being a-theoretical because they use little theoretical information in specification of model relationships between variables (Brooks 2008: 292; Enders 2015: 313). In addition, it is also difficult to choose an appropriate lag length for a model. Even though there are several approaches to finding an appropriate lag length, they often do not give the same outcome. With regard to ERPT, Choudhri and Hakura (2012: 5) argue that exchange rate innovations characterise a composite of structural disturbances that are difficult to identify.

The other debate is centered on whether all the variables in a VAR model should be stationary. Brooks (2008: 292) asserts that if the aim is to conduct statistical significance of the coefficients, then the series in the model should be stationary. If the series are non-stationary, stationarity may be induced by transforming the variables through differencing (Gujarati 2004: 853). However, many scholars (Lütkepohl 2005; Brooks 2008) argue against differencing the variables because it does not serve the purpose of the model. The main purpose of estimating VARs is to analyse relationships between variables (Brooks 2008: 293). However, differencing

the data series has the effect of throwing away all the long-run information on relationships between the variables (Stroe-Kunold & Werner 2009: 914). Using a first difference VAR model instead of VECM is likely to lead to misspecification if there are cointegrated relationships between the variables (Ca' Zorzi *et al.* 2007: 11). In general, VAR models seem to do well in data description as compared to policy analysis (Stock & Watson 2001: 102).

To circumvent the shortcomings of VAR models, some scholars used VECMs (Frankel, Parsley & Wei 2005; Sweidan 2013; Cheikh & Louhichi 2014) or Bayesian VARs (Donayre & Panovska 2015). The argument is that VECMs are more suitable for long-run analysis in the presence of cointegrated relationships between variables. On the other hand, Bayesian VARs are more robust (depending on the set priors) than VARs in forecasting and policy analysis (Ciccharelli & Rebucci 2003: 3 – 4).

3.2.3 Vector Error Correction Models (VECM)

The concept of non-stationarity in time series became predominant in the 1970s. To deal with this challenge⁹, Brooks (2008: 337) states that scholars independently take the first difference of the non-stationary time series. The first differenced time series is then subsequently used in econometric modelling. The differencing of variables is important because most macroeconomic time series are non-stationary in level terms (Nelson & Plosser 1982: 140). This means that the option to difference the variables provides an approach to circumvent the challenge of using non-stationary data series. The transformation of variables to stationarity before any analysis is important because using non-stationary data is likely to lead to spurious regressions (Hendry 1986: 204).

A majority of macroeconomic series are integrated of order one, $I(1)$, hence can be made stationary through first differencing. However, Granger (1981: 128) observes that it is possible for two or more time series to be individually of order one but with linear combination(s) integrated of order zero, $I(0)$. In such cases, the variables are assumed to be cointegrated (Davidson & MacKinnon 1993: 716).

⁹ Conducting time series analysis with non-stationary data can lead to spurious regressions.

According to Asari *et al.* (2011: 53) the existence of cointegrated relationships among variables points to a long-run relationship among the variables under analysis. The presence of long-run relationships is regardless of any short-term divergence among the variables. The cointegration between variables inhibits the use of VARs because it will lead to spurious regressions; thus the preference for VECM. The concept of cointegration and the use of VECM was pioneered by Granger (1983) and Engle and Granger (1987) respectively (Johansen 2014: 1). Zeugner (2002: 8) argues that VECMs are special forms of VARs pioneered to specifically accommodate non-stationary variables which are cointegrated. Hill *et al.* (2011: 503) define a VECM as a multivariate dynamic model which has the capacity to incorporate cointegrated relationships among variables.

Like VARs, VECMs are also a useful tool in economic forecasting (Lastrapes 2001: 5). Contrary to VARs, VECMs can accommodate the analysis of both short-run and long-run correlations between variables in instances where variables are cointegrated. This implies that a VECM has the capability to avoid the problem of losing long-run information as is the case under VARs (Brooks 2008: 293). However, Ca' Zorzi *et al.* (2007: 12) argue that choosing a wrong cointegration vector to impose on the VECM may lead to inconsistent estimates. Authors such as Frankel *et al.* (2005), Sweidan (2013), Cheikh and Louhichi (2014) among others used VECM to estimate ERPT.

3.2.4 Bayesian Vector Autoregressive (BVAR) Models

The strength of VARs lies in identification because they avoid the imposition of 'incredible' restrictions (Sims 1980: 3). However, this strength creates two problems (Ciccharelli & Rebucci 2003: 3). Firstly, unrestricted VARs require the estimation of a large number of parameters which often leads to over-parameterisation of the model (Bańbura, Giannone & Reichlin 2008: 8). The likelihood of over-fitting in VARs makes them susceptible to losing degrees of freedom thus resulting in inefficient estimates (Ciccharelli & Rebucci 2003: 3). Ciccharelli and Rebucci (2003: 3) succinctly express the second challenge that:

...using reduced form VARs to avoid imposing identification restrictions on the contemporaneous causation among the variables of interest one may not go beyond a simple description of the data.

To address these problems, many scholars (Doan, Litterman & Sims, 1984; Litterman, 1986a) propose the use of Bayesian VAR (BVAR) methods.

In Bayesian VARs, the problem of over-parameterisation can be solved through shrinkage. According to Koop and Korobilis (2009: 2) shrinkage can be achieved either through shrinking the parameters towards zero or by imposing restrictions on the parameters. Bayesian VAR methods use informative priors which help to provide a consistent and logical method of imposing parameter restrictions (Koop & Korobilis 2009: 2).

In contrast to standard VAR models, Bayesian VARs treat parameters as random variables and then prior probabilities are assigned to the random variables. This process helps to shrink an unrestricted VAR model to a parsimonious naïve benchmark hence maintaining degrees of freedom. The other difference with VARs is that under BVARs, the empirical model and theory work closely together (Brooks 2008: 599). At the beginning, a researcher assesses existing knowledge and formulates the knowledge into probabilities. Then based on Bayes' theorem, the probabilities are combined with observed data using a likelihood function (Brooks 2008: 599). The combination is then updated during the model estimation phase consequently yielding a set of *posterior* probabilities.

The Minnesota prior proposed by Litterman (1986b) is the most commonly used Bayesian procedure in BVAR analysis. Kadiyala and Karlsson (1993: 365) also make the same observation. However, other priors such as the Normal-Wishart prior, Natural conjugate prior and Normal-diffuse prior are also generally used in imposing Bayesian priors (Kadiyala & Karlsson 1993; Ciccarelli & Rebucci 2003; Koop & Korobilis 2009; Tahir 2014).

Although VARs are good for hypothesis inferences, they are usually not parsimonious and have higher chances of providing unrealistic forecasts (Bessler & Kling 1986: 145). The possibility of providing unrealistic forecasts is what led to the

growing interest in the use of BVARs (Carriero, Clark & Marcellino 2015: 46). In support, Ciccarelli and Rebucci (2003: 3) assert that BVARs produce better forecasts than structural models or reduced form VARs or univariate autoregressive moving average processes. Apart from providing better forecasts, BVARs can also accommodate the analysis of large models¹⁰ without running out of degrees of freedom (up to some point) like standard VARs (Koop 2013: 178). The estimation of large BVARs has also become more feasible due to the continual development of computational tools over the years (Koop & Korobilis 2009: 2).

Irrespective of their superiority, BVARs still require decision making with respect to the specifications of optimal lag length, treatment of non-stationary variables, shrinking procedures and imposition of cross-variable shrinkage (Carriero *et al.* 2015: 47 – 48). Brooks (2008: 599) highlights that many statisticians criticise the Bayesian approach because the prior probabilities are often set based on a researcher's personal judgment. Not only is this a disadvantage, but mistakenly setting too strong priors is likely to require a lot of evidence to derive meaningful results from the BVAR model. In addition, Berg (2015: 1) also criticises the *status quo* in BVARs research for concentrating on point and density forecasts for distinct series while overlooking analysis of co-movements in major variables. For ERPT, it is important to use a model that can help to assess the co-movement in exchange rate and domestic prices. The co-movement of these variables such as inflation and GDP growth are of particular interest to policymakers in their policy making decisions.

Since this study focuses on the structural analysis of ERPT instead of forecasting (in which BVARs are more robust), the difference of structural results with reduced form VARs is likely to be insignificant. Moreover, it seems the BVARs are rarely used in literature (e.g. Donayre & Panovska, 2015) to estimate ERPT.

3.2.5 Dynamic Stochastic General Equilibrium (DSGE) Models

The last fifteen years have been characterised by major progress in the estimation and specification of DSGE models (Tovar 2009: 1). This progress as well as the

¹⁰ These models can estimate as many as 130 variables in a single model (Koop 2014: 178).

superiority over other models in policy analysis has created interest in their use. Improvements in the modelling capabilities of computing tools due to technological advancements have also made it simpler to use DSGE models. Tovar (2009: 1) argues that DSGE models can help to predict and forecast the effects of policy changes, identify sources of fluctuations, clarify structural change issues and perform counterfactual experiments. The analysis of ERPT is no exception to this recent bandwagon effect. Studies such as Devereux, Engel and Storgaard (2004), Corsetti, Dedola and Leduc (2005), Bouakez and Rebei (2008), Devereux and Yetman (2010), Marmolejo (2011), Choudhri and Hakura (2012) used DSGE models to estimate the degree and speed of ERPT.

The estimation of DSGE models is mainly through two ways; either through econometric estimation or calibration. Tovar (2009: 14) highlights that calibration methods were the dominating approach since the invention of the DSGE models. For instance, Bouakez and Rebei (2008: 256) calibrate the parameters of their DSGE model in analysing whether ERPT has declined in Canada. However, in recent years, econometric estimation has become the preferred approach in estimating DSGE models (Del Negro & Schorfheide 2004: 644). These econometric estimation techniques include Maximum likelihood, Generalised method of moments, Simulated methods of moments and Bayesian methods (Ruge-Murcia 2007: 2599 – 2600). Of the econometric estimation techniques, Ruge-Murcia (2007: 2600) observes that most scholars tend to favour the Bayesian methods in recent years.

Compared to VARs, DSGE models are superior in that they provide a coherent and precise framework of the source of each restriction. Unlike DSGEs, VARs impose fewer restrictions which makes it challenging to extract a proper story for some of the model's predictions (Tovar 2009: 22 – 23).

The major criticism against DSGE models is that they are too complex and this creates a natural barrier for communicating their results (Tovar 2009: 2). In other words, the models require well-trained economists with a strong understanding of modelling, statistical and programming skills. The DSGE models have also been questioned by scholars such as Sims (2006) for being too stylised to properly describe dynamics in data. Instead, Sims (2006: 7) argues that using prior beliefs

about parameters in DSGE models to generate prior and posterior distribution for the parameters of a VAR is a promising direction. This path was proposed by Del Negro and Schorfheide (2004).

In terms of prediction power, DSGE models are performing just as well as other traditional models. For instance, DSGE models perform fairly the same as VARs in forecasting. These DSGE models are often complex and tend to introduce unnecessary interactions. In addition, parameter identification and model misspecification often lead to biased estimates (Tovar 2009: 3). Although parameter identification is a prerequisite to the estimation of parameters in DSGE models, this area is yet to be properly explored by scholars. Moreover, big scale DSGE models may be very tedious to estimate all the parameters and this leads to a problem called ‘curse of dimensionality’ (Tovar 2009: 23). Despite VARs performing generally better in forecasting than DSGE models, they also suffer from the problem of dimensionality. The problem of dimensionality is generally common to most analyses involving time series data. An effort to further improve DSGE models therefore is likely to make them more complex and difficult to handle, analyse, understand and communicate the results.

This study uses the VAR approach because it is widely used in estimating ERPT and neither of the modern approaches (BVARs and DSGE) offer significantly better structural analysis. Besides their complexities, the more recent modelling approaches do not offer significantly different results from the reduced form VARs or VECM. Therefore, this study proposes that it is unnecessary to attempt to use complex models without significantly improving the results.

To sum up, besides the dilemma a researcher faces with regards to which model to use in estimating ERPT, there are also other data measurement problems. These data measurement problems are the focus of the next section.

3.3 ERPT Data Measurement Challenges

Similar to many other areas of economics, ERPT studies are also confronted with challenges related to selecting appropriate variables, as well as how to best measure

these variables. Menon (1995: 209) identifies the measurement issues in ERPT studies as being related to the measurement of price proxies, exchange rate and data aggregation or disaggregation. This section discusses these three challenges with respect to ERPT studies.

According to Menon (1995: 209) many studies rely on price proxies such as import, export, producer or wholesale and consumer indices. These indices have their own limitations. In addition, many countries do not collect price data for exports and imports which are needed to compute the respective indices (Lipsey, Molinari and Kravis 1990: 2). The lack of data forces most studies to rely on import and export unit values. However, these unit values are flawed because they are inaccurate measurements of individual prices of products and they often overlook changes in the quality of products (Lipsey *et al.* 1990: 2). Moreover, comparisons between countries' ERPT is also misleading because different countries use different weights or index number formulas (Lipsey *et al.* 1990: 2).

Lipsey *et al.* (1990: 3) argue that using the producer, wholesale or consumer price indices are better since they are collected with a higher degree of quality control. However, these three indices also suffer from similar defects discussed above, but they are less severe. The measurement errors are inherited in the construction of all these price proxies. These errors introduce bias in the estimation of ERPT. Menon (1995: 2009) also argues that the discrepancy between true measurements and proxies is significant enough to raise concerns over the accuracy of price proxy estimates.

Similar to challenges of measuring prices, Menon (1995) cites a number of authors who discussed the challenge in the computation of exchange rate. These cited scholars include: Woo (1984), Klein and Murphy (1988), Citrin (1989) and Feinberg (1991). Most studies use a trade-weighted exchange rate index as a proxy for exchange rate. The decision with regard to which currencies to include and the weighting schemes employed to compute the index often leads to under-or overstatement of currency variations (Menon 1995: 209). The commonly used trade-weight proxies are the nominal effective exchange rate (NEER) and the real effective exchange rate (REER). This study uses the NEER which is a trade-weighted proxy of

South Africa's exchange rate with its fifteen major trading partners.¹¹ To analyse ERPT, the NEER is a better proxy to use because REER excludes the impact on inflation which is captured in nominal variables.

Unlike other studies, Athukorala and Menon (1994: 274) propose the use of a contract currency-weighted index as a proxy for exchange rate. The authors assert that a contract currency-weighted index is a better reflection of the exchange rate variations that exporting countries experience. However, their proxy (Athukorala & Menon 1994) can only be used for analysing ERPT at a disaggregated price level. Using this index for aggregate price level analysis is difficult because of the challenges of accessing the data to compute the proxy.

The third challenge with regard to data measurement relates to whether to use aggregate or disaggregate data. Although majority of the studies use aggregate data, Menon (1995: 209) argues that aggregate data suffer from aggregation biases. To justify this, Menon (1995: 209) posits that disaggregate (industry or product or sector level) data is likely to capture accurate estimation of the dynamic movements in prices in response to exchange rate movements. In support, Rossana and Seater (1995: 442) affirm that aggregating data alters the time series characteristics of data through severe loss of information. However, Rossana and Seater (1995) further highlight that aggregating data can help in eliminating high frequency noise that may obscure meaningful properties in data.

As cited in Menon (1995: 209), Citrin (1989) and Lawrence (1990) claim that many of the ERPT uncharacterised trends are primarily caused by data issues than the actual behaviour of exchange rate. Nonetheless, disaggregate data analysis remains prevalent on industry level than at national level. Due to the challenges regarding access to disaggregate data for South Africa, this study uses quarterly aggregate data. Even though the use of higher frequency data such as monthly time series would most probably capture exchange rate variations better, this study uses quarterly data due to the difficulty of accessing the monthly import price index for the entire study period (1980 – 2014). However, Rossana and Seater (1995: 450) report that quarterly

¹¹ Euro Area, USA, China, UK, Japan, Switzerland, Australia, Sweden, India, Republic of Korea, China - Hong Kong, Singapore, Brasil, Israel and Zambia

data does not seem to suffer from high frequency problems of monthly data nor aggregation distortions.

3.4 Model Estimation Techniques

This section covers the issues related to data analysis. Section 3.4.1 discusses the nature of time series data and its implications in econometric modelling and analysis. This is followed by an analysis on long-run relationships in data (cointegration) in Section 3.4.2. Section 3.4.3 covers the approaches or tests generally used in econometrics to test the adequacy of the model to be specified in Chapter 4. The last section focuses on techniques that are commonly used to interpret results from VAR models, that is, impulse response functions and variance decompositions.

3.4.1 Stationarity and Non-Stationarity

According to Granger and Newbold (1986: 3 - 4) a time series is a sequence of observations ordered by a time parameter. Generally, most finance and macroeconomic data is in the form of time series, that is, a series of repeated variable observations over time (Cochrane 1997: 7). Under OLS analysis, one of the important prerequisites is that these time series must be stationary.

Gujarati (2004: 797) defines a stationary series as a ‘stochastic process whose variance and mean are constant over time and a covariance between two time periods that depend only on the lag between the two time periods’. In other words, shocks to a stationary time series should be temporary such that with time the shock dies out and the series will converge back to its long-run unconditional mean (Enders 1995: 212). Granger (1986: 213) notes that a stationary series means the linear properties of the series exist and are time-invariant. The author highlights that a stochastic process is defined as integrated of order (d) generally denoted as $x_t \sim I(d)$ if the process requires differencing (d) times in order to induce stationarity (Johnston & DiNardo 1997: 20). Lütkepohl (2005: 24) defines a stationary series as a process with first and second moments which are time invariant. The process of differencing helps to remove unit roots from the data series. In this perspective, a stationary series is integrated of order zero, $I(0)$ thus does not require any differencing.

As discussed in Section 3.2, using non-stationary variables in their levels to make econometric inferences is likely to lead to spurious regressions (Asari *et al.* 2011: 51; Brooks 2008: 319). Moreover, results from a non-stationary data analysis are only useful to understand the behaviour of the variable under analysis and cannot be used as a generalisation to other time periods (Gujarati 2004: 798). This problem makes non-stationary variables less desirable for forecasting purposes. According to Vinh and Fujita (2007: 11) macroeconomic time series usually experience high degree of persistence. High persistence in data series signals that the data follows a unit root process.

Unlike a stationary series, a non-stationary series does not have a constant mean; rather the series diverges from the mean and its variance increases as the sample size increases (Yaffee & McGee 2000: 6). Johnston and DiNardo (1997: 215) emphasise that it is important to consider possible ways to transform the variable in order to induce stationarity once a series has been identified as non-stationary. A non-stationary series can either be a random walk, random walk with drift or random walk with trend (Yaffee & McGee 2000: 6). A random walk is a stochastic process that experiences random fluctuations similar to a drunkard's walk. In comparison, a random walk with a drift is a series that exhibits sporadic variations around a nonzero mean (Yaffee & McGee 2000: 6). Lastly, a random walk with trend is a series that experiences changes in level over time. However, these changes are difficult to predict from the past movements of the series only (Yaffee & McGee 2000: 6).

The distinction between these random walks is important for data transformation purposes. For example, a random walk with a trend does not need to be differenced to induce stationarity; it can be achieved through de-trending the series (Maddala & Kim 1998: 37). A trend-stationary data generating process (DGP) y_t can be expressed as:

$$y_t = \gamma_0 + \gamma_1 t + \varepsilon_t \quad \dots\dots\dots(3.1),$$

where t is time and ε_t is a stationary process. On the other hand, a difference-stationary process (DSP) can be represented as:

$$y_t = \alpha_0 + y_{t-1} + \varepsilon_t \dots\dots\dots(3.2)$$

Johnston and DiNardo (1997: 215) suggest two principal methods of detecting non-stationary data series. The detection can either be through subjective judgement or through formal tests (Johnston & DiNardo 1997: 215). Detection through subjective judgment involves the use of time series graphical analysis and correlograms. On the other hand, formal methods are statistical tests for presence of unit roots in data series. The number of roots (degree of integration I(d)) a series poses determines the number of differencing the series requires before it is stationary.

