

**Burgernomics: Raw BMI vs Adjusted BMI. A Comparative Analysis of Appropriate Exchange Rate Valuation Measures**

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## **DEDICATION**

*I would like to dedicate this thesis to my mother. Fakudze Mntolo May'sandzaba Mphotholoz  
Nkhaba yashona NJENGEL' BHODLELA. I am because you are.*

## **DECLARATION**

With the exception of the sources listed in the text and the help I received from my supervisor, I, Siyanda Gumedze, hereby declare that this thesis is entirely original work of mine and has not been submitted for credit towards any degree by any other university or educational institution.

Signed \_\_\_\_\_ on this 10<sup>th</sup> day of January 2024

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## ABSTRACT

The Big Mac Index was developed in 1986 by *The Economist* magazine as a playful take on the Purchasing Power Parity theory. Its purpose is to indicate whether a currency is overpriced or undervalued in relation to the real exchange rate and whether it can be used as a reliable indicator of exchange rate predictions. There are two versions of the Big Mac Index: the raw Big Mac Index and the adjusted Big Mac Index. If appropriate, this index might be developed into an economic theory that can be applied to corporate finance, international trade, and international finance.

To determine which Big Mac Index measure is a better indicator of exchange rate valuation, a comparison analysis was conducted. This study set out to determine how well the adjusted Big Mac Index performed as a gauge for exchange rate valuation. The research then compares the two Big Mac Index measures' ability to anticipate future exchange rates in order to determine which is more accurate.

Data from the South African Reserve Bank and The Economist databases covering 37 nations from 2000 to 2022 were used for the analysis. Exchange rate misalignment trends were assessed globally, and the results indicated that the adjusted BMI was a more accurate measure of purchasing power. Tests of correlation revealed that there was a positive association between the real exchange rate and the Big Mac Index. Findings from a panel ARDL Model indicated that taking into consideration country-specific GDP variations and group heterogeneity can enhance the real exchange rates' ability to predict the raw BMI.

The research also focused on the South African Rand to ascertain whether the Big Mac Index validates the Purchasing Power Parity theoretical framework. Using cointegration tests and graphic analysis, it was possible to find evidence for a cointegrating relationship between the real exchange rate and the Big Mac Index measures during the last 20 years. Additionally, a positive correlation between the modified Big Mac Index and terms of trade was discovered in the results, confirming the hypothesis that the Big Mac Index satisfies current account assumptions. Finally, a VEC model demonstrated that the modified BMI outperforms the raw BMI in terms of forecasting estimates. Overall, the study found that the Big Mac Index is more than a bit of fun as per its origin. The results showed that the adjusted Big Mac Index has practical applications and the potential to be considered as an economic theory.

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## LIST OF ACRONYMNS

ADF	Augmented Dickey-Fuller
ARDL	Autoregressive Distributed Lag
BMI	Big Mac Index
CLP	Chilean Peso
CPI	Consumer Price Index
ECM	Error Correction Model
EUR	Euro
EViews	Econometric Views
GBP	Great British Pound
GDP	Gross Domestic Product
IPS	Im, Pesaran and Shin test

JPY	Japanese Yen
LLC	Levin, Lin and Chu test
LOOP	Law of One Price
PMG	Pooled Mean Group
MW	Maddala and Wu test
PPP	Purchasing Power Parity
RER	Real Exchange rate
RUB	Russian Ruble
SAIFM	South African Institute of Financial Markets
SARB	South African Reserve Bank
TOT	Terms of Trade
DF	Dickey-Fuller test
USD	United States Dollar
VECM	Vector Error Correction Model
ZAR	South African Rand

## CHAPTER ONE

### INTRODUCTION TO THE STUDY

#### 1.1 Introduction and Background of the Study

The value of one country's currency relative to another is known as the exchange rate (Taylor, 1995). It displays the quantity of foreign money that may be bought with a single unit of the national currency. For instance, the South African Rand's nominal exchange rate on the foreign currency market as of November 2023 was 18.83 to the US dollar (South African Reserve Bank, 2023).

According to Taylor's (2004) theory, exchange rate valuations play a crucial role in the global economy. Imports are preferred over goods and services that are made domestically when the currency is too strong. Exports benefit from a lower currency since locally produced goods are "cheaper" for customers in other countries. However, because it artificially lowers local assets for foreign investors, a weak exchange rate may distort returns on investment. For these reasons, it's critical to evaluate exchange rates accurately in order to assess whether a currency is overpriced or undervalued at any given time. The term "currency misalignment" describes this phenomenon. Currency valuation can be done through the three main measures of exchange rates: the real approach, monetary approach and Purchasing Power Parity (PPP). Purchasing Power Parity is the focus of the study hence it will be discussed in much greater detail.