3.4.1.1 Graphical Analysis

According to Elder and Kennedy (2001: 139) graphing the data series (time sequence plot) against time should be the starting point in any time series analysis. Graphical analysis provides the easiest way to get a synopsis on the nature and behaviour of a time series. The visual plots help to provide an insight in the nature of the series before formal statistical tests for stationarity are applied (Gujarati 2004: 807). The method also helps in identifying possible trend in data series.

Unfortunately, graphical analysis alone is inadequate to conclude on the nature of the variable; thus formal statistical stationarity tests are required to reach more accurate conclusions (Rachev, Mittnik, Fabozzi, Focardi & Jašić 2007: 246). Brooks (2008: 327) also advises against the use of correlograms, autocorrelation function (ACF) and partial autocorrelation function (PACF) to test for the presence of unit roots. Enders (1995: 212) complements Brook (2008) by arguing that correlograms provide imprecise results. As such, one observer may observe the presence of a unit root whilst another person will interpret the same data series as stationary.

3.4.1.2 Unit Root Tests

According to Brooks (2008: 327) Dickey and Fuller (Fuller 1976; Dickey & Fuller 1979) are the pioneers of statistical unit root testing. Macroeconomists developed an interest in unit roots in an effort to address the issue of how to represent trends in time series (Cochrane 1997: 98). Over the years, unit root tests have become the

common method of testing for stationarity in data series (Gujarati 2004: 814). Unlike graphical analysis, these unit root tests are more objective (Yaffee & McGee 2000: 81).

Nelson and Plosser (1982: 140) and Dolado, Gonzalo and Marmol (2001: 637) concur that most macroeconomic series are non-stationary or integrated of order more than zero. Nelson and Plosser (1982) reached this conclusion after failing to reject the presence of unit roots in several variables they tested. Asset prices such as exchange rates and stock prices are some of the variables which are usually non-stationary (Gujarati 2004: 798). These unit roots in time series are mainly a product of past insistent shocks of different characteristics to the economy (Dolado 1992: 143). The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests are the common methods used in literature to test for the presence of unit roots.

The ADF test is a widely used method due to its general nature and simplicity (Harris 1995: 28). Before the ADF test, Dickey and Fuller (DF test) proposed a simple test based on a data generating process:

$$y_t = \rho y_{t-1} + \mu_t \dots\dots\dots(3.3)$$

The aim is to test the null hypothesis that $\rho = 1$, that is, the data series have a unit root against the alternative hypothesis that the series is stationary ($\rho = 0$). However, in actual practice the above regression is transformed (Brooks 2008: 327) to:

$$\Delta y_t = (\rho - 1)y_{t-1} + \mu_t \dots\dots\dots (3.4)$$

such that the test is for $\rho - 1 = 0$. Hendry and Jeselius (2000: 22) highlight that the DF test struggles to identify the presence of roots especially where the data series have a root close to unit. In addition, the DF test struggles to detect serial correlations in data series in some circumstances (Davidson & MacKinnon 1993: 611). To address these problems, the DF test was extended to an Augmented Dickey-Fuller (ADF) test. The ADF test has the potential to detect higher order autoregressive roots because it is a fine-tuned DF test with an inherit ability to correct for serial autocorrelation in error terms (Gujarati 2004: 817). The ADF test corrects the serial

autocorrelation by including lagged difference values of the dependent variable in the data series. The model for ADF test can be represented as:

$$\Delta y_t = \beta_0 + \varphi t + \phi y_{t-1} + \sum_{i=1}^{k-1} \psi_i \Delta y_{t-i} + \varepsilon_t \dots\dots\dots(3.5)$$

where ε_t is white noise residual term, Δy_{t-i} is the lag differenced values of variable y_t , Δ is the difference operator, $k-1$ is the optimal lag length chosen using an information criterion, φt is time trend parameter, β_0 is the constant term and the ADF coefficient of interest $\phi = \rho - 1$.

Under the ADF test, the null hypothesis is that the series is non-stationary ($\phi = 0$) against an alternative hypothesis of stationarity ($\phi < 0$). If a series is non-stationary, it means previous values of a variable (y_{t-i}) help to predict the path of the current value (y_t). This is a one-sided test. It implies that the more negative the ADF statistic in comparison to the critical values, the higher the chances of the null hypothesis being rejected. A rejection of the null hypothesis means that the variable is stationary but if not rejected then the variable is non-stationary. Under the later, the series should be difference d times ($I(d)$) in order to induce stationarity.

Another test is the Phillips-Perron (PP) test. According to Brooks (2008: 330) the PP test is similar to the ADF test but is more comprehensive by incorporating an automatic correction to the DF test which allows for autocorrelated residuals. However, Brooks (2008: 330) notes that the two methods (ADF & PP) usually provide same results and are constrained by the same limitations.

The main weakness of both tests is that their power is low where the data generating process is stationary (Brooks 2008: 330). This is the case especially where the root is close to the non-stationary ($\phi = 0$) boundary, for instance $\rho = 0.95$. To circumvent this problem, Brooks (2008: 331) proposes the use of these unit root tests together with a stationarity test which acts as a confirmatory test.

The Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test provides a good alternative test to the unit root tests discussed above. Unlike the ADF and PP tests, the KPSS test is one of the methods that assume a null hypothesis of no unit roots, that is, the data series is stationary. One of the advantages of this stationarity test is that, the data series will appear stationary by default where there is little information in the sample (Brooks 2008: 331). As outline by Maddala and Kim (1998: 120), the KPSS test can be analysed using the model:

$$y_t = \delta t + \zeta_t + \varepsilon_t \dots\dots\dots(3.6)$$

where ε_t is a stationary process and ζ_t is a random walk given by:

$$\zeta_t = \zeta_{t-1} + \mu_t ; \mu_t \sim iid(0, \sigma_u^2) \dots\dots\dots(3.7)$$

The null hypothesis of stationarity is formulated as $H_0 : \sigma_u^2 = 0$ or ζ_t is a constant. The aim of the KPSS test is to test for the constancy of parameters against the alternative hypothesis that the parameters follow a random walk process. The main assumption is that the error terms are independently and identically distributed ($\mu_t \sim iid(0, \sigma_u^2)$). Like many studies, this study uses the ADF and PP test as the main test with the KPSS test acting as a confirmatory test. The results of these tests are discussed in Chapter 4.

3.4.2 Cointegration

Hamilton (1994: 571) observes that the concept of cointegration was first implicitly covered in Davidson, Hendry, Srba and Yeo (1978) when the authors were dealing with their work on error correction models. In comparison, Johansen (2014: 1) argues that the concept of cointegration was first explicitly defined by Granger (1983) and later explained by Engle and Granger (1987). In fact, Engle and Granger (1987: 254) posit that a combination of non-stationary processes can have linear combinations that are stationary. In other words, if two or more vectors are individually of integrated order one but there exists a combination which is stationary, the series are said to be cointegrated (Maddala 1992: 588).

Cointegration between variables exhibits the existence of a long-run relationship. This relationship means the variables can drift apart from each other in the short run but they will always revert to their long run equilibrium (Brooks 2008: 336). Thus, cointegrated variables share a similar long-run trend (Hendry & Nielson 2007: 254). A cointegration process is driven by feedback mechanisms which force the process to keep the variables close to each other (Rachev *et al.* 2007: 373). The issue of cointegration is best illustrated by Murray (1994) in the author's discussion of "a drunkard and her dog". Murray (1994: 37) highlights that if one observes the two in the short run, the dog might wander around the road so as the drunkard staggering on her way home. However, a closer observation of the two will show that they both wander towards home (long-run equilibrium).

The differencing of variables to induce stationarity where there is cointegration between the variables has the effect of throwing away valuable information (Enders 2015: 291). Moreover, Rachev *et al.* (2007: 380) assert that caution must be exercised in performing cointegration tests because there are other factors that affect the accuracy of the results. For instance, structural breaks in data series may cause biased results, that is, show presence of cointegration even though there is none or vice versa. This study uses the Chow test to check for the presence of structural breaks.

Cochrane (1997: 113) notes that the interest in understanding cointegration is as a result of the economic interest and statistical reasons that time-series behaviour represents. The cointegration tests have found wide application in economics in testing issues such as rationality of expectations, purchasing power parity, market efficiency and permanent income hypothesis (Maddala 1992: 601). In the literature, the Engle-Granger and the Johansen approach are the two dominantly used methods in testing for the presence of cointegration. Generally, these tests examine the null hypothesis against an alternative hypothesis that:

H_0 : μ has a unit root (The variables are not cointegrated)

H_0 : The variables are cointegrated (the combination is 1(0))

3.4.2.1 Engle-Granger Approach

The Granger representation theorem states that the short-run dynamics of cointegrated variables can be explained by an error correction model (Maddala 1992: 597). The error correction model can be used to combine short-run and long-run forecasts in a consistent fashion (Maddala 1992: 602). Hill *et al.* (2011: 489) postulate that testing for cointegration is similar to testing for stationarity except that cointegration testing involves testing for stationarity of the residuals rather than the variables. According to the Engle-Granger approach, the stationarity of the residuals suggests that the variables are cointegrated.

The Engle-Granger approach is a two-step estimation procedure. The first step involves checking if all the variables are integrated of the same order and then estimating a cointegration model using an OLS regression (Brooks 2008: 341). For instance, assuming variables x and y , the regression can be represented by:

$$y_t = \alpha_1 + \beta_1 x_t + \mu_t \dots\dots\dots(3.8)$$

After estimating the regression, the residuals (μ_t) are tested using the ADF test as discussed in Section 3.4.1. If the variables were of integrated order one, I(1), but the residuals show that they are of integrated order zero, I(0), it means that the variables are cointegrated. The linear combination of the non-stationary variables which is stationary is also known as a cointegration vector.

If the null hypothesis is rejected, which means the variables are cointegrated, the second step of the Engle-Granger approach is to estimate an error correction model. In the model, the residuals are treated as one of the variables. The regression can be represented by:

$$\Delta y_t = \beta_1 \Delta x_t + \beta_2 (\hat{\mu}_{t-1}) + v_t \dots\dots\dots(3.9)$$

where $\hat{\mu}_{t-1} = y_{t-1} - \tau x_{t-1}$.

Similar to unit root testing, the Engle-Granger approach is criticised for the lack of power in cointegration testing (Brooks 2008: 342). The Engle-Granger approach

requires the classification of one variable as dependent and all the other variables as regressors. This means the regression might suffer from simultaneity bias where there is bi-directional causality between the two variables (Brooks 2008: 342). Moreover, it is difficult to perform statistical inferences on the cointegration relationship estimated in step one. Even though the OLS estimators are consistent, they are asymptotically biased and have a nonstandard distribution (Ogaki 1993: 140).

3.4.2.2 Johansen Approach

Johansen (1988) proposes the maximum likelihood procedure for the determination of a cointegration vector in general VAR model with k lags and n variables. According to Maddala (1992: 596) the importance of testing for cointegration especially in VAR modelling systems is that it helps to determine if the model should be estimated in levels or first difference or both complemented with some restrictions. Assuming that there are g variables, a VAR with k lags can be represented as:

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t-2} + \dots + \beta_k y_{t-k} + \mu_t \quad \dots\dots\dots(3.10)$$

In order to test for cointegration using the Johansen test, the VAR above must be transformed to a VECM of the form:

$$\Delta y_t = \Pi y_{t-k} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \dots + \Gamma_k \Delta y_{t-(k-1)} + \mu_t \quad \dots\dots\dots(3.11)$$

where $\Pi = \left(\sum_{i=1}^k \beta_i\right) - I_g$ and $\Gamma_i = \left(\sum_{j=1}^i \beta_j\right) - I_g$

From the VECM above, the Johansen test focuses on analysing the Π matrix. This matrix represents the long-run coefficient matrix because in the long run equilibrium $\Delta y_{t-i} = 0$ (Brooks 2008: 350). The Johansen cointegration test centers on estimating the rank of the Π matrix. Under the Johansen approach, the rank of the matrix can be determined by either the trace or the maximum eigenvalue tests (Dolado *et al.* 2001: 644). The trace test aims to ascertain the null hypothesis that there are less than

or equal to (r) rank cointegrating variables against a general alternative of m cointegrating variables. The m represents the number of endogenous variables in the model. Hendry and Juselius (2001: 23) assert that the trace test distinguishes variables with respect to the number of unit roots the variable poses. The test is estimated by:

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^g \ln(1-\hat{\lambda}_i) \dots\dots\dots(3.12)$$

where r represents the number of cointegrating variables, T is the sample size and $\hat{\lambda}_i$ represents the estimated eigenvalues. If the trace test statistic is greater than the critical value, the null hypothesis (no cointegration) is rejected.

Unlike the trace test, the maximum eigenvalue test aims to detect for the presence of r cointegrating vectors against a specific alternative of $r+1$ cointegrated vectors. However, similar to the trace test, the null hypothesis is rejected if the test statistic is greater than the critical value. The maximum eigenvalue test can be represented by the following equation:

$$\lambda_{max}(r, r+1) = -T \ln(1-\hat{\lambda}_{r+1}) \dots\dots\dots(3.13)$$

Regardless of its wide application in various studies, the Engle-Granger approach is criticised for ignoring the lagged terms especially in small samples which is likely to cause biased estimated parameters (Banerjee, Dolado, Hendry & Smith 1986: 209). Ogaki (1993: 140) also notes the bias of the OLS estimators from Engle-Granger approach. Therefore, this study follows the Johansen approach to check for the presence of cointegrated relationships between the variables. Section 4.3.2 provides a discussion of the cointegration results in this study.

3.4.3 Model Adequacy (Diagnostic Checks) Tests

According to Box and Jenkins (1976: 285) the specification of a model must be followed by tests to evaluate if the model is adequate. The process of identifying misspecifications in a model helps in discovering in what way a model is inadequate and the formulation of appropriate modifications thereof. A desirable model should be able to extract all systematic information from the given data such that the

unexplained residuals follow a white noise process (Rachev *et al.* 2007: 262). As a consequence, most diagnostic checks analyse the behaviour of the residuals of the estimated model. In other words, a well-specified model should show well-behaved residuals, that is, normally distributed, serially uncorrelated and have homoscedastic residuals (Dlamini 2008: 60). Generally, visual plots of the residual series of a model provide a first step in detecting presence of model deficiencies (Lütkepohl 2004: 67).

3.4.3.1 Testing for Serial Autocorrelation

Lütkepohl (2004: 40) postulate that the commonly used methods to test for serial autocorrelation are the Portmanteau and the Breusch-Godfrey (Lagrange Multiplier - LM) tests. As its null hypothesis, the Portmanteau test determines the presence of any remaining residual serial autocorrelation at lags one to h (Lütkepohl 2004: 44). This null hypothesis is against an alternative hypothesis of nonzero autocorrelation(s) in at least one of the residual distributions. In comparison, the Breusch-Godfrey test (used in this study) uses an autoregressive (h) model for the residuals:

$$u_t = u_{t-1} + \dots + \beta_h u_{t-h} + error_t \dots \dots \dots (3.14)$$

From the above residuals, the test checks for the hypotheses that:

$$H_0 : \beta_1 = \dots = \beta_h = 0 \quad H_1 : \beta_1 \neq 0 \text{ or } \dots \text{ or } \beta_h \neq 0$$

3.4.3.2 Testing for Heteroscedasticity

The presence of heteroscedasticity in residuals is detected when the variance of the residuals is not constant over time (Brooks 2008: 445). This study relies on the White test of the residuals as provided in EViews 9. Johnston and DiNardo (1997: 166) point out that the White test is an asymptotic test in which an auxiliary regression of the squared residuals, a set consisting of non-redundant variables of the regressors, respective squares and cross products are computed. The White test checks for the null hypothesis that the residuals are homoscedastic against an alternative hypothesis of heteroscedasticity. The weakness of the White test is that in the χ^2 test, the degrees of freedom may become too large hence reducing the power of the test.

3.4.3.3 Testing for Normality

The Jarque-Bera test is commonly used in time series analysis to detect presence of non-normality in residuals. The test is based on the third and fourth moments, that is, on the skewness and kurtosis of a given distribution (Lütkepohl 2004: 45). The aim of the test is to check if the skewness and kurtosis of standardised residuals are in line with the behaviour of a standard normal distribution. Rachev *et al.* (2007: 266) highlight that skewness, \hat{S} of residual distribution is calculated as:

$$\hat{S} = \frac{1}{T} \sum_{t=1}^T \frac{\hat{\varepsilon}_t^3}{\hat{\sigma}^3} \dots\dots\dots(3.15)$$

and the kurtosis, \hat{K} as:

$$\hat{K} = \frac{1}{T} \sum_{t=1}^T \frac{\hat{\varepsilon}_t^4}{3\hat{\sigma}^4} - 1 \dots\dots\dots(3.16)$$

where T is the number of observations and $\hat{\sigma}$ is the estimator of the standard deviation. If the residual distribution is normal, skewness and kurtosis must have a mean zero asymptotic normal distribution. A rejection of the null hypothesis (normality of residuals) entails the distribution does not have third and fourth moments similar to a standard normal distribution hence the residuals are non-normal.

3.4.4 Structural Analysis

According to Brooks (2008: 296) coefficients of VAR models are often difficult to interpret. The author states that:

some lagged variables may have coefficients which change sign across the lags, and this, together with the interconnectivity of the equations, could render it difficult to see what effect a given change in a variable would have upon the future values of the variables in the system.

Therefore, Ajilore and Ikhida (2013: 376) highlight that this difficulty can be avoided through the construction of impulse response functions and variance decompositions to trace the dynamic structure of the model. In short, these econometric tools help to determine whether exchange rate movements have a positive or negative effect on domestic prices and the speed such effects take to reflect in the economy (Mnjama 2011: 65).

3.4.4.1 Impulse Response Functions

VARs can be expressed as a vector of moving average (Enders 2015: 294). As proposed by Sims (1980) representing a vector autoregressive into a vector moving average helps to trace the path of different shocks on the variables contained in the VAR model. Thus, impulse response functions assist in tracing the persistence of shocks from exchange rate changes to domestic prices.

Brooks (2008: 299) highlights that separate shocks can be introduced on each variable in the system. The effect of these shocks on each of the other variables in the model can then be traced over time. These shocks can be observed as one-period responses to unit changes in the error terms or as cumulative effects of unit impulses (Hamilton 1994: 318). Cumulated responses are derived from appropriate summation of the coefficients of the impulse response functions. Importantly, these shocks must be finite thus should converge to zero over time because they cannot have permanent effects on generally stationary variables. The decaying of the shocks overtime is likely to happen if the whole system is stable; thus stability of the model matters in producing accurate impulse responses.

To a large extent, the results that are derived from impulse response analysis depend on the ordering of the variables. The estimation of these impulses is often imprecise hence the inclusion of confidence intervals around the impulses to capture the inherit parameter uncertainty in the estimation process. Lütkepohl (2005: 62) argues that:

...if the model has important omitted variables, this usually leads to major distortions of the impulse responses thus making structural interpretation worthless.

Given a system with g variables, g^2 impulse response functions can be derived from the system.

3.4.4.2 Variance Decompositions

Another complementary tool to analyse the relationship between variables in a VAR or VECM system is the use of variance decompositions. Variance decompositions help to explain the proportion of variations in a sequence due to shocks from other variables as well as own shocks (Enders 2015: 302). The presence of own shocks is

based on the assumption that shocks to a variable usually have an effect on that variable first before causing disturbances to other variables in the system (Brooks 2008: 300).

3.5 Data and Description of Variables

This study uses quarterly data from the first quarter of 1980 (1980Q1) to the fourth quarter of 2014 (2014Q4). In terms of exchange rate policy, South Africa moved from a fixed exchange rate regime to a floating (managed) exchange rate framework in 1979. Therefore, the year 1980 is chosen as the starting date of analysis because this helps to avoid the problem of fixed-to-floating regime shift (Aron *et al.* 2012). The study uses quarterly data instead of higher frequency monthly data because of the unavailability of the monthly import price index, a variable which is central in the model proposed in Chapter 4. With the exception of the interest rate and output gap all the variables are expressed in logarithmic form (Logs). Table 3.1 provides a descriptive summary of all the variables and their sources.