Purchasing Power Parity is a measure for comparing the currencies of different countries using a 'basket of goods' to measure changes in purchasing power (O'Connell, 1998). PPP is based upon the theory of a market basket which serves as a representation of the spending patterns of consumers. To compare living standards between nations, PPP metrics are created by comparing the local costs of a wide range of products and services. Firms involved in international trade use the PPP to evaluate whether certain currencies may be misvalued. For example, investors who hold stock from foreign countries may utilize this metric to forecast the effects of the fluctuation of exchange rates to a specific country and how this exchange rate affects investment decisions as well as potentially utilize that information for arbitrage (Taylor *et al.*, 2004).

Moreover, PPP serves as the standard for assessing the competitiveness of real exchange rates and offers long-term benchmarks for the equilibrium value of exchange rates. The relative costs of items are used by the real exchange rate to represent the value of two currencies. According to PPP theory, exchange rates must converge at a certain equilibrium level in order for foreign currencies to have the same buying power (Cashin & McDermott, 2006).

However, over the years many arguments have been made for and against purchasing power parity. Many studies point out that it is difficult to find a suitable basket of goods for all countries, scholars argue that PPP is not a reliable indicator of exchange rates because the law of one price is not met. There have been debates about what should be included in the "basket" that is used to compare currencies. The view is that productivity differentials as well as the different goods that are included in the basket differ according to the geolocation of these countries, hence it makes it difficult to accurately measure exchange rates in the global economy.

*The Economist* magazine humorously created the Big Mac Index, which it argued would be a simpler measure of establishing purchasing power and determining exchange rates. The idea was to use one homogenous good which is sold in many countries which could be used to determine exchange rates based on how much it costs in each country. The expectation was that the Big Mac burger would be used, because as a franchise McDonalds produces the same product for all its different stores using the same ingredients and resources. Hence the expectation is that the price should be the same in dollar terms. The idea is that a correctly valued currency would be close to parity upon conversion to dollar terms. Over the years, the Big Mac theory advanced and there are now two methods for calculating the BMI, the raw BMI which uses a ratio of burger prices bilaterally for the exchange rate and the adjusted BMI which accounts for Gross Domestic Product per Capita in determining the ratio of GDP-adjusted price of the burger bilaterally. This theory caught the attention of many scholars and has become a source of debate amongst economists as to whether PPP can hold using the Big Mac Index. And if so, what method provides the best metric and potentially could be used in place of traditional PPP measures.

Accordingly, this study seeks to examine whether the adjusted BMI can be utilised as an effective measure of exchange rate valuation compared to the raw BMI. Or whether the BMI as a whole works simply as an interesting theoretical concept without empirical backing.

## 1.1.2 Background of the South African economy and exchange rates

### 1.1.2.1 South African Exchange Rate Regime

Table 1.1: Summary of South African Exchange Rate Regime

Period	Exchange rate regime
1945 - 1971	Bretton woods era – Fixed Exchange Rate
1971 - 1979	Fixed, Crawling and Dual exchange regime
1985 - 1995	Dual exchange rate regime
1995 - 2000	Unitary exchange rate
2000 - current	Managed floating rand, with inflation targeting framework of monetary policy

Source: SAIFM booklet: The Forex Market

The South African rand is categorised as a commodities and emerging market currency (Khomo & Aziakpono, 2020). This is because South Africa is a major exporter of commodities, especially gold and platinum, and one of the developing markets globally. The value of the rand has been greatly impacted by opinions about how safe these two markets are.

South Africa has implemented a range of currency rate management strategies (see Table 1.1) in an effort to mitigate big shocks such as sharp declines in the price of gold and political unrest. Since 1994, the South African economy has grown more integrated. According to Coco & Viegi (2020), the South African economy became more integrated since 1994 and it is presently a floating exchange rate with an inflation targeting framework of monetary policy. As a result, the rand has had significant fluctuations, mostly brought on by regional and worldwide economic crises, such as the Covid-19 Pandemic of 2020, the East Asian Crisis of 1997, political unrest in South Africa in 2000, and the Global Financial Crisis of 2008.

Given the current managed floating exchange rate supported by exchange controls in South Africa, the sticky price monetary model<sup>1</sup> is the most appropriate exchange rate model (Deo, 2023). The sticky price and overshooting model of exchange rates allows short-term overshooting of the nominal and real exchange rates above their long-run equilibrium levels

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<sup>1</sup> The sticky-price monetary model (associated with Dornbusch, 1976) assumes that prices of goods are sticky in the short run, and that PPP holds only in the long run but does not hold in the short run because goods prices adjust slowly relatively to asset prices

(Dornbusch, 1976). This stems from the sluggish adjustment of the goods markets and asset markets.