Table 3.1: Description of Variables and Data Sources

Variable	Data Measurement and Source
Crude oil (LOIL)	The Brent crude oil price is used as a proxy for fluctuations in the world price of crude oil. The crude oil price is sourced from the International Monetary Fund (IMF), International Financial Statistics on the IMF website. However, the index is expressed in USA dollars (USD) (Index, 2010 = 100) thus the South African rand (ZAR) /USD exchange rate is used to convert the crude oil price from dollars to rand terms. The rand/dollar exchange rate is also sourced from the IMF, International Financial Statistics. In the model, movements in crude oil price capture aggregate supply side shocks.
Nominal Effective Exchange Rate	The nominal effective exchange rate (NEER) index is used as a proxy to capture movements in the exchange rate. This index is a weighted average based on consumption of, and

(LNEER)	trade in, manufactured goods between South Africa and its 15 major trading partners ¹² . A decrease in the index indicates periods of rand depreciation and vice versa (rand appreciation) for increase in the index. The source of the index is IMF International Financial Statistics, Index 2010 = 100.
Output Gap	<p>The gross domestic product (GDP) is used to derive an output gap series to capture volatility in output. An output gap series is generated from the GDP using a standard Hodrick-Prescott (HP) Filter¹³ data smoothing technique in EViews 9. The output gap represents the deviations of actual output from potential output within a given period. Before computing the output gap, the GDP series is expressed in logarithmic form.</p> <p>Similar to crude oil prices (supply side shocks), the output gap captures demand side shocks in the model. The source of the quarterly GDP data is the South Africa Reserve Bank (SARB), seasonally adjusted at an annual rate. The variable is series KBP6006D on the SARB website.</p>
Import Price Index (LIMP)	The import price index is a proxy for import prices and captures the import component of production prices. The variable is sourced from SARB and is time series KBP5035L (Foreign trade: Imports of goods and services: Prices indices), Index 2010 = 100.
Producer price Index (LPPI)	The producer price index is a proxy for producer prices. The series is a quarterly average of monthly producer prices and sourced from Statistics South Africa (StatsSA) data files,

¹² Euro Area, USA, China, UK, Japan, Switzerland, Australia, Sweden, India, Republic of Korea, China - Hong Kong, Singapore, Brasil, Israel and Zambia

¹³ This study follows many other studies (e.g. Bhundia 2002; Ito & Sato 2006; Stulz 2007; Ocran 2010; Masha & Park 2012) who used the HP filter to derive the output gap.

	Index 2012 = 100.
Consumer price Index (LCPI)	The consumer price index is a proxy for consumer prices. The data series is also a quarterly average of monthly consumer prices (CPI headline). The index is sourced from StatsSA data files, Index 2012 = 100.
Interest rate (Prime_rate)	<p>Generally, many central banks around the world react to inflationary developments in an economy. This study uses the prime rate as a proxy for movements in the short-term interest rate. Although the repurchase (repo) rate would have been the ideal rate to mimic a reactionary function of SARB, the series is only available from 1999.</p> <p>Thus, the data span is insufficient for the time period under consideration (1980Q1 – 2014Q4). Ocran (2010: 299) assumes that the prime rate is closely related to the policy rate (repo rate). Therefore, this study uses the prime rate instead of the repo rate. The data is sourced from the IMF, International Financial Statistics.</p>
Dummy95q1	Dummy variable for trade liberation in South Africa. Dummy95q1 = 1 from 1995 to 2014 and 0 otherwise. The dummy variable is included in the model to control for a structural break ¹⁴ in data.
Dummy08q3	Dummy variable to control for the global financial crisis, dummy08q3 = 1 from 2008 to 2014 and 0 otherwise. The dummy variable is included in the model to control for a structural break in data.

As discussed in Section 3.3, where possible, the selection of proxy variables is informed by the different challenges. The three price proxies (import, producer and

¹⁴ The Chow test for structural breaks is used to determine the presence of structural changes in the data series.

consumer) are price indices instead of unit value indices. The choice of using the NEER as a proxy for exchange rate is because it is the generally used proxy in many ERPT studies. Most of the variables in Table 3.1 are also used in other studies and this helps in ensuring comparability of results even though the time periods of analysis may differ.

3.6 Concluding Remarks

Over the last four decades, the techniques used to estimate ERPT have been changing from OLS regressions to the most recent development of DGSE models. The changes have been necessitated by the shortcomings of the older models as well as advancement in computational ability due to technological developments.

Even though the most recent development is the DGSE models, this study prefers to estimate the speed and degree of ERPT using an unrestricted VAR approach. This VAR model is complemented by a VECM. The complexity of BVAR or DSGE models is one of the reasons for this preference. Moreover, the results of the BVAR and DSGE models are not significantly different from the standard VAR model results. In particular, DSGE models do not address the main criticisms of VAR models in a similar way to how VARs overcame the non-stationarity and simultaneity challenges of the OLS regressions. Due to this reason, VAR models continue to be the most preferred econometric method in estimating ERPT.

It has also been established that, apart from the challenge of selecting a model to use, ERPT studies also have the challenge of data measurement. The decisions of whether to use aggregate or disaggregate data, which price proxies to use, or how to measure the exchange rate have a direct effect on the end results. This study uses a VAR model to analyse the speed and magnitude of ERPT. The VAR model is then complemented by a VECM. Due to accessibility of data challenges, the study also uses quarterly aggregate data and price indices as proxies for domestic prices. To capture more exchange rate shocks, the study uses the NEER, which is a weighted index of currencies as opposed to a rand/dollar exchange rate.

The next chapter specifies the unrestricted VAR model used to estimate ERPT. Given the presence of cointegration between the variables, the chapter also outlines the VECM used to estimate long-run pass-through. After proposing the models, Chapter Four provides an analysis of the various tests (e.g. stationarity tests, lag length, cointegration) and the econometric results from the estimation of ERPT.



CHAPTER 4

4 ECONOMETRIC MODEL AND RESULTS

4.1 Introduction

The main aim of this study is to empirically estimate the speed and magnitude of exchange rate pass-through (ERPT). This chapter introduces the models and the results thereof. Section 4.2 specifies the Vector Autoregressive (VAR) baseline model proposed by McCarthy (2000) to estimate the speed and magnitude of ERPT. Moreover, Section 4.2 outlines the restrictions of the VAR model as well as its shortcomings and discusses another complementary model; a Vector Error Correction Model (VECM).

Next is Section 4.3 which analyses results from different econometric tests and results from the above models. Conclusions of the models' results are deduced from structural examination of impulse response functions and variance decompositions. The results from the two baseline models are also compared to other models to check the robustness of the estimates. The results show the estimates of ERPT as well as the pass-through (PT) of import price shocks and producer price shocks to consumer prices. Finally, Section 4.4 provides the chapter's concluding remarks.

4.2 Model Specification

According to Faruqee (2006: 66) a VAR approach simplifies the analysis of joint historical time series behaviour of exchange rate and prices. Therefore, this section proposes a VAR model to estimate the ERPT. VAR models are primarily classified into three categories, namely structural, reduced form and recursive VARs.

A structural VAR (SVAR) model uses economic theory in order to identify the contemporaneous relationships between variables (Brooks 2008: 296). The SVAR has n structural parameters and $n - 1$ reduced form parameters. Due to this imbalance, the model parameters cannot be identified unless at least one restriction is imposed on the system (Zivot 2000: 3). Generally, economic knowledge is often not

rich enough to suggest the optimal identification restrictions (Zivot 2000: 3). The difference between the number of structural parameters and the reduced form parameters means that an Ordinary Least Squares (OLS) approach cannot be used to estimate the model. Thus, the best approach is to use a reduced form system to estimate the SVAR model. Unlike structural VARs, reduced form VAR models express each variable as a linear function of past values of other variables and its own past values. Then each linear function can be estimated using the OLS technique.

In comparison to the two types of VARs above, a recursive VAR aims to identify the structure of the model, as such economic knowledge is only important in deciding the order of the variables. The identification process is through constructing the error term in each regression such that it is uncorrelated with the error term in the previous equation(s). This identification is achieved through estimating the functions of the model by including in some of the functions contemporaneous values of other variables as regressors.

This study uses a recursive VAR approach to estimate the speed and magnitude of ERPT. The recursive structure makes it easier¹⁵ to trace the impact of exchange rate variations on the three domestic prices (import, producer and consumer prices) and it is the most commonly used methodology in the literature. Solow (2001: 111) recommends that a good methodology ought to be correctly specified, simple and plausible. Thus, the presence of cointegrated vectors between the variables necessitates the transformation of the VAR model into a VECM.

4.2.1 Recursive VAR Model

According to Ito and Sato (2006: 9) the use of Cholesky decomposition on VARs makes it easier to identify structural shocks. In contrast to single-equation-based approach which can only analyse ERPT to a single price index, a VAR technique allows the investigation of ERPT to a composite of domestic prices. In other words, the approach enables an analysis of ERPT into more than one price index such as

¹⁵ Standard VAR models do not properly accommodate this type of analysis but recursive VARs allow the estimation of both the speed and magnitude of ERPT.

along a distribution chain – import price index, producer price index then consumer price index. An and Wang (2012: 365) outline a standard VAR model of the form:

$$Y_t = \Gamma_0 + \sum_{i=1}^n \beta_i Y_{t-i} + \mu_t \dots\dots\dots(4.1)$$

where Y_t is a 7 x 1 vector of variables (price of crude oil, exchange rate, import price index, output gap, producer price index, consumer price index and interest rate), μ_t is a one-step-ahead prediction error with variance-covariance matrix Σ and a constant Γ_0 . However, the aim of this study is to understand the relationship between exchange rate fluctuations and domestic prices (import, producer and consumer prices) thus a standard VAR model does not adequately provide this analysis.

Hyder and Shah (2004: 7) assert that a recursive VAR approach is better suited to examine ERPT to domestic prices. Many studies (Bhundia 2002; Hyder & Shah 2004; Rowland 2004; Ito & Sato 2006; Stulz 2007; Ca' Zorzi *et al.* 2007; Jankov, Krznar, Kunovac & Lang 2008; Omisakin 2009; Ocran 2010; Cozmâncă & Manea 2010; Mash & Park 2012; An & Wang 2012; Tandrayen-Ragoobur & Chicooree 2013) use a recursive VAR model. In particular, they follow a recursive VAR system proposed by McCarthy (2000) in order to accommodate the examination of ERPT along a distribution chain. According to Cozmâncă & Manea (2010: 27), McCarthy's (2000) recursive VAR model is well suited to analyse both the speed and magnitude of ERPT. Like the studies above, this study follows the recursive VAR model pioneered by McCarthy (2000). McCarthy (2006) also provides an update study using the same model.

The recursive VAR model by McCarthy (2000) examines prices along the distribution chain (import, producer and consumer) to analyse ERPT at each stage of the distribution chain. The model is anchored on a number of assumptions. Inflation at each stage in period t is assumed to consist of five components. Firstly, the expected inflation at each stage is based on the information available at the end of the previous period ($t - 1$). The second component captures the effect of a period's domestic 'supply' shocks on inflation at each stage. Then the third component is the

effect of that period's domestic 'demand' shocks on inflation at each stage. Exchange rate shocks on inflation at each stage constitute the fourth component. Finally, there are previous stage shocks on the chain and own-stage shocks in the current period.

Besides the above components, the model assumes that shocks at each stage represent the proportion of that stage's inflation that cannot be accounted for by last period ($t-1$) information, contemporaneous information about domestic supply and demand variables, exchange rate and previous period inflation of the distribution chain. McCarthy (2000: 6) argues that the shocks can be assumed to represent dynamics in the pricing power and mark-ups of firms at each respective stage. Also absent from the model are contemporaneous feedback effects, that is, a variable down the distribution chain does not have immediate effect on a variable up in the model except through influencing expected inflation in the next period ($t+1$)¹⁶. Moreover, shocks to import prices can pass through (PT) to consumer prices either directly or indirectly via their impact on producer prices. Under these assumptions, McCarthy (2000) presents the following model:

$$\pi_{it}^{oil} = E_{t-1}(\pi_{it}^{oil}) + \varepsilon_{it}^s \dots\dots\dots(4.2)$$

$$\tilde{y}_{it} = E_{t-1}(\tilde{y}_{it}) + a_{1i}\varepsilon_{it}^s + \varepsilon_{it}^d \dots\dots\dots(4.3)$$

$$\Delta e_{it} = E_{t-1}(\Delta e_{it}) + b_{1i}\varepsilon_{it}^s + b_{2i}\varepsilon_{it}^d + \varepsilon_{it}^e \dots\dots\dots(4.4)$$

$$\pi_{it}^m = E_{t-1}(\pi_{it}^m) + \alpha_{1i}\varepsilon_{it}^s + \alpha_{2i}\varepsilon_{it}^d + \alpha_{3i}\varepsilon_{it}^e + \varepsilon_{it}^m \dots\dots\dots(4.5)$$

$$\pi_{it}^p = E_{t-1}(\pi_{it}^p) + \beta_{1i}\varepsilon_{it}^s + \beta_{2i}\varepsilon_{it}^d + \beta_{3i}\varepsilon_{it}^e + \beta_{4i}\varepsilon_{it}^m + \varepsilon_{it}^p \dots\dots\dots(4.6)$$

$$\pi_{it}^c = E_{t-1}(\pi_{it}^c) + \gamma_{1i}\varepsilon_{it}^s + \gamma_{2i}\varepsilon_{it}^d + \gamma_{3i}\varepsilon_{it}^e + \gamma_{4i}\varepsilon_{it}^m + \gamma_{5i}\varepsilon_{it}^p + \varepsilon_{it}^c \dots\dots\dots(4.7)$$

$$r_{it} = E_{t-1}(r_{it}) + \varphi_{1i}\varepsilon_{it}^s + \varphi_{2i}\varepsilon_{it}^d + \varphi_{3i}\varepsilon_{it}^e + \varphi_{4i}\varepsilon_{it}^m + \varphi_{5i}\varepsilon_{it}^p + \varphi_{6i}\varepsilon_{it}^c + \varepsilon_{it}^{MP} \dots\dots\dots(4.8)$$

where π_{it}^m , π_{it}^p and π_{it}^c represents import, producer and consumer inflation and their respective shocks ε_{it}^m , ε_{it}^p and ε_{it}^c , $E_{t-1}(\bullet)$ are the serially uncorrelated expectations of a variable depending on the information set at the end of the previous period ($t-1$) and they are also uncorrelated with each other in any period. Lastly, ε_{it}^s , ε_{it}^d , ε_{it}^{MP} and ε_{it}^e represent the demand, supply, interest rate and exchange rate shocks respectively.

¹⁶ The position of the variables in the model depends on the chosen ordering of the variables. This ordering is usually informed by economic theory or the value judgment of the researcher.

Equations (4.2)–(4.4) above capture the supply, demand and exchange rate shocks respectively. In the supply equation (4.2) the local currency denominated oil price inflation (π_{it}^{oil}) identifies dynamics in supply side shocks (ε_{it}^s). The demand equation (4.3) captures the dynamics in the output gap (\tilde{y}_{it}) which in turn identify demand side shocks after adjusting for the contemporaneous effect of supply side shocks. After adjusting for both supply and demand shocks, Equation 4.4 identifies exchange rate movements (Δe_{it}) or the exchange rate shocks.

Equations 4.5 to 4.7 show dynamics in domestic inflation, that is, import price inflation, producer price inflation and consumer price inflation respectively. The underlying assumption is that import inflation does not have a contemporaneous effect on oil prices, output gap and exchange rate but it affects producer and consumer inflation contemporaneously. A similar argument holds for producer inflation in relation to consumer inflation or consumer inflation in relation to interest rate. Lastly, monetary policy reacts to exchange rate variations because these fluctuations have the potential to cause price instability. Therefore, Equation (4.8) constitutes the reaction function of the central bank. The short-term interest rate (r_{it}) mimics the monetary policy instrument of the central bank (repurchase rate) and the rate relates to the other variables in the model.

4.2.1.1 *Model Restrictions*

Following McCarthy (2000), Equations (4.2) to (4.8) are estimated by assuming that the conditional expectations ($E_{t-1}(\bullet)$) can be substituted by linear projections on lags of the 7 variables in the system. Under this assumption, the model can be estimated and expressed as a VAR using the Cholesky decompositions to identify distributional shocks. Tandrayen-Ragoobur and Chicooree (2013) provide a more detailed account on how to derive a recursive VAR from a structural VAR as represented by the following steps. Firstly, they illustrate a VAR as represented by the equation below:

$$A_0 Y_t = A(L) Y_{t-1} + \varepsilon_t \dots\dots\dots(4.9)$$

where A_0 is a $n \times n$ matrix which outlines the contemporaneous relationships among the variables, Y_t is a $n \times 1$ matrix of endogenous variables, $A(L)$ is the lag polynomial matrix of infinity order and ε_t represents the unobserved matrix of structural shocks.

Secondly, from Equation (4.9) a reduced form of the model can be derived by multiplying both sides of the equation by A_0^{-1} , an inverse of matrix A_0 . Transforming Equation (4.9) to a reduced form is important because the equation is difficult to directly observe; hence, it provides a challenge in correctly identifying structural shocks (Enders 2015: 292). In this case, a reduced form VAR can be represented as follows:

$$Y_t = A_0^{-1}A(L)Y_{t-1} + \varepsilon_t \dots\dots\dots(4.10)$$

In this reduced form VAR, ε_t is a vector of serially uncorrelated structural errors of the model which can be derived from:

$$A_0 e_t = \mu_t \text{ or } e_t = A_0^{-1} \mu_t \dots\dots\dots(4.11)$$

Enders (2015: 294) states that the residuals can be decomposed in a triangular fashion through a process called Cholesky decomposition.

Thirdly, on the residual variance-covariance matrix, $k(k-1)/2$ restrictions are imposed on matrix A_0 such that the matrix defines A as a lower triangular matrix. Since the Cholesky decompositions are triangular, they impose exactly $k(k-1)/2$ values of the matrix A to be zero. This lower triangular matrix A suggests a recursive scheme among the variables.

The implication of the recursive scheme is that structural shocks have no contemporaneous impact on some endogenous variables depending on the ordering of the variables (Lütkepohl 2005: 59). To clearly illustrate the Cholesky decomposition, equation (4.11) can be represented in a matrix form in which μ_t is a matrix of reduced form VAR residuals. The representation can be depicted as:

$$\begin{pmatrix} \mu_t^{oil} \\ \mu_t^d \\ \mu_t^e \\ \mu_t^m \\ \mu_t^p \\ \mu_t^c \\ \mu_t^{MP} \end{pmatrix} = \begin{pmatrix} s_{11} & 0 & 0 & 0 & 0 & 0 & 0 \\ s_{21} & s_{22} & 0 & 0 & 0 & 0 & 0 \\ s_{31} & s_{32} & s_{33} & 0 & 0 & 0 & 0 \\ s_{41} & s_{42} & s_{43} & s_{44} & 0 & 0 & 0 \\ s_{51} & s_{52} & s_{53} & s_{54} & s_{55} & 0 & 0 \\ s_{61} & s_{62} & s_{63} & s_{64} & s_{65} & s_{66} & 0 \\ s_{71} & s_{72} & s_{73} & s_{74} & s_{75} & s_{76} & s_{77} \end{pmatrix} \begin{pmatrix} \varepsilon_t^{oil} \\ \varepsilon_t^d \\ \varepsilon_t^e \\ \varepsilon_t^m \\ \varepsilon_t^p \\ \varepsilon_t^c \\ \varepsilon_t^{MP} \end{pmatrix} \dots\dots\dots(4.12)$$

Since there are no contemporaneous effects, the ordering of the variables plays an important role in the identification of shocks. McCarthy (2000; 2006) suggests the following ordering:

$$\pi_{it}^{oil} \rightarrow \tilde{y}_{it} \rightarrow \Delta e_{it} \rightarrow \pi_{it}^m \rightarrow \pi_{it}^p \rightarrow \pi_{it}^c \rightarrow r_{it}$$

At the start is the price of oil (supply shocks); the price of oil influences the output gap. The second variable is the output gap which then has an impact on the nominal effective exchange rate. The third variable is the nominal effective exchange rate which in turn influences domestic inflation starting with import prices, then producer prices and lastly consumer prices. The last variable in the distribution is the short-term interest rate which represents the reactionary function of the central bank to inflationary pressures. The underlying assumption of the recursive scheme is that any variable has a contemporaneous effect on all the other variables below it but not vice versa.

Unfortunately, there are no statistical methods to assist with the identification of optimal ordering of the variables. The contemporaneous restrictions discussed above can either be informed by *a priori* theory or based on the value judgment of the researcher (Lütkepohl 2005: 59). In this study, *a priori* knowledge of pricing along the distribution chain informs the ordering of the variables. The ordering of the variables is important because a misinformed order can lead to misleading results. To circumvent the challenge of deriving wrong conclusions due to mis-specified ordering, the best approach is to try a different ordering of the variables. To put it simply, robustness checks can help to minimise the possibility of concluding wrong results.

The empirical framework of the recursive VAR impulse response functions to the Cholesky orthogonalised shocks of exchange rate movements to import, producer and consumer inflation provides estimates of the impact of exchange rate shocks on domestic inflation. Since the main focus of this study is to estimate ERPT, the impulse response of domestic inflation to other variables is not reported. These impulse response functions are complemented by variance decompositions of import, producer and consumer inflation in order to identify the importance of external variables on domestic inflation. The variance decompositions can also help to assess how much of the variation in domestic inflation is attributed to exchange rate variations (Omisakin 2009: 39).

4.2.1.2 Shortcomings of the Model

Bhundia (2002: 6) argues that the ordering above implies that the degree of endogeneity increases down the distribution chain. The shortcoming of this recursive structure is that it is not possible for domestic prices to have a feedback effect on the exchange rate in the same period (Bhundia 2002: 6).

Even though Hyder and Shah (2004) follow the model suggested by McCarthy (2000), they differ with regard to the ordering of the variables. Hyder and Shah (2004) acknowledge the importance of including a central bank reaction function but argue for a different ordering. The authors believe instead of reacting to domestic inflation, central banks often react to expected inflation which is a characteristic of forward-looking behaviour of central banks. Therefore, they suggest that the central bank reaction function (interest rate) should be ordered after the demand shocks but before the exchange rate shocks.

To address the above drawbacks, this study conducts robustness checks by considering different orderings of the variables. These different orders help to identify a more robust conclusion. More so, these checks also provide clarity if considering South African Reserve Bank (SARB) as a reactionary or forward-looking central bank has a bearing on the speed and magnitude of ERPT.

In this context, the term ‘reactionary’ means that the SARB reacts to a rise in inflation by raising interest rates only when the higher inflation figures become available. Such a move will be the opposite of a forward-looking inflation targeting policy where the bank raises interest rates pre-emptively before the actual figures of domestic inflation become available. A forward-looking approach predominantly depend on the bank’s ability to accurately anticipate inflationary trends.

4.2.2 Vector Error Correction Model (VECM)

The analysis of ERPT using the recursive VAR above is also affected by another important underlying assumption: a restriction of zero cointegrated relationships. Kenny and McGettigan (1998: 1151) point out that most time series data used in ERPT studies are cointegrated. For a robustness check, a Johansen cointegration approach is adopted to estimate the existence and number of cointegrated variables in the model. The recursive VAR has a disadvantage in that it does not track well the long-term relationships in the model. Ponomarev *et al.* (2014: 7) highlight that the Johansen procedure using the VECM helps to track long-term relations between the variables. Thus, the VECM allows the drawing of conclusions for both short- and long-term periods.

The standard VAR model in equation (4.1) $Y_t = \Gamma_0 + \sum_{i=1}^n \beta_i Y_{t-i} + \mu_t$ can be transformed into a VECM of the form:

$$\Delta y_t = \Pi y_{t-k} + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \dots + \Gamma_{k-1} \Delta y_{t-(k-1)} + \mu_t \dots\dots(4.13)$$

where y_t is a vector of the endogenous variables, $\Pi = -(I_k - A_1 - \dots - A_p)$ or $(\sum_{i=1}^k \beta_i) - I_s$ represents the long-run relationship(s) between variables and $\Gamma_i = -(A_{i+1} + \dots + A_p)$ or $(\sum_{j=1}^i \beta_j) - I_s$ represents the short-run deviations of the variables from their long-run equilibrium.

This VECM is obtained from equation (4.1) by subtracting y_{t-1} from both sides and then rearranging the terms. The coefficients Γ_i ($i=1,2,\dots,p-1$) are the short-run

parameters and Π is a matrix of long-run parameters of the model. This study utilises these two set of parameters in order to analyse both the short-run and long-run speed and degree of ERPT.

4.3 Main Findings – Econometric Results

4.3.1 Non-Stationarity and Stationarity Tests

As discussed in Chapter 3, before undertaking any empirical data analysis it is important to test if the variables are stationary through conducting unit root tests. This study uses the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to check for unit roots with the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) test acting as a confirmatory test as suggested by Maddala and Kim (1998: 121). The ADF and PP tests help to identify whether a variable is non-stationary (null hypothesis) while the KPSS test aims to ascertain if the variable is stationary (null hypothesis). However, before the actual empirical test, visual inspection of the plotted graphical series can provide important insights into the nature of the variables. Visual inspection (Figure A1 in Appendix) of the variables suggests that most of the variables have unit roots. Nonetheless, it is still important to perform empirical tests because graphical depiction of variables can be misleading.

The ADF, PP and KPSS tests results¹⁷ are presented in Table 4.1. These tests are computed using EViews 9 and all options are explored – intercept only; intercept and trend; and no intercept and trend. The test statistic values are compared to the critical values at 1%, 5% and 10% levels of significance. For the ADF and PP tests, if the absolute value of the test statistic exceeds the absolute critical value, the null hypothesis that a variable has a unit root is rejected. On the other hand, if the critical value in absolute terms is greater than the test statistic, we fail to reject the null hypothesis. This implies that the variable poses a unit root and thus is non-stationary. Unlike the first two tests, the KPSS test for the null hypothesis that a variable is stationary is opposite to the ADF and PP tests as discussed in Chapter 3.

¹⁷ All the variables are in logarithmic form except the prime rate and output gap

With the exception of the output gap and the interest rate, the ADF and PP test statistics indicate that all the variables have unit roots but the variables are stationary in first difference at 1% level of significance. The output gap is stationary at 1% in level for all the tests. However, the prime rate is stationary in level but at different levels of significance, that is; 1%, 5% and 10% for the ADF, KPSS and PP tests respectively. The confirmatory results from the KPSS test also confirm that all the other variables are stationary in first difference.

Table 4.1: Unit Root Test Results

Variables	ADF		PP		KPSS	
	Level	1 st difference	Level	1 st difference	Level	1 st difference
LOIL	2.9549	9.8506***	3.1096	10.4700***	0.2781	0.0446**
Output Gap	5.2363***	13.3188***	5.2797***	14.6074***	0.0251***	0.0548***
LNEER	2.6314	5.2915***	1.9288	10.2606***	0.2689	0.0400***
LIMP	2.1266	10.3677***	2.2886	10.3689***	0.2565	0.0283***
LPPI	1.7145	12.1985***	1.6208	12.3394***	0.3565	0.0827***
LCPI	1.9151	9.5173***	1.6688	9.8154***	0.3700	0.1587**
Prime rate	4.1909***	6.7707***	3.3457*	6.7204***	0.2098**	0.0409***

Note: ***, **, * represents 1%, 5% and 10% significance levels. The lag order was determined by SIC and Bartlett kernel respectively

4.3.2 Cointegration Test Results

Given that most of the variables are non-stationary, estimating a regression with such variables can lead to spurious regressions. As argued by Granger (1986: 216), it is possible that a vector of non-stationary variables may be stationary (cointegrated). In that case, the variables are assumed to have a long-run relationship. Even though they may diverge from each other in the short run, they always converge to a long-run equilibrium (Brooks 2008: 336).

Enders (2004: 288) advises against differencing variables that enter a VAR model if they are cointegrated. Differencing these variables may lead to spurious regressions and throw away important long-run information as noted by Brooks (2008). Nevertheless, a VAR model with differenced variables can provide useful short-run analysis. The presence of this relationship can be tested using the Johansen

cointegration approach. Dolado *et al.* (2001: 643) assert that prior to the cointegration test, it is important to ascertain the optimal lag length of the system.

4.3.2.1 VAR Lag Order Choice

To obtain accurate results, it is crucial to specify the correct number of lags. Imposing too many lags can lead to loss of degrees of freedom and over parameterisation of the model while too few lags may fail to properly capture the dynamics in the model thus leading to omitted variable bias (Ajilore & Ikhide 2013: 374). In this study, the lag length is chosen through a battery of tests provided in EViews 9 to ascertain the optimal lag length for the model. In empirical analysis, most studies rely on the Akaike information criterion (AIC) and the Schwarz information criterion (SIC) to determine the optimal lag length. The Hannan-Quinn information criterion (HQ), Final prediction error (FPE) and sequential modified LR test (LR) are usually used as confirmatory tests. The results for the optimal lag length are presented in Table 4.2.

Table 4.2: VAR Lag Order Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-65.05899	NA	1.43e-07	1.268076	1.663141	1.428609
1	36.67655	189.4921	5.26e-08	0.264480	1.449676*	0.746078*
2	83.16077	82.32319	4.50e-08*	0.104416	2.079742	0.907079
3	115.1306	53.68975	4.84e-08	0.165945	2.931402	1.289674
4	155.6896	64.39909*	4.60e-08	0.096342*	3.651929	1.541136
5	187.9013	48.19457	5.02e-08	0.154179	4.499897	1.920038
6	204.1355	22.80225	7.11e-08	0.455947	5.591795	2.542871
7	227.3352	30.46067	9.20e-08	0.651371	6.577350	3.059361
8	250.2161	27.94617	1.22e-07	0.851662	7.567772	3.580718

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

Unfortunately, the AIC and SIC suggest different lags; four lags and one lag respectively. The FPE suggests two lags whilst the HQ indicates one lag. After a number of iterations, four lags suggested by AIC are robust because they remove

serial autocorrelation in the residuals. The LR test also confirms four lags. The choice of four lags differs from Ellyne and Hearn (2014) who used one lag for quarterly data in South Africa. In theory, four lags seem more reasonable than one lag for quarterly data because it is likely to take more than one quarter for exchange rate fluctuations to pass-through to consumer inflation.

4.3.2.2 *Johansen Cointegration Tests*

Using an optimal lag length of four as suggested by the AIC above, the next step is to test for cointegration. As discussed in the methodology chapter Section 3.4.2, the Johansen cointegration approach uses two tests. The two tests are the trace and maximum eigenvalue tests. Either of the two tests can be used as a benchmark to ascertain the number of cointegrated equations in a model. However, Lütkepohl, Saikkonen & Trenler (2001: 305) argue that the trace test provides more robust results than the eigenvalue test. The null hypothesis is rejected at r rank (number of cointegrating equations) provided the trace or eigenvalue statistic is greater than the respective critical value, or the MacKinnon-Haug-Michelis p – value is less than 5%.

The results are presented in Table 4.3. Choosing option 3¹⁸ in EViews 9, the trace test suggests three cointegration equations while the maximum eigenvalue test reports two cointegration vectors. However, after subtracting the number of stationary variables (output gap and interest rate) there is only one cointegration vector for the trace test and zero for the maximum eigenvalue test¹⁹. The stationary variables create stationary relationships which are likely to be recorded by the two tests as cointegrated relationships even if it should not exist. Therefore, subtracting the number of stationary variables from the estimated cointegrated vectors is primarily to address this challenge.

¹⁸ Intercept and no trend in cointegration equation and test vector autoregressive

¹⁹ The number of cointegration vectors excludes the number of stationary variables in the model. Since the unit root test shows that output gap and interest rate are stationary we subtract two cointegrated vectors from the cointegration results. See Hüfner and Schroder (2002: 10).

Table 4.3: Johansen Trace and Maximum Eigenvalue Likelihood Tests

Hypothesised No. of CE(s)	Trace Statistic	Critical Value	Prob. **	Max-Eigen Statistic	Critical Value	Prob.**
$r = 0$	194.76*	125.62	0.0000	81.32*	46.23	0.0000
$r \leq 1$	113.44*	95.75	0.0018	43.29*	40.08	0.0210
$r \leq 2$	70.16*	69.82	0.0470	28.97	33.88	0.1722
$r \leq 3$	41.18	47.86	0.1829	25.88	27.58	0.0812

Trace and Max-eigenvalue test indicates 3 and 2 cointegrating equations at 5%
 r denotes number of cointegration equations
 *denotes rejection of the hypothesis at 0.05 level
 **MacKinnon-Haug-Michelis (1999) p values

The presence of cointegration relationship(s) signals the existence of a long-run relationship between variables in the model. As such, the study can provide both short-run and long-run analysis of ERPT. However, the dilemma is that the trace test suggests one cointegration relationship (after adjustment) but the maximum eigenvalue test detects no presence of cointegration vectors among the variables. Therefore, this study analyses pass-through using two models. The study uses a VAR model in case there are zero cointegration relationships as suggested by the maximum eigenvalue test. If the variables are cointegrated, the ideal model to use is the VECM; thus the study also analyses the data using a VECM and imposing one cointegrated relationship. The results from the two models are compared and analysed in relation to other studies on pass-through in South Africa.

4.3.3 Residuals Diagnostic Check Results

Besides testing for unit roots and cointegration, a good model should have residuals which are normally distributed, homoscedastic and not serially correlated. More so, the model must be stable. In this regard, Lütkepohl (2005: 24) proposes that generally a stable VAR(p) process is stationary.

To fulfil the stability condition, it must be true that the VAR is an infinite-order vector moving-average and invertible. Table A1 (in Appendix) shows the results of

the roots of a characteristic polynomial. The results indicate that the VAR model is stable thus all roots lie within the unit circle. Tables A2, A3 and A4 (also in appendix) report the results for the tests of serial autocorrelation, normality and heteroscedasticity of the residuals respectively.

Using the Breusch-Godfrey Lagrange-Multiplier (LM) Test, Table A2 indicates that there is no serial autocorrelation in the residuals. This is because at the 4th lag, we fail to reject the null hypothesis of no serial correlation at 5% level of significance. However, the results from the Jarque-Bera normality test using Cholesky of covariance suggest that the residuals are not normally distributed. As shown in Table A3, the joint Jarque-Bera statistic (180.46) rejects the null hypothesis that residuals are multivariate normal at 5% level of significance. Harris (1995: 83) argues that non-normality of residuals is acceptable in cases where some of the variables in the model are weakly exogenous (for instance, supply and demand side shocks). In support, Bangura, Caulker and Pessima (2012: 102) also argue that the test results are still accurate even though they may be slightly biased.

Similarly, the heteroscedasticity test (using the White test) of the residuals shows that the variances of the residuals are not homoscedastic. The results are presented in Table A4. The White test examines the null hypothesis that the residuals are homoscedastic. Maddala and Kim (1998: 61) posit that this is a limitation due to volatility clustering in most exchange rate studies. Figure 2.4 in Chapter 2 indicates the presence of volatility clustering in the rand in South Africa. Despite the presence of heteroscedasticity, Brooks (2008: 135) highlights that the estimators are still unbiased and consistent except that they no longer have minimum variance.

A visual inspection of the residuals in Figure A2 in the Appendix shows that the variances of all the residuals are fairly constant with the exception of the output gap. The output gap experiences high variations from the late 2000s most probably due to the 2008 global financial crisis. Two dummy variables²⁰ are included to address these variations. These are **dummy08q1** which captures the period after the global financial crisis and **dummy95q1** which captures the transformation of South Africa

²⁰ The determination of which significant dummy variables to include in the models is informed by the Chow test for structural breaks.

to open trade policy in 1995. The two dummy variables significantly improve the results of the model. However, the inclusion of dummy variables for the shift to inflation targeting regime in 2000 or the Asian crisis in the late 1990s have insignificant effects on the model results hence they are excluded. The dummy variables are included to control for structural breaks in the data series as suggested by the Chow test.

According to Gujarati (2004: 399) the presence of heteroscedasticity in a model is of concern if the model is intended to be used for forecasting purposes. Dlamini (2008: 61) and Karoro *et al.* (2009: 392) also echo these sentiments. Actually, Gujarati (2004: 426) argues that heteroscedasticity should never be the reason to disregard a good model. Since the purpose of this study is to conduct structural analysis rather than forecasting, there is no reason to believe that the presence of heteroscedasticity lessens the accuracy of the findings.

4.3.4 Structural Analysis of VAR Model Results

The main focus is to determine the speed and magnitude of ERPT to domestic prices. Thus, this study focuses on the impact of exchange rate on the three domestic prices. Besides analysing the pass-through (PT) of exchange rate shocks, the study also provides an estimate of the impact of import price shocks and producer price shocks on consumer prices. The impulse response functions and variance decompositions offer convenient tools to analyse the short-run and long-run speed and degree of PT.

4.3.4.1 Impulse Response Analysis

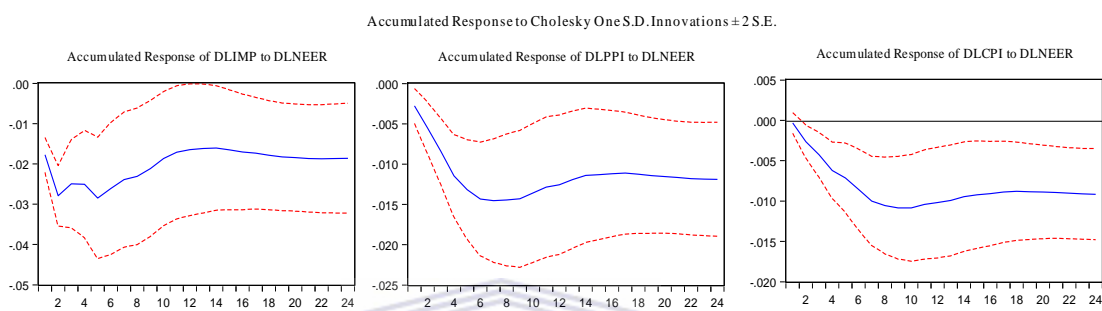
The purpose of impulse response functions is to trace out the effect of the Cholesky orthogonal exchange rate shocks on domestic prices.

Pass-Through to Domestic Prices from Exchange Rate Shocks

Figure 4.1 illustrates the impulse responses of import, producer and consumer price indices to a 1% appreciation in the rand. The impact of an exchange rate shock (appreciation) is traced by the solid lines in the graphs while the dotted lines show the error confidence band (two standard errors) around the estimates. The results in

Figure 4.1 confirm the suggestion in the literature that the impact of the exchange rate shock on domestic prices is negative. Interestingly, the results also confirm the proposition by McCarthy (2000; 2006) of pricing along the distribution chain. The speed and degree of response of the domestic prices to a 1% exchange rate appreciation is different. In descending order, import prices respond quickly and with the biggest magnitude followed by producer prices and then consumer prices.

Figure 4:1: Response of Domestic Prices to 1% Appreciation in the Rand



Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

After a 1% appreciation of the rand, import prices approximately fall by 0.018% immediately. They continue to fall and reach a trough of 0.028% after six months (two quarters) before gradually increasing up to the fourth quarter. In the fourth quarter, they recede again to a trough low of 0.028% before eventually returning towards their initial level.

The response of producer and consumer prices is gradual and slow. The producer price index only drops to its trough of 0.015% after seven quarters. In comparison, the same 1% exchange rate appreciation causes only a 0.011% fall in consumer prices after ten quarters. The import prices also start receding back to its initial level before the producer and consumer prices. In sum, the declining response of domestic prices along the distribution chain is consistent with the model proposed in Section 4.2.

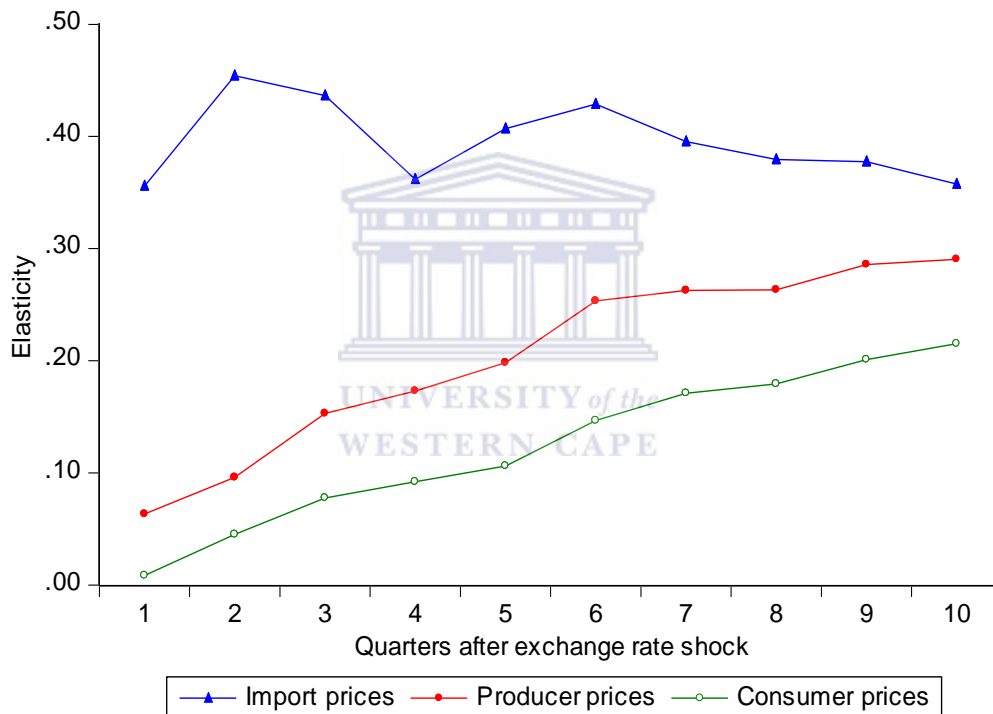
Pass-Through Elasticity of Domestic Prices to Exchange Rate

The most convenient approach to analyse ERPT using impulse response functions is to estimate the pass-through elasticity of the domestic prices. According to Bhundia (2002: 7) the ERPT elasticity at time t can be represented by the following ratio:

$$\text{Pass-through elasticity at time } t = \frac{\text{Percentage change in price level } t \text{ quarters after shock}}{\text{initial percentage change in the exchange rate at } t = 0}$$

The numerator is the percentage change in price level (import, producer or consumer) over some period (t quarters) after the disturbance. In short, it is the percentage change in prices given the initial exchange rate shock. On the other hand, the denominator represents the percentage change in the nominal effective exchange rate at the initial time of the shock ($t=0$).

Figure 4:2: ERPT Elasticities for Import, Producer and Consumer Prices



Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

Table 4.4: VAR Time Profile of ERPT Elasticity for Domestic Prices

Time	$t = 2$	$t = 4$	$t = 6$	$t = 8$	$t = 10$
Import prices	0.45	0.36	0.43	0.38	0.36
Producer prices	0.09	0.17	0.25	0.26	0.29
Consumer prices	0.05	0.09	0.15	0.17	0.22

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

Figure 4.2 above shows the comparability of elasticity of import, producer and consumer prices to a one standard error (approximately 5.1 %). Figure 4.2 shows that exchange rate shocks have a gradual and prolonged impact on consumer prices. The impact on import prices is immediate and pronounced while the effect on producer prices is in between that of import and consumer prices. Exchange rate shocks have the highest impact on import prices (high of 45% after 2 quarters) then on producer prices and the least effect on consumer prices. As mentioned above, this declining rate of pass-through down the distribution chain confirms the proposition by some scholars (McCarthy 2000; Ghosh & Rajan 2007; Choudhri & Hakura 2006) of pricing along the distribution chain. Moreover, the declining results substantiate that exchange rate shocks have a consequently smaller effect on domestic prices along the distribution chain. Ellyne and Hearn (2014: 13) suggest that the successive decline shows evidence of intermediate processing firms choosing to absorb most of the price variations in order to stabilise consumer prices.

The pass-through to import prices peaks at approximately 45% within six months (Figure 4.2) before declining to about 36% during the next six months. This decrease is followed by another increase to about 43% by the sixth quarter before a continuous decrease. However, the effect on producer prices is gradual from 6% in three months to approximately 29% in ten quarters months. Similarly, the impact on consumer prices is also gradual and increasing from 1% in the first quarter to 22% in two and half years. Table 4.4 also provides a summary of pass-through for domestic prices over a period of ten quarters.

Another important deduction from the results above is that ERPT to all domestic prices is incomplete in South Africa. In other words, a 10% depreciation in the exchange rate leads to a less than proportional increase in domestic prices. Rogoff (1996: 665) credits the incomplete PT of exchange rate to adjustment costs that provide a sufficient buffer such that the exchange rate can fluctuate without ensuing an immediate proportional change in domestic prices. These adjustment costs include nontariff barriers, lack of labour mobility, information costs, transportation costs and threatened or actual tariffs. Similarly, Krugman (1987: 49 – 70) asserts that pricing to market by firms can also be the reason that domestic prices do not reflect one for one

to changes in exchange rate (incomplete pass-through). In contrast, Wang (2009: 40) posits that incomplete pass-through is a by-product of how price indices are constructed. In comparison to disaggregated prices, price indices capture movements in prices of both tradable and non-tradable goods and the inclusion of non-tradable goods is the possible source of the partial PT.

The results in this study are consistent with findings of other studies on PT in South Africa. For instance, both Bhundia (2002) and Ocran (2010) found that short-run pass-through peaks at 40% in the third quarter and after eight months respectively. Razafimahefa (2012) also reports an average of 40% pass-through in sub-Saharan Africa. In support, Ellyne and Hearn (2014) show a pass-through of 46% after ten quarters. Similarly, using single equations, Aron *et al.* (2012) establish a PT into import prices in the range of 44% to 55% depending on the model.

Conversely, Nell (2000), SARB (2002) and Karoro *et al.* (2009) established a long-run ERPT to import prices of 82%, 78% and 79% respectively. These results are in sharp contrast to 40% in Bhundia (2002), 20% in Ocran (2010), 46% in Ellyne and Hearn (2014) and 36% in this study. The speed and degree of ERPT to consumer prices is low. For instance, after a year, consumer prices only increased by 12%. Bhundia (2002: 9) notes that the possibility of firms being constrained by the New Keynesian menu cost as frictions in price-setting could be the reason why ERPT is low in South Africa.

Table 4.5: Comparison of Short-run ERPT to Prices in South Africa

Study	Import	Producer	Consumer
Bhundia (2002)	40% 3Q	23% 10Q	12% 8Q
Choudhri & Hakura (2006)	-	-	13% 4Q
Ocran (2010)	40% 8M	27% 7M	13% 24M
Aron <i>et al.</i> (2012)	44% 12M	-	-
Ellyne & Hearn (2014)	45.7% 10Q	24% 8Q	10% 12Q
This study	45% 2Q	25% 6Q	15% 6Q

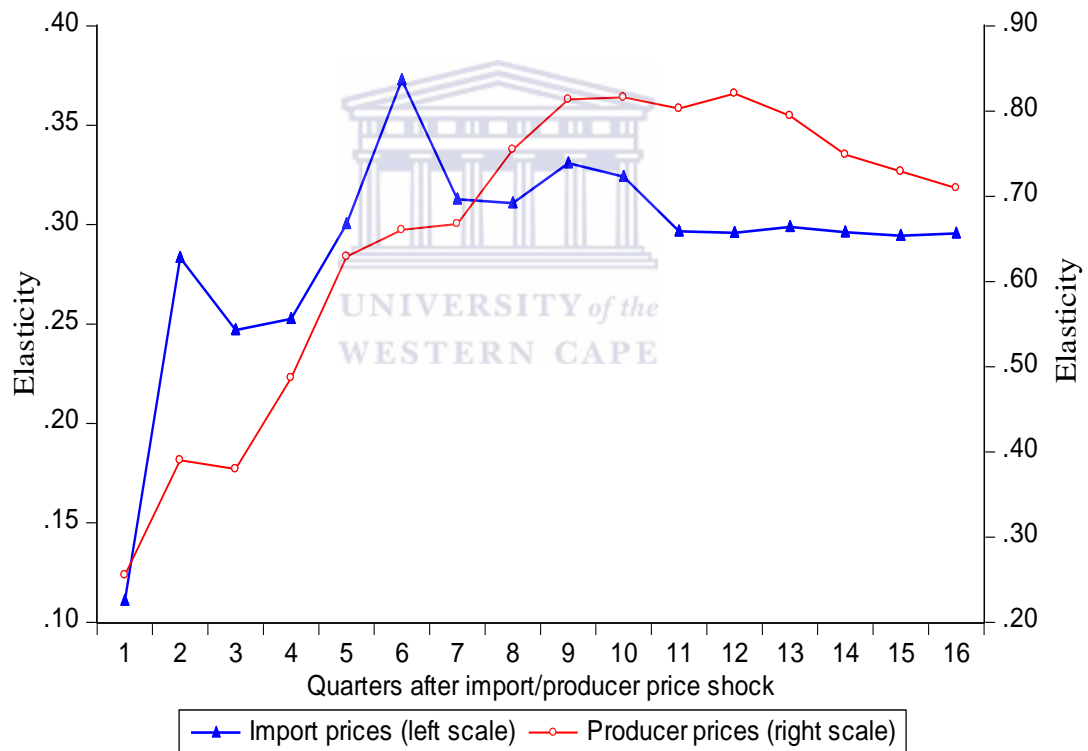
Source: Own compilations from various studies

Besides the findings in Nell (2000), SARB (2002) and Karoro *et al.* (2009) the results across all the domestic prices are in line with other studies. Table 4.5 above provides a comparison of ERPT into domestic prices in South Africa.

Pass-Through to Consumer Prices from Import and Producer Price Shocks

The impulse response functions can also be used to estimate the impact of import price and producer price shocks on consumer prices. McCarthy (2000) classifies this category as the second stage of ERPT. Figure 4.3 shows the elasticity of consumer prices to import and producer price shocks.

Figure 4:3: Pass-Through Elasticities from Import and Producer Price Shocks to Consumer Prices

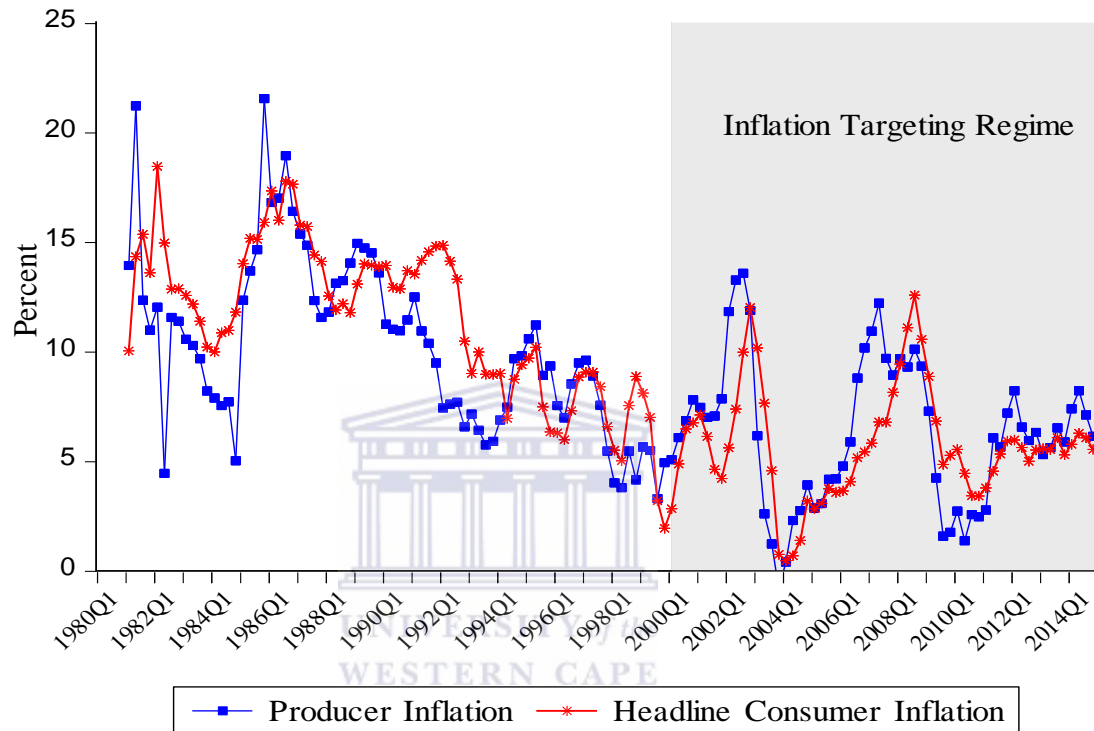


Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

In comparison to exchange rate shocks, the degree of PT from producer price shocks to consumer prices is very high rising up to 75% after eight quarters. In other words, consumer prices increase by 7.5% after a 10% increase in producer prices. In the long run, the degree increases to about 82% in three years. The results are consistent with Bhundia (2002) who finds a pass-through of 75% by the eighth quarter and a

long-run pass-through of 85%. In contrast, Ellyne and Hearn (2014) show a pass-through peak of 19.8% in the long run. The strong correlation between consumer inflation and producer inflation in Figure 4.4 supports the high pass-through from producer price shocks to consumer prices.

Figure 4:4: Consumer Inflation and Producer Inflation, 1980 – 2014



Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

Table 4.6: Comparison of Long-run Pass-Through in South Africa

Study	Elasticity of consumer prices from:	
	Import	Producer
Bhundia (2002)	3.5%	85%
Ellyne & Hearn (2014)	18.5%	19.8%
This study	37%	82%

Source: Own Compilation from Bhundia (2002) & Ellyne & Hearn (2014)

Bhundia (2002) finds a low pass-through of import price shocks to consumer prices of 3.5% in the long run. This study finds a long-run pass-through peak of 37% after six quarters. Ellyne and Hearn also establish a long-run pass-through of 18.5%. Table 4.6 provides a summary of the comparison.

4.3.4.2 Variance Decompositions

The variance decomposition indicates the proportion of movements in a variable in response to own shocks against that of the other variables in the model. In other words, variance decompositions help to provide an analysis of the relative significance of the random shocks in explaining variations in a given variable in the model (Ocran 2010: 303). A variable whose shocks are non-significant in explaining movements in another variable can be classified as fairly exogenous. In this study, the variance decompositions are acting as a complement to impulse response results by decomposing the variations in domestic prices. The variance decompositions of the domestic prices are tabulated in Table 4.7 – 4.9.

The three tables show that exchange rate is important in explaining the variations in all the three domestic prices – import, producer and consumer. Interestingly, for all the three price indices exchange rate shocks are more important in explaining variations in domestic prices than supply side (oil price) or demand side (output gap) shocks. Moreover, in the short run exchange rate shocks are better at explaining variations in import prices than the producer and consumer prices. The producer price shocks contribute the highest variance other than own shocks in explaining consumer prices. Lastly, own price shocks are crucial in explaining variations in all the three price levels.

Table 4.7: VAR Model - Variance Decomposition of Import Prices

Period	Oil price	Output gap	Exchange rate	Import prices	Producer prices	Consumer prices	Interest rate
$t=1$	12.23	9.09	36.06	42.61	0.00	0.00	0.00
$t=4$	16.51	6.81	32.99	35.52	2.43	3.31	2.42
$t=8$	13.79	6.57	33.14	34.64	2.81	6.45	2.59
$t=10$	14.89	6.20	32.13	34.333	2.86	6.54	3.04

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

Table 4.8: VAR Model - Variance Decomposition of Producer Prices

Period	Oil price	Output gap	Exchange rate	Import prices	Producer prices	Consumer prices	Interest rate
$t=1$	11.76	1.93	9.04	3.20	74.08	0.00	0.00
$t=4$	11.48	5.29	30.90	2.26	44.31	1.16	4.59
$t=8$	12.41	4.30	44.77	1.65	32.50	1.04	4.55
$t=10$	13.23	3.85	46.08	1.51	29.68	0.96	4.69

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

Table 4.9: VAR Model - Variance Decomposition of Consumer Prices

Period	Oil price	Output gap	Exchange rate	Import prices	Producer prices	Consumer prices	Interest rate
$t=1$	3.68	2.95	1.26	8.14	9.39	74.56	0.00
$t=4$	5.41	10.76	26.19	6.52	7.40	43.60	0.12
$t=8$	4.57	7.56	37.60	7.23	7.35	33.95	1.72
$t=10$	4.56	7.9	38.60	7.15	6.91	32.64	2.84

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

The variance decomposition results review that supply side shocks (oil price shocks) are relatively important in explaining domestic inflation. Besides oil price shocks and own shocks of domestic prices, exchange rate shocks are also important in identifying domestic price movements. The significance of the exchange rate in explaining domestic prices shown in the results above further strengthen the need to analyse the speed and size of ERPT especially for monetary policy purposes.

4.3.5 Structural Analysis of VEC Model Results

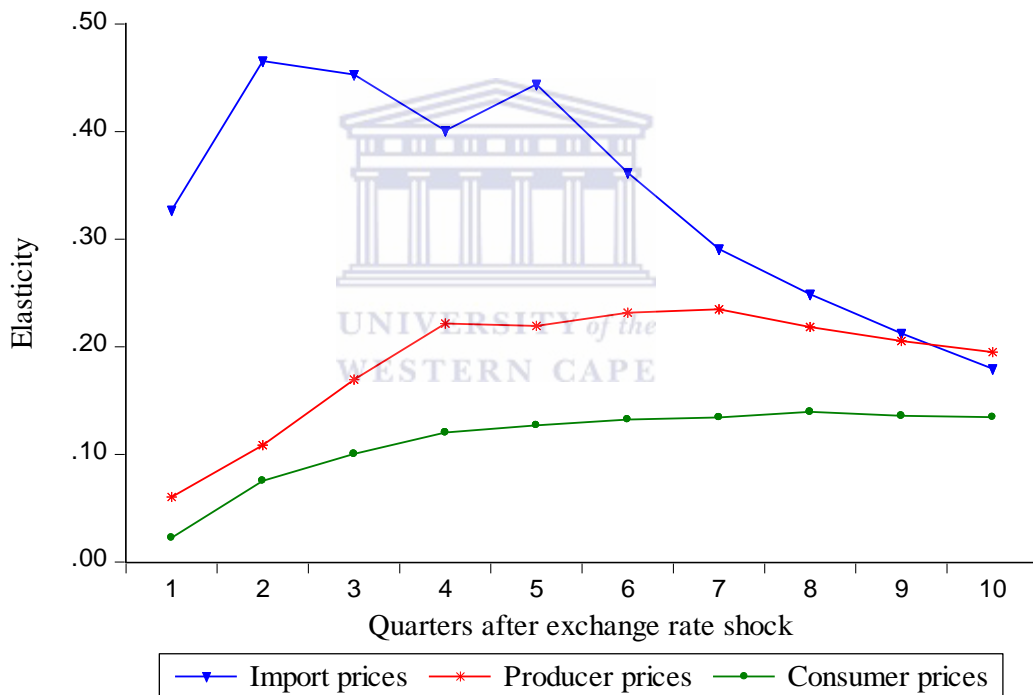
Many authors (Johansen 2000; Brooks 2008; Hill *et al.* 2011; Sweidan 2013; Johansen 2014) criticise the use of unrestricted VAR models when there is one or more cointegration vectors among the data series. Instead, they recommend the use of VECM which has the ability to support both short-run and long-run analysis. Therefore, this section discusses the VECM results and draws comparison with the

VAR results discussed in the previous section. The basis of this model is that there is one cointegration vector (after adjustments) as suggested by the trace test.

4.3.5.1 Impulse Response Analysis

The VEC model is also stable but suffers from heteroscedasticity and non-normality in residuals as in the VAR model. As argued in Section 4.3.3, failure to satisfy these two diagnostic checks does not significantly affect structural analysis. Figure 4.5 shows the elasticities of domestic prices in response to exchange rate shocks.

Figure 4:5: ERPT Elasticities for Import, Producer and Consumer Prices



Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

Table 4.10: VECM Time Profile of ERPT Elasticity for Domestic Prices

Time	$t=2$	$t=4$	$t=6$	$t=8$	$t=10$
Import prices	0.47	0.40	0.36	0.24	0.18
Producer prices	0.10	0.22	0.23	0.22	0.19
Consumer prices	0.07	0.12	0.13	0.14	0.13

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

The results in Figure 4.5 and Table 4.10 are in line with the VAR model results. The results show that import prices respond quickly to exchange rate shocks, reaching a peak of 47% by the second quarter. Bhundia (2002) and Ocran (2010) establish a peak of 40% but the results are closer to Ellyne and Hearn (2014) who report a peak of 46%. In contrast to the VAR results, long-run ERPT to import prices is low at 18% after two and half years. This low long-run pass-through is more in line with findings in Ocran (2010) of 20%.

Figure 4.5 shows a gradual and prolonged ERPT to producer and consumer prices. The producer prices reach a peak of 23% after six quarters while consumer prices reach a high of 14% after two years. The ERPT to producer prices is consistent with 23% reported in Bhundia (2002). Similarly, ERPT to consumer prices is in line with 12% and 13% established in Bhundia (2002), and Choudhri and Hakura (2006) respectively.

Table 4.11 below shows a comparison of elasticity of consumer prices from import and producer price shocks for the two models. The speed and degree of pass-through is relatively similar for both models. The results show that pass-through of producer price shocks into consumer prices is very high and nearly complete for both models. Bhundia (2002) reports a pass-through of 75% after eight quarters and 85% in the long run. These results are consistent with approximately 82% after ten quarters using the VAR model and 78% for the VECM.

In terms of pass-through of import price shocks to consumer prices, the two models (VAR & VECM) show conflicting results. The degree of pass-through peaks at about 45% in the VAR model as compared to a low of 10% in the VECM. The VECM results are consistent with Bhundia (2002) who reports a low pass-through of 3.5% in the long run. The author argues that the low import price pass-through may be reflecting the reaction of consumers substituting import goods with domestically produced products (Bhundia 2002: 9). Huang (2010: 136) argues that the lower pass-through of import price shocks to consumer prices could be the result of firms hedging against volatility in the rand. Generally, firms which engage in high degree of hedging should have a lower degree of pass-through.

Table 4.11: Comparison of Long Run Pass-Through across Models

	Elasticity of Consumer Prices from:					
Model	Import Prices			Producer Prices		
Quarters	<i>t</i> = 1	<i>t</i> = 5	<i>t</i> = 10	<i>t</i> = 1	<i>t</i> = 5	<i>t</i> = 10
VAR	11.1%	24.7%	23.3%	25.5%	62.9%	81.6%
VECM	5.3%	8.4%	1.7%	22.5%	63.4%	77.9%

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

4.3.5.2 Variance Decompositions

The main interpretation from Table 4.12 to 4.14 is that oil price shocks are important in explaining the variations in domestic prices. Moreover, exchange rate shocks play an important role in identifying movements in import prices and producer prices but have a minimum role in explaining variations in consumer prices. Price shocks of producer and consumer prices are crucial in explaining producer and consumer price movements. However, for the latter, the percentage of its shocks falls rapidly from about 63% in the three months to only approximately 5% after ten quarters.

Besides oil price shocks, producer price shocks play a significant role in explaining movements in consumer prices. This significant role confirms the elasticity results above; elasticity of consumer prices to producer price shocks is very high. It is above 77% for both the VAR and VEC models. The results also confirm the low elasticity of consumer prices to import price shocks.

Table 4.12: VECM - Variance Decomposition of Import Prices

Period	Oil price	Output gap	Exchange rate	Import prices	Producer prices	Consumer prices	Interest rate
<i>t</i> = 1	24.29	15.21	22.54	37.96	0.00	0.00	0.00
<i>t</i> = 4	46.67	13.46	27.48	12.00	0.48	0.87	1.08
<i>t</i> = 8	43.64	9.17	30.49	9.29	3.65	2.56	1.20
<i>t</i> = 10	42.64	9.38	29.41	9.25	5.35	2.75	1.21

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

Table 4.14 below shows that import price shocks explain less than 1% of the variations in consumer prices. The demand side shocks (output gap) and interest rate shocks are generally insignificant in explaining movements in domestic prices.

Table 4.13: VECM - Variance Decomposition of Producer Prices

Period	Oil price	Output gap	Exchange rate	Import prices	Producer prices	Consumer prices	Interest rate
$t=1$	9.10	2.15	3.31	3.20	82.24	0.00	0.00
$t=4$	16.95	8.13	24.35	1.74	43.74	2.00	3.09
$t=8$	20.44	7.29	32.88	0.95	31.87	2.88	3.68
$t=10$	21.71	7.43	34.04	0.79	29.37	3.08	3.58

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

Table 4.14: VECM - Variance Decomposition of Consumer Prices

Period	Oil price	Output gap	Exchange rate	Import prices	Producer prices	Consumer prices	Interest rate
$t=1$	11.52	2.24	1.87	0.97	20.33	63.07	0.00
$t=4$	42.81	12.77	4.75	0.65	18.47	20.41	0.13
$t=8$	44.73	12.47	13.80	0.38	21.37	6.79	0.45
$t=10$	45.88	12.94	15.25	0.37	20.22	4.90	0.43

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

4.3.6 Robustness Check Results

In contrast to McCarthy (2000), Hüfner and Schroder (2002) suggest a different order of the variables. The authors are in consensus with McCarthy (2000) in that oil price shocks and exchange rate fluctuations have an influence on import prices. However, they differ in that they order output gap after both exchange rate and import prices. Hüfner and Schroder (2002: 11) argue that import prices have a direct impact on economic activity thus output gap (measure of economic activity) should be ordered after import prices. The authors also propose a different position for interest rate. Hüfner and Schroder (2002) assert that most central banks are forward-

looking in that they react to expected inflation instead of realised inflation. Also Hyder and Shah (2004) raise the same argument. Thus, they position interest rates before both producer and consumer prices.

The argument of forward-looking central banks is also most likely to be applicable to South Africa. Central banks that are operating under an inflation targeting framework have to rely on expected inflation rather than actual inflation in order to keep inflation under control. The SARB is likely to observe movements in oil prices, the rand and import prices then react through monetary policy (adjusting repo rate) rather than waiting for the actual change in consumer prices. Therefore, this study attempts different permutations of order of the variables as depicted in the schematic diagram below.

Model 1 – *dloil, output gap, dlneer, interest rate, dlimp, dlppi, dlcp*

Model 2 – *dloil, dlneer, dlimp, output gap, interest rate, dlppi, dlcp*

Model 3 – *dloil, output gap, interest rate, dlneer, dlimp, dlppi, dlcp*

The results in Table 4.15 show that the baseline model results are robust across different ordering of the variables. In other words, assuming either a reactionary or forward-looking central bank does not significantly change the results of ERPT in South Africa. Table 4.16 reports basically the same findings; results are also robust across the different models using a VEC model. The noticeable difference in Table 4.16 is with respect to elasticity of consumer prices to exchange rate shocks. Models 1, 2 and 3 indicate a slower speed of pass-through in comparison to the Baseline VEC model. However, the magnitude of pass-through is similar by the tenth quarter.

Table 4.15: VAR Model ERPT Elasticities for the Different Models

	Import prices			Producer prices			Consumer prices		
	<i>t</i> = 4	<i>t</i> = 8	<i>t</i> = 10	<i>t</i> = 4	<i>t</i> = 8	<i>t</i> = 10	<i>t</i> = 4	<i>t</i> = 8	<i>t</i> = 10
Baseline	36.16	37.93	35.75	17.29	26.31	29.05	9.19	17.92	21.52
Model 1	35.59	37.8	34.40	16.71	25.42	28.07	8.95	17.88	21.54
Model 2	36.27	37.02	33.99	16.63	24.09	26.31	9.57	17.89	21.32
Model 3	36.24	43.75	44.71	17.12	27.87	32.00	9.27	19.85	23.79

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

Table 4.16: VEC Model ERPT Elasticities for the Different Models

	Import prices			Producer prices			Consumer prices		
	$t=4$	$t=8$	$t=10$	$t=4$	$t=8$	$t=10$	$t=4$	$t=8$	$t=10$
Baseline	40.09	24.88	17.94	22.14	21.84	19.49	12.04	14.28	13.19
Model 1	38.65	22.53	20.33	13.9	20.20	22.07	2.26	7.35	9.06
Model 2	41.57	21.64	21.46	14.86	21.08	22.97	3.26	8.50	10.34
Model 3	41.20	22.23	22.26	14.36	21.27	23.38	1.8	7.14	8.95

Source: Own calculations using SARB, StatsSA & IMF data, 1980 – 2014

4.4 Concluding Remarks

This chapter set out the models used to estimate the speed and degree of ERPT as well as the main findings from the models. Following the proposition by McCarthy (2000), this study applied a VAR model which introduces restrictions to the model (Cholesky decompositions), in order to transform the standard VAR model into a recursive VAR. The recursive VAR model makes it easier to estimate pass-through along the distribution chain. Due to the presence of a weak cointegration relationship, the VECM was also used in this study. The ordering of the variables plays an important role on the bearing of the results.

All the variables are non-stationary except output gap and interest rates. Thus, the non-stationary variables are transformed to stationarity using first differencing before running the VAR model. There is also a cointegration relationship between variables which warrant the use of a VECM. Both the VAR and VECM show that the rate at which exchange rate shocks feed into import prices is moderate. These results are consistent with other studies; 40% from Bhundia (2002), 40% reported in Ocran (2010) and 46% established in Ellyne and Hearn (2014). In comparison, ERPT to producer and consumer prices was relatively low at around 20% for both models. In descending order of rank – the results also show that ERPT is highest to import prices, then producer prices and lowest to consumer prices. This outcome verifies the

existence of pricing along the distribution chain which complements the model suggested in this study. This study also observes that pass-through in South Africa is incomplete.

The long-run speed and degree of PT of producer price shocks to consumer prices is very high and almost complete at approximately 82% for the VAR model and 78% for the VECM. However, PT of import price shocks to consumer prices is very low for the VECM (below 10%) and a peak of approximately 25% for the VAR model. The VECM results are consistent with Bhundia's (2002) findings of a pass-through below 5%. Besides the ordering in the main model, this study also conducts robustness checks of different ordering of the variables (using three different options). The results show that the estimates in the baseline models are robust against different ordering of variables.



CHAPTER 5

5 GENERAL CONCLUSION

5.1 Introduction

This study set out to examine the short-run and long-run speed and degree of exchange rate pass-through (ERPT) to domestic prices in South Africa. In doing so, the study used impulse response functions and variance decompositions for the analysis. Firstly, Chapter One provided an introduction and motivation why it is important to analyse how domestic prices behave in response to exchange rate movements. Secondly, Chapter Two reviewed both theoretical and empirical literature on ERPT. Thirdly, Chapter Three covered a discussion on the widely used econometric techniques to estimate ERPT, challenges of data measurement and description of the data. Lastly, Chapter Four suggested the baseline models used to estimate ERPT and an analysis of the results thereof.

As argued in Chapter One, exchange rate movements are one of the determinants of domestic inflation in that depreciation of currency results in an increase in import, producer and consumer prices. Chapter Two further explained that ERPT to domestic prices is generally incomplete; a 10% shock to the exchange rate creates a less than proportional change in domestic prices. Similarly, there is also a possibility of ERPT asymmetry in which the same magnitude of exchange rate shock can prompt a different effect on domestic prices in a period of exchange rate depreciation against a period of appreciation. The determination of the speed and magnitude of ERPT and the presence of asymmetry is important for designing optimal monetary policy mix. Generally, low speed and degree of ERPT accommodate more monetary policy autonomy for policy makers (Taylor 2000; Mohanty & Klau 2001; McCarthy 2006).

The speed and magnitude of ERPT depend on the transmission mechanism of exchange rate shocks to domestic prices. Exchange rate shocks can feed into domestic prices via a distribution chain; shocks first affect import prices which eventually lead to changes in producer prices and consumer prices. Alternatively, the

channels can be classified into direct and indirect transmission mechanisms. The direct channel is similar to the distribution chain channel but the indirect channel is via the effect of exchange rate shocks on the competitiveness of a country's goods and services.

Apart from understanding the channels of ERPT, it is also important to investigate the determinants that affect the rate at which these shocks feed into domestic prices. Chapter Two discussed some of the factors which include: exchange rate volatility, inflationary environment, market structures, pricing behaviour of firms, product substitutability, trade openness and cross-border production sharing.

The review of empirical literature showed that pass-through is generally low in developed economies as compared to developing economies. Furthermore, countries with a low and stable inflationary environment (mostly developed countries), have low speed and degree of ERPT. Most studies established that the degree of ERPT to be incomplete. Incomplete ERPT means a given shock (positive or negative) in exchange rate results in less than proportional change in domestic prices. For developing countries, the speed and degree of ERPT is mixed; from low (for instance: South Africa, Tanzania & Chile) in some countries to almost complete in other countries (for example: Maldives, Ukraine, Sri Lanka & Colombia). The ERPT studies in South Africa also reported mixed results; some studies (Nell, 2000 & Karoro *et al.* 2009) established a high ERPT above 70% to import prices while other studies (Bhundia, 2002; Ocran, 2010 & Ellyne & Hearn, 2014) reported a pass-through of below 50%.

Chapter Three elaborated on the different econometric models used to estimate ERPT in the literature. It is clear from the review of literature that the preferred method in estimating ERPT has been changing over the past five decades. The OLS models were dominant in the 1970s, VAR models in the 1980s and beyond, and in recent years the BVAR and DSGE models are beginning to take center stage. Nevertheless, the VAR model is still a widely used method. Thus, this study utilised a VAR model to estimate ERPT. Chapter Three also provided a discussion on the general challenges faced by researchers in analysing ERPT. The three main challenges related to data are whether to use aggregate or disaggregate data, how to

compute the exchange rate and which price proxies to use in case of aggregate based analysis.

5.2 Main Findings

The first part of Chapter Four was dedicated to specifying the VAR model. Due to the presence of a cointegration relationship between the variables, the VAR model was further transformed into a VECM. The conflicting results of the trace and the maximum eigenvalue tests necessitated the use of both models (VAR and VECM). Thus, the study used two baseline models (VAR and a VECM) and the results from the two models were analysed and compared.

The second part of Chapter Four provided an analysis of the results from each model which are divided into two categories. The first category provided an estimation of ERPT to all domestic prices while the second category investigated the speed and magnitude of pass-through (PT) of import and producer price shocks to consumer prices.

5.2.1 ERPT to Domestic Prices

Unit root tests results showed that all the variables have unit roots except output gap and interest rate which are stationary. However, all the variables are stationary after first differencing suggesting that they are integrated of order one. Using the Johansen cointegration approach, the trace and maximum eigenvalue tests indicated three and two cointegration vectors respectively. After adjusting for the two stationary variables (as suggested by Hüfner & Schroder, 2002) the two tests suggested one and zero cointegrated relationships. The models are also stable and there is no autocorrelation in residuals but the error terms are neither multivariate normal nor homoscedastic. Besides the use of dummy variables and permutations of ordering the variables, this study did not pursue any other measures to address the issues of heteroscedasticity and non-multivariate normality of the residuals. Due to volatility clustering in exchange rate studies, it is usually difficult to remove heteroscedasticity in the model. As argued in Chapter Four, the justification was that these shortfalls have an insignificant effect on the structural analysis of the results.

The impulse response function results were consistent with literature in that import, producer and consumer prices responded negatively to a one percent appreciation in the rand. This response means that the depreciation of the rand has the potential to cause price instability in South Africa. Moreover, the results confirmed the existence of ERPT along the distribution chain. For the VAR model, the impact of exchange rate shocks is immediate and moderately high, reaching a peak of 45% by the second quarter. This compared to a low of 9% and 5% for producer and consumer prices respectively. Besides this difference, ERPT to producer prices and consumer prices is gradual and prolonged. The degree of ERPT increased in the long run to 29% and 22% respectively as compared to 36% for import prices. The deduction is that exchange rate shocks take longer time to feed into producer and consumer prices in South Africa.

The VECM results also showed a similar pattern; ERPT to import prices is immediate and moderately high (47% after 2 quarters) in comparison to 10% and 7% for producer and consumer prices respectively. The VECM long-run results indicated an ERPT of 19% and 13% to producer prices and consumer prices, which differed by a margin of 10% to the VAR results. For import prices, the magnitude of ERPT sharply declined to 18% in the long run in comparison to 36% from the VAR model. Generally, these results are in line with studies such as Bhundia (2002), Ocran (2010) and Ellyne and Hearn (2014).

The two models showed that ERPT is incomplete in South Africa. The incomplete ERPT may be due to adjustment costs such as transportation costs, nontariff barriers, information costs, and lack of labour mobility (Rogoff 1996) that are providing firms with adequate buffers to keep prices constant even if the exchange rate fluctuates. Alternatively, the results could be due to the inclusion of both tradable and non-tradable goods in the computation of price indices (Wang 2009). The low degree of ERPT to producer and consumer prices could also be due to firms facing the New Keynesian-type menu cost dilemma (Bhundia 2002). This dilemma is where the cost of changing menu prices is higher than the possible gain from change in prices to reflect the change in exchange rate, thus firms end up choosing to absorb the shocks by adjusting their mark-ups. However, all these factors are speculative since it is

difficult to ascertain the real cause of incomplete ERPT especially using aggregate data.

For both models (VAR & VECM), the variance decompositions show that oil price shocks, exchange rate shocks and own price shocks play an important role in explaining variations in domestic prices. The producer price shocks also significantly explain movements in consumer prices which confirmed the strong correlation between producer inflation and consumer inflation as shown in Figure 4.4. The significance of oil price shocks in explaining domestic prices substantiated the importance of also monitoring supply side shocks if policy makers desire to attain price stability in South Africa.

5.2.2 Import and Producer Price Shocks PT to Consumer Prices

Unlike the magnitude of ERPT to domestic prices, the study found that the degree of pass-through of producer price shocks to consumer prices is very high, rising in the long run to 82% and 78% for the VAR model and VECM respectively. However, pass-through of import price shocks to consumer prices is fairly moderate for the VAR model, 37% after six quarters in comparison to a low of 10% in the VECM. The VECM results showed a decline to 1.7% in the long run. These long-run VECM results are in line with Bhundia (2002) who reported a low pass-through of 3.5%. The deduction from these results was that movements in producer prices have a stronger impact on consumer prices than variations in import prices.

Robustness check using different ordering of the variables showed that the results are generally robust across different models. In other words, all VAR models showed consistent results and also a similar outcome for VECM results.

5.2.3 Limitations of the study

The main limitation of this study is the presence of heteroscedasticity and non-multivariate normal residuals in the models. Although it has been argued that the presence of non-multivariate normal residuals and heteroscedasticity does not significantly affect the results in terms of structural analysis, they still remain as limitations of the study. All the different models (robustness check) and dummy

variables used to improve the results failed to address these two limitations thus suggesting the problem might be related to the nature of the data such as volatility clustering in the exchange rate. Another limitation is that quarterly data does not adequately reflect the high volatility in the exchange rate. Higher frequency data such as monthly data could provide better estimates. The decision to use quarterly data was primarily driven by the author's inability to secure the monthly import price index which is an important variable in the model outlined in Chapter Four. Lastly, the study is also susceptible to weaknesses of price indices (constantly changing weights) in capturing movements in prices and the inadequacy of the nominal effective exchange rate to accurately reflect movements in the exchange rate (only captures the 15 major trading partners).

5.3 Areas for Further Research

The results in this study can help to understand how exchange rate shocks affect domestic prices. To further strengthen this knowledge, research into the presence of ERPT asymmetry can help to deepen understanding. Similarly, there is also need to investigate ERPT at disaggregate price level across different sectors or industries in South Africa. The ERPT analysis at disaggregate price level can help in identifying industries which are likely to be most affected by exchange rate shocks and some of the actual reasons why ERPT is incomplete in South Africa.

REFERENCES

- Ahmed, S. & Zlate, A. 2013. Capital Flows to Emerging Market Economies: A Brave New World? *International Finance Discussion Papers No. 1081*, Washington D.C.: International Finance Division of the Board of Governors of Federal Reserve System.
- Ajilore, T. & Ikhiede, S. 2013. Monetary Policy Shocks, Output and Prices in South Africa: A Test of Policy Irrelevance Proposition. *The Journal of Developing Areas*, 47(2): 363 – 386.
- An, L. & Wang, J. 2012. Exchange Rate Pass-Through: Evidence Based on Vector Autoregression with Sign Restrictions. *Open Economies Review*, 23(2): 359 – 380.
- Andren, T. 2007. *Econometrics*. London: Thomas Andren and Ventus Publishing.
- Arndt, S. W. 2005. *Cross-Border Sharing and Exchange Rates in East Asia*. Claremont, CA: Lowe Institute of Political Economy.
- Aron, J., Creamer, K., Muellbauer, J. & Rankin, N. 2014. Exchange Rate Pass-Through to Consumer Prices in South Africa: Evidence from Micro-Data. *The Journal of Development Studies*, 50(1): 1 – 21.
- Aron, J., Farrell, G., Muellbauer, J. & Sinclair, P. 2012. Exchange Rate Pass-Through to Import Prices, and Monetary Policy in South Africa. *SARB Working Paper WP/08/12*, Pretoria: South African Reserve Bank.
- Asari F. F. A. H., Baharuddin, N. S., Jusoh, N., Mohamad, Z., Shamsudin, N. & Jusoff, N. 2011. A Vector Error Correction Model (VECM) Approach in Explaining the Relationship between Interest Rate and Inflation towards Exchange Rate Volatility in Malaysia. *World Applied Sciences Journal*, 12(Special Issue on Bolstering Economic Sustainability): 49 – 56.
- Athukorala, P. & Menon, J. 1994. Pricing-to-Market Behaviour and Exchange Rate Pass-Through in Japanese Exports. *Economic Journal*, 104(423): 271 – 281.
- Bañbura, M., Giannone, D. & Reichlin, L. 2008. Large Bayesian VARs. *Working Paper Series No. 966*, Frankfurt: European Central Bank.
- Bangura, M., Caulker, E. & Pessima, S. 2012. Exchange Rate Pass-Through to Inflation in Sierra Leone: A Structural Vector Autoregressive Approach. *Western African Journal of Monetary and Economic Integration*, 12(1): 93 – 123.

- Beckmann, E. & Fidrmuc, J. 2013. Exchange Rate Pass-Through in CIS Countries. *Comparative Economic Studies*, 55(4): 705 – 720.
- Banerjee, A., Dolado, J., Hendry, D. F. & Smith, G. 1986. Exploring Equilibrium Relationships in Econometrics Through Static Models. *Oxford Bulletin of Economics and Statistics*, 48(3): 253 – 277.
- Berg, T. O. 2015. Multivariate Forecasting with BVARs and DSGE Models. *MPRA Paper No. 62405*, Munich: Munich Personal RePEc Archive.
- Bessler, D. A. & Kling, J. L. 1986. Forecasting Vector Autoregressions with Bayesian Priors. *American Journal of Agricultural Economics*, 68(1): 144 – 151.
- Bhattacharya, P., Karayalcin, C. & Thomakos, D. 2008. Exchange Rate Pass-Through and Relative Prices: An Industry-level Empirical Investigation. *Journal of International Money and Finance*, 27(7): 1135 – 1160.
- Bhundia, A. 2002. An Empirical Investigation of Exchange Rate Pass-Through in South Africa. *IMF Working Paper WP/02/165*, Washington D.C.: International Monetary Fund.
- Bouakez, H. & Rebei, N. 2008. Has Exchange Rate Pass-Through Really Declined? Evidence from Canada. *Journal of International Economics*, 75(2): 249 – 267.
- Box, G. E. P. & Jenkins, G. M. 1976. *Time Series Analysis: Forecasting and Control*. Revised edition. San Francisco: Holden-Day, Inc.
- Brooks, C. 2008. *Introductory Econometrics for Finance*. 2nd edition. New York: Cambridge University Press.
- Bussière, M. & Peltonen, T. A. 2008. Exchange Rate Pass-Through in the Global Economy: The Role of Emerging Market Economies. *ECB Working Paper No. 951*, Frankfurt: European Central Bank.
- Ca' Zorzi, M., Hahn, E. & Sánchez, M. 2007. Exchange Rate Pass-Through in Emerging Economies. *ECB Working Paper series No. 739*, Frankfurt: European Central Bank.
- Campa, J. M., Goldberg, L. S. & González-Mínguez, J. M. 2005. Exchange Rate Pass-Through to Import Prices in the Euro Area. *Staff Report No. 219*, New York: Federal Reserve Bank of New York.
- Carriero, A., Clark, T. E. & Marcellino, M. 2015. Bayesian VARs: Specification Choices and Forecast Accuracy. *Journal of Applied Econometrics*, 30(1): 46 – 73.

- Cheikh, N. B. & Louhichi, W. 2014. Measuring the Impact of Exchange Rate Movements on Domestic Prices: A Cointegrated VAR Analysis. *FIW Working Paper No. 131*, [Online]. Available: www.fiw.ac.at/fileadmin/...Paper/N_131-BenCheikhWaelLouhichi.pdf. [Accessed 17 December 2014].
- Choudhri, E. U. & Hakura, D. S. 2006. Exchange Rate Pass-Through to Domestic Prices: Does the Inflationary Environment Matter? *Journal of International Money and Finance*, 25(4): 614 – 639.
- Choudhri, E. U. & Hakura, D. S. 2012. The Exchange Rate Pass-Through to Import and Export Prices: The Role of Nominal Rigidities and Currency Choice. *IMF Working Paper WP/12/226*, Washington D.C.: International Monetary Fund.
- Ciccarelli, M. & Rebucci, A. 2003. Bayesian VARs: A Survey of the Recent Literature with an Application to the European Monetary System. *IMF Working Paper WP/03/102*, Washington D.C.: International Monetary Fund.
- Cochrane, J. H. 1997. *Time Series for Macroeconomics and Finance: Lecture Notes for PhD Time Series*. [Online]. Available: http://quant-econ.net/downloads/time_series_book.pdf. [Accessed 23 August 2014].
- Constitution of the Republic of South Africa Act No. 108 of 1996*. [Online]. Available: www.gov.za/documents/constitution/1996/a108-96.pdf. [Accessed 7 July 2014].
- Corsetti, G., Dedola, L. & Leduc, S. 2005. DSGE Models of High Exchange-Rate Volatility and Low Pass-Through. *Board of Governors Discussion Paper 845*. [Online]. Available: <https://ideas.repec.org/p/fip/fedgif/845.html>. [Accessed 5 December 2014].
- Cozmâncă, B. & Manea, F. 2010. Exchange Rate Pass-Through into Romanian Price Indices. A VAR Approach. *Romanian Journal of Economic Forecasting*, 13(3): 26 – 52.
- Davidson, R. & MacKinnon, J. G. 1993. *Estimation and Inference in Econometrics*. New York: Oxford University Press.
- Del Negro, M. & Schorfheide, F. 2004. Priors from Equilibrium Models for VARs. *International Economic Review*, 45(2): 643 – 673.
- Devereux, M. B. & Yetman, J. 2002. Price Setting and Exchange Rate Pass-Through: Theory and Evidence. *HKIMR Working paper 22/2002*, Hong Kong: Hong Kong Institute for Monetary Research.

- Devereux, M. B. & Yetman, J. 2010. Price Adjustment and Exchange Rate Pass-Through. *Journal of International Money and Finance*, 29(1): 181 – 200.
- Devereux, M. B., Engel, C. & Storgaard, P. E. 2004. Endogenous Exchange Rate Pass-Through when Nominal Prices are Set in Advance. *Journal of International Economics*, 63(2): 263 – 291.
- Dlamini, S. K. 2008. *Bank Credit Extension to the Private Sector and Inflation in South Africa*. Unpublished Masters Thesis. Grahamstown: Rhodes University. [Online]. Available: www.eprints.ru.ac.za/2002/1/dlamini-mcom-tr09-70.pdf. [Accessed 10 March 2015].
- Doan, T. A., Litterman, R. B. & Sims, C. A. 1984. Forecasting and Conditional Projection using Realistic Prior Distributions. *Econometric Reviews*, 3(1): 1 – 100.
- Dolado, J. J. 1992. A Note on Weak Exogeneity in VAR Cointegrated Models. *Economic Letters*, 38(2): 139 – 143.
- Dolado, J. J., Gonzalo, J. & Marmol, F. 2001. Cointegration, Chapter 30. In Baltagi, B. H., ed. 2001. *A Companion to Theoretical Econometrics*. Massachusetts: Wiley-Blackwell Publishing Ltd.
- Donayre, L. & Panovska, I. 2015. *Asymmetric Exchange Rate Pass-Through Behaviour over the Business Cycle*. [Online]. Available: <http://apps.olin.wustl.edu/conf/sbies/files/pdf/2015/125.pdf>. [Accessed 21 July 2017].
- Du Plessis, S. & Smit, B. 2007. South Africa's Growth Revival After 1994. *Journal of African Economies*, 16(5): 668 – 704.
- Edwards, S. 2006. The Relationship Between Exchange Rates and Inflation Targeting Revisited. *NBER Working Paper 12163* Cambridge: National Bureau of Economic Research.
- Elder, J. & Kennedy, P. E. 2001. Testing for Unit Roots: What Should Students be taught? *Journal of Economic Education*, 32(2): 137 – 146.
- Ellyne, M. & Hearn, N. 2014. Estimating Exchange Rate Pass-Through in South Africa. [Online]. Available: https://www.academia.edu/7020024/estimating_exchange_rate_pass-through_in_south_africa. [Accessed 18 October 2014].

- Enders, W. 1995. *Applied Econometric Time Series*. Hoboken, New Jersey: John Wiley & Sons, Inc.
- Enders, W. 2004. *Applied Econometric Time Series*. 3rd edition. Hoboken, New Jersey: John Wiley & Sons, Inc.
- Enders, W. 2015. *Applied Econometric Time Series*. 4th edition. Hoboken, New Jersey: John Wiley & Sons, Inc.
- Engel, C. 2009. Pass-Through, Exchange Rates, and Monetary Policy. *Journal of Money, Credit, and Banking*, 41(1): 177 – 185.
- Engle, R. F. & Granger, C. W. J. 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 55(2): 251 – 276.
- Faruquee, H. 2006. Exchange Rate Pass-Through in the Euro Area. *IMF Staff Papers*, 50(1): 63 – 88.
- Frankel, J. A., Parsley, D. C. & Wei, S. 2005. Slow Pass-Through Around the World: A New Import for Developing Countries? *NBER Working Paper 11199*, Cambridge: National Bureau of Economic Research.
- Froot, K. A. & Klemperer, P. D. 1989. Exchange Rate Pass-Through when Market Share Matters. *The American Economic Review*, 79(4): 637 – 654.
- Gagnon, J. & Ihrig, J. 2004. Monetary Policy and Exchange Rate Pass-Through. *International Journal of Finance and Economics*, 9(4): 315 – 338.
- Ghosh, A. & Rajan, R. S. 2007. A Survey of Exchange Rate Pass-Through in Asia. *Asian-Pacific Economic Literature*, 21(2): 13 – 28.
- Ghosh, A. & Rajan, R. S. 2009. What is the Extent of Exchange Rate Pass-Through in Singapore? Has it changed over Time? *Journal of the Asia Pacific Economy*, 14(1): 61 – 72.
- Goldfajn, I. & Werlang, S. R. C. 2000. The Pass-Through from Depreciation to Inflation: A Panel Study. *Working Paper Series 5*, Brasilia: Banco Central do Brasil.
- Granger, C. W. J. 1981. Some Properties of Time Series Data and their Use in Econometric Model Specification. *Journal of Econometrics*, 16(1): 121 – 130.
- Granger, C. W. J. 1986. Developments in the Study of Cointegrated Economic Variables. *Oxford Bulletin of Economics and Statistics*, 48(3): 213 – 228.

- Granger, C. W. J. & Newbold, P. 1974. Spurious Regressions in Econometrics. *Journal of Econometrics*, 2(1974): 111 – 120.
- Granger, C. W. J. & Newbold, P. 1986. *Forecasting Economic Time Series*, 2nd edition, Orlando, Florida: Academic Press, Inc.
- Gujarati, D. 2004. *Basic Econometrics*. 4th edition. New York: McGraw Hill.
- Hamilton, J. D. 1994. *Time Series Analysis*. Princeton: Princeton University Press.
- Harris, R. 1995. *Using Cointegration Analysis in Economic Modelling*. London: Prentice Hall.
- Hendry, D. F. 1986. Econometric Modelling with Cointegrated Variables: An Overview. *Oxford Bulletin of Economics and Statistics*, 48(3): 201 – 212.
- Hendry, D. F. & Juselius, K. 2000. Cointegration Analysis: Part I. *The Energy Journal*, 21(1): 1 – 42.
- Hendry, D. F. & Juselius, K. 2001. Explaining Cointegration Analysis: Part II. *The Energy Journal*, 22(1): 75 – 120.
- Hendry, D. F. & Nielsen, B. 2007. *Econometric Modelling: A Likelihood Approach*. Princeton: Princeton University Press.
- Herr, H. 2007. *Theories of Financial Globalisation*, A Paper Presented at the Global Labour University Conference. Kassel: University of Kassel Germany.
- Hill, R. C., Griffiths, W. E. & Lim, G. C. 2011. *Principles of Econometrics*. 4th edition. New York: John Wiley & Sons, Inc.
- Huang, J. 2010. Hedging on U.S. Exporting Pricing: An Exchange Rate Pass-Through Analysis. *International Journal of Economics and Finance*, 2(3): 134 – 142.
- Hüfner, F. P. & Schröder, M. 2002. Exchange Rate Pass-Through to Consumer Prices: A European Perspective. *ZEW Discussion paper No. 02-20*, Mannheim: Centre for European Economic Research.
- Hyder, Z. & Shah, S. 2004. Exchange Rate Pass-Through to Domestic Prices in Pakistan. *State Bank of Pakistan Working Paper No. 5*, Karachi: State Bank of Pakistan.

- Ito, T. & Sato, K. 2006. Exchange Rate Changes and Inflation in Post-Crisis Asian Economies: VAR Analysis of the Exchange Rate Pass-Through. *NBER Working Paper 12395*, Cambridge: National Bureau of Economic Research.
- Jankov, L., Krznar, I., Kunovac, D. & Lang, M. 2008. The Impact of the USD/EUR Exchange Rate of Inflation in the Central and East European Countries. *Comparative Economic Studies*, 50(4): 646 – 662.
- Johansen, S. 1988. Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control*, 12(2 – 3): 231 – 254.
- Johansen, S. 2000. Modelling of Cointegration in the Vector Autoregressive Model. *Economic Modelling*, 17(3): 359 – 373.
- Johansen, S. 2014. *Time Series: Cointegration*. Aarhus: Centre for Research in Econometric Analysis of Time Series.
- Johnston, J. & DiNardo, J. 1997. *Econometric Methods*. 4th edition. New York: McGraw-Hill.
- Kadiyala, K. R. & Karlsson, S. 1993. Forecasting with Generalised Bayesian Vector Autoregressions. *Journal of Forecasting*, 12(3): 365 – 378.
- Kardasz, S. W. & Stollery, K. R. 2001. Exchange Rate Pass-Through in Canadian Manufacturing: Its Direct and Indirect Components. *Canadian Journal of Economics*, 34(3): 719 – 738.
- Karoro, D. K. 2007. *An Analysis of Exchange Rate Pass-Through to Prices in South Africa*. Unpublished Masters Thesis. Grahamstown: Rhodes University. [Online]. Available: www.eprints.ru.ac.za/2260/1/karoro-mcom-tr08-54.pdf. [Accessed 28 July 2014].
- Karoro, T. D., Aziakpono, M. J. & Cattaneo, N. 2009. Exchange Rate Pass-Through to Import Prices in South Africa: Is There Asymmetry? *South African Journal of Economics*, 77(3): 380 - 398.
- Kenny, G. & McGettigan, D. 1998. Exchange Rate and Import Prices for a Small Open Economy: The Case of Ireland. *Applied Economics*, 30(9): 1147 – 1155.
- Khundrakpam, J. K. 2007. Economic Reforms and Exchange Rate Pass-Through to Domestic Prices in India. *BIS Working Paper No. 225*, Basel: Bank of International Settlements.

- Koop, G. M. & Korobilis, D. 2009. Bayesian Multivariate Time Series Methods for Empirical Macroeconomics. *Working Paper WP 09-47*, Rimini: The Rimini Centre for Economic Analysis.
- Koop, G. M. 2013. Forecasting with Medium and Large Bayesian VARs. *Journal of Applied Econometrics*, 28(2): 177 – 203.
- Krugman, P. R. 1987. Pricing to Market when the Exchange Rate Changes. In Arndt, S. W. & Richardson, J. D., eds. 1987. *Real-Financial Linkages among Open Economies*, Massachusetts: MIT Press, 49 – 70.
- Lafèche, T. 1997. The Impact of Exchange Rate Movements on Consumer Prices. *Bank of Canada Review*, Winter (1996-97): 20 – 32.
- Lan, L., Lin, L., Lin, W. & Chuang, S. 2013. Theoretical and Empirical Evidence for the Impact of Cross-Border Production Sharing on Exchange Rate Pass-Through. *Emerging Markets Finance & Trade*, 49(4): 280 – 300.
- Lastrapes, W. D. 2001. *A Vector Error Correction Forecasting Model of the U.S. Economy: A Comment*. Department of Economics. Terry College of Business. Athens: University of Georgia.
- Lipsey, R. E., Molinari, L. & Kravis, I. B. 1990. Measures of Prices and Price Competitiveness in International Trade in Manufactured Goods. *NBER Working Paper No. 3442*, Cambridge: National Bureau of Economic Research.
- Litterman, R. B. 1986a. A Statistical Approach to Econometric Forecasting. *Journal of Business & Economic Statistics*, 4(1): 1 – 4.
- Litterman, R. B. 1986b. Forecasting with Bayesian Vector Autoregressions – Five Years of Experience. *Journal of Business & Economic Statistics*, 4(1) 25 – 38.
- Lütkepohl, H., Saikkonen, P. & Trenler, C. 2001. Maximum Eigenvalue versus Trace Tests for the Cointegration Rank of a VAR Process. *Econometrics Journal*, 4(2): 287 – 310.
- Lütkepohl, H. 2004. Univariate Time Series Analysis, Chapter 2. In Lütkepohl, H. & Kräzig, M., eds. *Applied Time Series Econometrics*, New York: Cambridge University Press.
- Lütkepohl, H. 2005. *New Introduction to Multiple Time Series Analysis*. Berlin: Springer-Verlag.
- Lütkepohl, H. 2011. Vector Autoregressive Models. *EUI Working Paper ECO 2011/30*, Florence: European University Institute.

- Maddala, G. S. & Kim, I. 1998. *Unit Roots, Cointegration and Structural Change*. New York: Cambridge University Press.
- Maddala, G. S. 1992. *Introduction to Econometrics*. 2nd edition. New York: Macmillan Publishing Company.
- Marmolejo, A. L. 2011. Effects of a Free Trade Agreement on the Exchange Rate Pass-Through to Import Prices. *Review of International Economics*, 19(3): 475 – 493.
- Masha, I. & Park, C. 2012. Exchange Rate Pass Through to Prices in Maldives. *IMF Working Paper WP/12/126*, Washington D.C.: International Monetary Fund.
- McCarthy, J. 2000. Pass-Through of Exchange Rates and Import Prices to Domestic Inflation in some Industrialised Economies. *Staff Report No. 111*, New York: Federal Reserve Bank of New York.
- McCarthy, J. 2006. *A Revision on Pass-through of Exchange Rate and Import Prices to Domestic Inflation in Some Industrialised Economies*. New York: Federal Reserve Bank of New York.
- Menon, J. 1995. Exchange Rate Pass-Through. *Journal of Economic Surveys*, 9(2), 197 – 231.
- Menon, J. 1996. The Degree and Determinants of Exchange Rate Pass-Through: Market Structures, Non-Tariff Barriers and Multinational Corporations. *The Economic Journal*, 106(1): 434 – 444.
- Mihaljek, D. & Klau, M. 2001. A Note on the Pass-Through from Exchange Rate and Foreign Price Changes to Inflation in Selected Emerging Market Economies. *BIS Working paper No. 8*, Basel: Bank of International Settlements.
- Mirdala, R. 2014. Exchange Rate Pass-Through to Domestic Prices under Different Exchange Rate Regimes. *WDI Working Paper No. 1070*, Ann Arbor, Michigan: William Davidson Institute.
- Mishkin, F. S. 2008. Exchange Rate Pass-through and Monetary Policy. *NBER Working Paper 13889*, Cambridge: National Bureau of Economic Research.
- Mnjama, G. S. 2011. *Exchange Rate Pass-through to Domestic Prices in Kenya*. Unpublished Masters Thesis. Grahamstown: Rhodes University. [Online]. Available: www.eprints.ru.ac.za/2579/1/mnjama-mcom-tr11-217.pdf. [Accessed 22 September 2014].

- Mohanty, M. S. & Klau M. 2001. Modelling Aspects of the Inflation Process and the Monetary Transmission Mechanism in Emerging Market Countries: What Determines Inflation in Emerging Market Economies? *BIS Working paper No. 8*, Basel: Bank of International Settlements.
- Montiel, P. J. 2009. *International Macroeconomics*. West Sussex: John Wiley & Sons Ltd.
- Mtonga, E. 2011. Did it Matter? Monetary Policy Regime Change and Exchange Rate Dynamics in South Africa. [Online]. Available: <http://www.csae.ox.ac.uk/conferences/2011-edia/papers/354-mtonga.pdf>. [Accessed 8 July 2014].
- Murray, M. P. 1994. A Drunk and Her Dog: An Illustration of Cointegration and Error Correction. *The American Statistician*, 48(1): 37 – 39.
- Mwase, N. 2006. An Empirical Investigation of the Exchange Rate Pass-Through to Inflation in Tanzania. *IMF Working Paper WP/06/150*, Washington D.C.: International Monetary Fund.
- Nell, K. 2000. *Imported Inflation in South Africa: An Empirical Study*. [Online]. Available: <ftp://ftp.ukc.ac.uk/pub/ejr/RePEc/ukc/ukcedp/0005.pdf>. [Accessed 7 August 2014].
- Nelson, C. R. & Plosser, C. I. 1982. Trends and Random-Walks in Macroeconomic Time Series: Some Evidence and Implications. *Journal of Monetary Economics*, 10(2): 139 – 162.
- Nogueira, R. P. 2007. Inflation Targeting and Exchange Rate Pass-Through. *Economic Applications Journal*, 11(2): 189 – 208.
- Ocran, M. K. 2010. Exchange Rate Pass-Through to Domestic Prices: The Case of South Africa. *Prague Economic Papers*, 19(4): 291 – 306.
- Ogaki, K. B. 1993. Unit Roots in Macroeconomics: A Survey. *Bank of Japan Monetary and Economic Studies*, 110(2): 456 – 483.
- Omisakin, A. O. 2009. Exchange Rate Pass Through to Domestic Prices and Output in Nigeria. *International Business Management*, 3(3): 38 – 42.
- Ozcelebi, O. & Yildirim, N. 2011. Revisiting Relationship between Exchange Rates and Output within SVAR Blanchard-Quah Framework: Empirical Evidence from Turkey, Germany and Russia. *Economics and Business Review*, 13(3): 179 – 198.

- Palley, T. I. 2004. The Economics of Exchange Rates and the Dollarisation Debate. *International Journal of Political Economy*, 33(1): 61 – 82.
- Parsley, D. C. 2010. Exchange Rate Pass-through in South Africa: Panel Evidence from Individual Goods and Services. *SARB Working Paper WP/10/03*, Pretoria: South African Reserve Bank.
- Ponomarev, Y., Trunin, P. & Uluykaev, A. 2014. *Exchange Rate Pass-Through in Russia*. [Online]. Available: <http://www.iep.ru/files/RePEc/gai/wpaper/0099Trunin.pdf>. [Accessed 3 August 2014].
- Przystupa, J. & Wróbel, E. 2011. Asymmetry of the Exchange Rate Pass-Through. *Eastern European Economics*, 49(1): 30 – 51.
- Rachev, S. T., Mittnik, S., Fabozzi, F. J., Focardi, S. M. & Jašić, T. 2007. *Financial Econometrics: From Basics to Advanced Modelling Techniques*. Hoboken, New Jersey: John Wiley & Sons, Inc.
- Razafimahefa, I. F. 2012. Exchange Rate Pass-Through in sub-Saharan African Economies and its Determinants. *IMF Working Paper WP/12/141*, Washington D.C.: International Monetary Fund.
- Rebucci, A. 2010. Estimating VARs with Long Stationary Heterogeneous Panels: A Comparison of the Fixed Effects and the Mean Group Estimators. *Economic Modelling*, 27(5): 1183 – 1198.
- Roger, S. 2009. Inflation Targeting at 20: Achievements and Challenges. *IMF Working Paper WP/09/236*, Washington D.C.: International Monetary Fund.
- Roger, S. 2010. *Inflation Targeting Turns 20*. [Online]. Available: <https://www.imf.org/external/pubs/ft/fandd/2010/03/pdf/roger.pdf>. [Accessed 2 August 2015].
- Rogoff, K. 1996. The Purchasing Power Parity Puzzle. *Journal of Economic Literature*, 34(2): 647 – 668.
- Rossana, R. J. & Seater, J. J. 1995. Temporal Aggregation and Economic Time Series. *Journal of Business & Economic Statistics*, 13(4): 441 – 451.
- Rowland, P. 2004. *Exchange Rate Pass-Through to Domestic Prices: The Case of Colombia*. [Online]. Available: <http://ideas.repec.org/p/col/000094/002683.html>. [Accessed 5 August 2013].

- Ruge-Murcia, F. J. 2007. Methods to Estimate Dynamic Stochastic General Equilibrium Models. *Journal of Economic Dynamics and Control*, 31(8): 2599 – 2636.
- Shakeri, M. & Gray, R. S. 2013. The Industry Determinants of Exchange Rate Pass-Through into Canadian Producer Prices. *International Journal of the Economics of Business*, 20(1): 15 – 38.
- Shapiro, N. & Sawyer, M. 2003. Post Keynesian Price Theory. *Journal of Post Keynesian Economics*, 25(3): 355 – 365.
- Sims, C. A. 1980. Macroeconomics and Reality. *Econometrica*, 18(1): 1 – 48.
- Sims, C. A. 2006. Comment on Del Negro, Schorfheide, Smets and Wouters. [Online]. Available: <http://sims.princeton.edu/yftp/DSSW806/DSseattleComment.pdf>. [Accessed 30 December 2014].
- Solow, R. M. 2001. A Native Informant Speaks. *Journal of Economic Methodology*, 8(1): 111 – 112.
- South African Reserve Bank (SARB). 2002. Exchange Rate Pass-Through and South African Import Prices. *SARB Working Paper WP/02/03*. Pretoria: South African Reserve Bank.
- Stančík, J. 2006. Determinants of Exchange Rate Volatility: The Case of the New EU Members. *CERGE-EI Discussion paper No. 2006-158*, Praha: Centre for Economic Research and Graduate Education.
- Stock, H. J. & Watson, M. W. 2001. Autoregressions. *The Journal of Economic Perspectives*, 15(4): 101 – 115.
- Stone, M., Anderson, H. & Veyrune, R. 2008. Exchange Rate Regime: Fix or Float? *Finance and Development: A Quarterly Magazine of the IMF*, 45(1). [Online]. Available: <http://www.imf.org/external/pubs/ft/fandd/2008/03/basics.htm>. [Accessed 16 July 2015].
- Stroe-Kunold, E. & Werner, J. 2009. A Drunk and Her Dog: A Spurious Relation? Cointegration Tests as Instruments to Detect Spurious Correlations between Integrated Time Series. *International Journal of Methodology*, 43(6): 913 – 940.

- Stulz, J. 2007. Exchange Rate Pass-Through in Switzerland: Evidence from Vector Autoregressions. *Swiss National Bank Economic Studies No. 4*, Zurich: Swiss National Bank.
- Swanepoel, J. A. & Rangasamy, L. 2004. Exchange Rate Pass-Through and South African Manufacturing Export Prices: Evidence from Panel Data. *Journal for Studies in Economics and Econometrics*, 28(3): 67 – 79.
- Sweidan, O. D. 2013. Exchange Rate Pass-Through into Import Prices in Jordan. *Global Economy Journal*, 13(1): 109 – 128.
- Tahir, M. A. 2014. Analysing and Forecasting Output Gap and Inflation Using Bayesian Vector Autoregression (BVAR) Method: A Case of Pakistan. *International Journal of Economics and Finance*, 6(6): 257 – 266.
- Tandrayen-Ragoobur, V. & Chicooree, A. 2013. Exchange Rate Pass Through to Domestic Prices: Evidence from Mauritius. *Journal of Economic Research*, 18(1): 1 – 33.
- Taylor, J. B. 2000. Low Inflation, Pass-Through and the Pricing Power of Firms. *European Economic Review*, 44(7): 1389 – 1408.
- Tovar, C. E. 2009. DSGE Models and Central Banks. *Economics: The Open-Access, Open-Assessment E-Journal*. [Online]. Available: <http://www.economics-ejournal.org/economics/journalarticles/2009-16>. [Accessed 17 December 2014].
- United Nations Conference on Trade and Development (UNCTAD). 2013. *Trade and Development Report*: Geneva: United Nations Conference on Trade and Development.
- Vinh, N. T. T. & Fujita, S. 2007. The Impact of Real Exchange Rate on Output and Inflation in Vietnam: A VAR Approach. *Discussion Paper No. 0625*, Kobe: Kobe University.
- Wang, P. 2009. *The Economics of Foreign Exchange and Global Finance*. 2nd edition. Berlin: Springer-Verlag.
- Watson, M. W. 1994. Vector Autoregressions and Cointegration, Chapter 47. In Engle, R. F. & McFadden, D. L., eds. *Handbook of Econometrics*, 4(North Holland, Amsterdam): 2844 – 2915.
- Wimalasuriya, S. M. 2006. Exchange Rate Pass-Through: To What Extent Do Prices Change in Sri Lanka. *Staff Studies*, 37(1 – 2): 49 – 67.

- Yaffee, R. A. & McGee, M. 2000. *Introduction to Time Series Analysis and Forecasting with Applications of SAS and SPSS*. London: Academic Press, Inc.
- Yagci, F. 2001. Choice of Exchange Rate Regimes for Developing Countries. *African Region Working Paper Series No. 16*, Washington D.C.: World Bank.
- Zeugner, S. 2002. Evaluation of Vector Error Correction Models in Comparison with Simkins: Forecasting with Vector Autoregressive (VAR) Models Subject to Business Cycle Restrictions. Seminar Paper for: A. Geyer: Seminar aus Operations Research 3622.
- Zivot, E. 2000. *Notes on Structural VAR Modelling*. [Online]. Available: www.eco.uc3m.es/~jgonzalo/teaching/timeseriesma/zivotvarnotes-reading.pdf. [Accessed 27 August 2015].



APPENDIX

Figure A1: Graphical Depiction of LOIL, Output Gap, LNEER, LIMP, LPPI, LCPI and Prime Rate

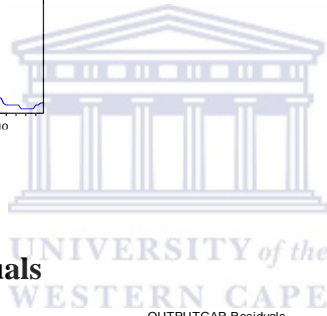
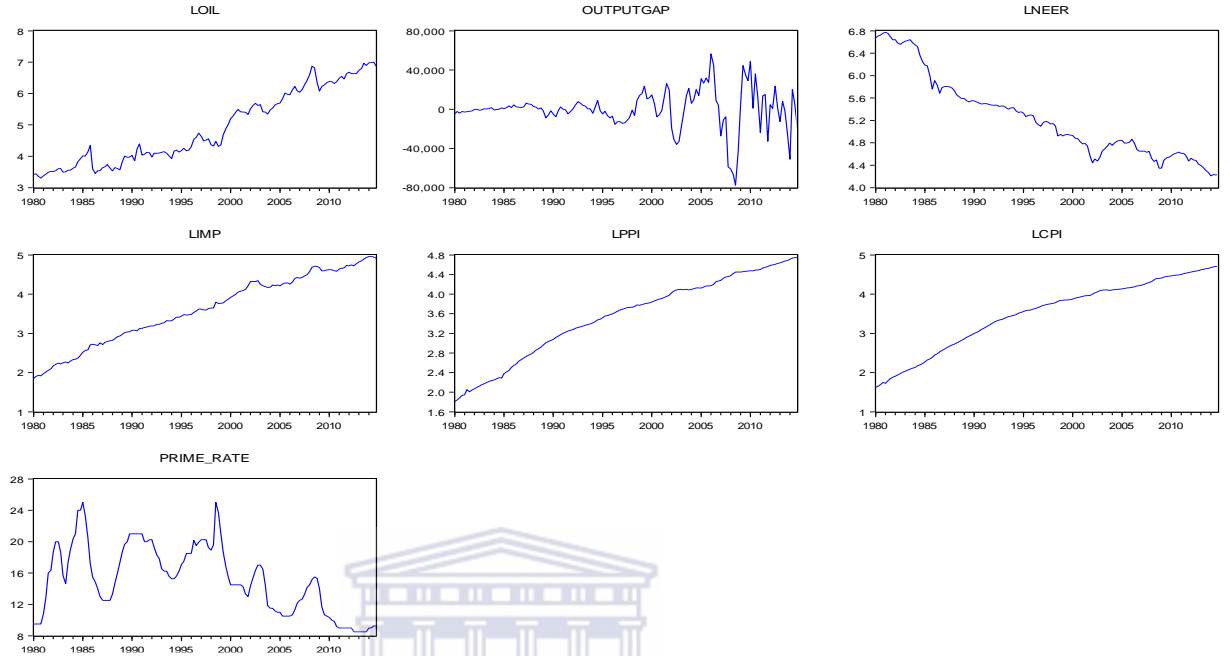


Figure A2: VAR Residuals

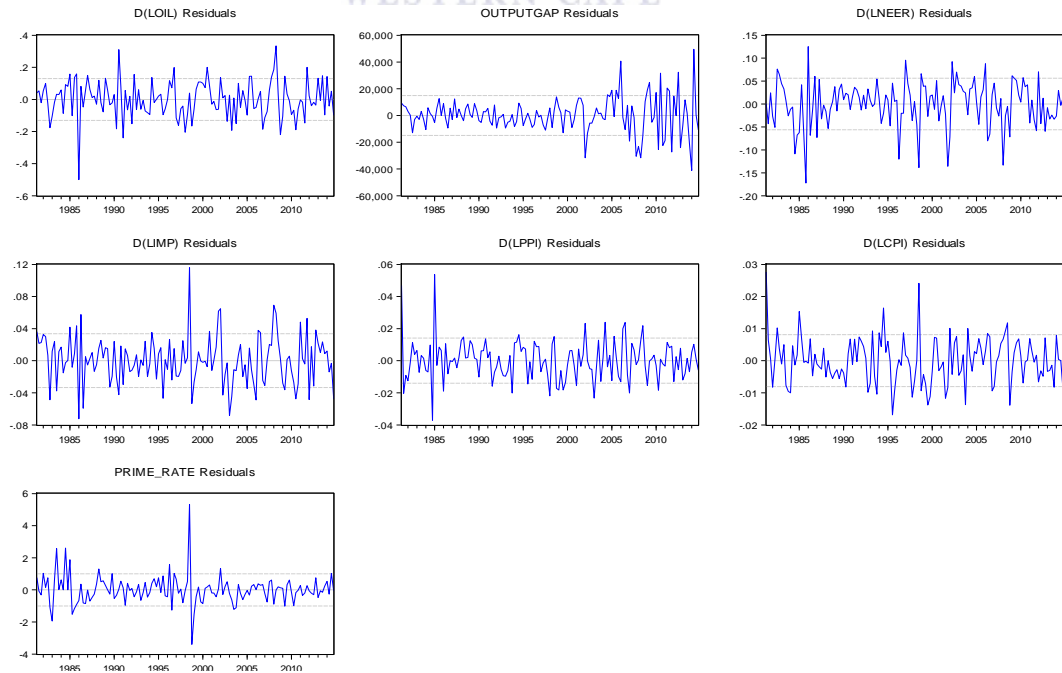


Table A1: Model Stability Checking - Roots of Characteristic Polynomial

Roots of Characteristic Polynomial
 Endogenous variables: D(LOIL) OUTPUTGAP
 D(LNEER) D(LIMP) D(LPPI) D(LCPI)
 Exogenous variables: C DUMMY94Q1 DUMMY08Q2
 Lag specification: 1 4
 Date: 07/29/15 Time: 15:21

Root	Modulus
0.797768 + 0.288990i	0.848498
0.797768 - 0.288990i	0.848498
-0.263265 - 0.770388i	0.814129
-0.263265 + 0.770388i	0.814129
-0.493492 - 0.601718i	0.778202
-0.493492 + 0.601718i	0.778202
-0.028860 - 0.760935i	0.761482
-0.028860 + 0.760935i	0.761482
-0.309590 - 0.671527i	0.739456
-0.309590 + 0.671527i	0.739456
0.669645 + 0.292940i	0.730916
0.669645 - 0.292940i	0.730916
0.477595 + 0.522352i	0.707777
0.477595 - 0.522352i	0.707777
-0.668525 - 0.042895i	0.669900
-0.668525 + 0.042895i	0.669900
0.111557 + 0.626955i	0.636802
0.111557 - 0.626955i	0.636802
-0.419027 + 0.429578i	0.600101
-0.419027 - 0.429578i	0.600101
0.355504 - 0.413281i	0.545146
0.355504 + 0.413281i	0.545146
-0.438356	0.438356
0.399109	0.399109

No root lies outside the unit circle.
 VAR satisfies the stability condition.

Table A2: Langrage Multiplier Test for Serial Autocorrelation

VAR Residual Serial Correlation LM Tests
 Null Hypothesis: no serial correlation at lag
 order h
 Date: 07/29/15 Time: 15:24
 Sample: 1980Q1 2014Q4
 Included observations: 135

Lags	LM-Stat	Prob
1	77.27115	0.0001
2	56.71151	0.0153
3	45.74872	0.1280
4	35.18466	0.5072
5	34.89611	0.5210

Probs from chi-square with 36 df.

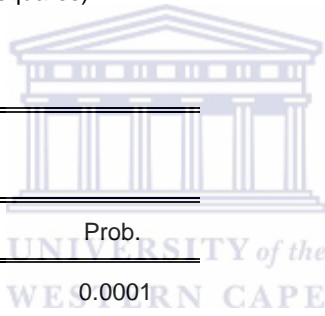
Table A3: Jarque-Bera χ^2 Normality Test

Component	Jarque-Bera	df	Prob.
1	89.18399	2	0.0000
2	15.30964	2	0.0005
3	14.51478	2	0.0007
4	5.609009	2	0.0605
5	51.10406	2	0.0000
6	4.738973	2	0.0935
Joint	180.4605	12	0.0000

Table A4: VAR Residual Heteroscedasticity Tests

VAR Residual Heteroskedasticity Tests: No
 Cross Terms (only levels and squares)
 Date: 07/29/15 Time: 15:36
 Sample: 1980Q1 2014Q4
 Included observations: 135

Joint test:		
Chi-sq	df	Prob.
1227.306	1050	0.0001



TURNITIN REPORT

- [preferences](#)
[Document Viewer](#)

Turnitin **Originality Report**

- Processed on: 28-Sep-2015 13:58 GMT
- ID: 574429154
- Word Count: 30287
- Submitted: 3

Mini-Thesis

By Francis Chiparawasha

Similarity Index

11%

Similarity by Source

Internet Sources:

6%

Publications:

8%

Student Papers:

3%



UNIVERSITY of the
WESTERN CAPE

[Turnitin Print out on the next page]