### **1.1.2.2 South Africa and The Big Mac Index**

One of the difficulties in calculating the exchange rate using the PPP theory has been cited by Margoff (2015) as the goods and assets market's slowness to adjust in the long run. The introduction of the Big Mac Index theory has resulted into a new investigation into the BMI as a fun and accessible way to analyze exchange rate dynamics and compare the purchasing power of a currency (Rand) with other currencies on a global scale. The Economist (2023) says the BMI is an attractive and simple tool to monitor the Rand's performance and is helpful in figuring out how much the currency is worth.

The index, for instance, can be used to compare one country's currencies' purchasing parities with another currency. The index can also be used to monitor the rate of inflation. The relative price change may be determined by comparing the Big Mac's changes in South Africa over a specific time period. The index can also be used to show whether the country's inflation rate is higher or lower than that of other nations. The Big Mac Index can also be used to ascertain whether a currency is overvalued (appreciated) or undervalued (depreciated) in relation to another currency.

Since the end of apartheid, the Rand has significantly declined in value (Ansari, 2017). Takaendesa et Al, (2006) believed that this is due to South Africa's inflation rate being higher than those of its trading partners. They found that fluctuations in the real exchange rate may be of great concern to policymakers and businesses. It might discourage investors from making investment decisions about trade flows. Therefore, it is appropriate to look into whether or not these variations in the real exchange rate are a result of equilibrium phenomenon or not. The concept of the Big Mac Index presents an easier method of making these determinations.

## **1.2 Problem Statement**

Traditional PPP has received quite a bit of criticism over the years as some scholars have found that PPP theory fails to hold for determining the real exchange rate. The primary criticism of PPP is that, according to Taylor & Taylor (2004), looking at the asset market theory there is an inherent distinction between nominal pricing levels and exchange rates. This suggests that nominal price levels are less vulnerable to assumptions about future events than exchange rates,

similar to the pricing of other assets. This means there will be more volatility for exchange rates caused by ‘news’ than volatility for price levels. As a result, fluctuations will be unpredictable since we are unable to forecast news based on historical pricing data (Frenkel, 1978). Therefore, because aggregate price levels represent the cost of less durable goods, they are unable to demonstrate volatility. This indicates that the nominal exchange rate is fluctuating at a pace that is different from the rate of inflation during the adjustment process. However, scholars like Lacerda, Fedderke & Haines (2010), Abuaf & Jorian (1990), Bahmani – Oskooee (1995), Lothian & Taylor (1996), Holmes (2000, 2001), and McNown & Wallace (1988) amongst many others believe the fundamental idea of PPP is that, over time, the exchange rate should return to its mean, notwithstanding anomalies or disruptions.

*The Economist* introducing the concept of the Big Mac Index has brought favour back into the concept of PPP. The index aims to simplify the concept of PPP which has caused a lot of debate amongst scholars (*The Economist*, 2023). A study by Caetano *et al*, (2004) highlighted that the BMI is based on the idea of a homogenous good and the ‘law of one price’ - the anchor theory of Purchasing Power Parity. Which in essence suggests that the exchange rate will be mean reverting (PPP theory holds). This means that exchange rates and price levels cannot be divorced from each other. Consequently the BMI- PPP will not be subject to the disruptions that come with using the CPI basket of goods for determining exchange rates.

The idea is that when currencies are converted into one currency (the dollar), a correctly valued currency would be close to parity (mean reverting) using the BMI (Clements *et al*, 2012). The success of the BMI theory would inherently solve the problems tied to using PPP for determining exchange rates. Therefore the study aims to determine whether PPP theory can hold for exchange rates through the Big Mac Index. Specifically by comparing the raw and adjusted BMI to ascertain if the adjusted BMI can be a more effective and simpler method of valuation of real exchange rates.

### **1.3 Goal of the Research**

Determining the adjusted BMI's value as a gauge of acceptable exchange rate valuation at a particular moment in time is the primary goal of this research. establishing if the adjusted BMI is a more accurate predictor of future exchange rate changes than the raw BMI is another goal.

The following research questions are addressed:

- a) Globally, are the raw BMI and the adjusted BMI useful measures of appropriate exchange rate valuations. If so, which one is the better measure: the raw BMI or the adjusted BMI?
- b) Is the adjusted BMI an appropriate measure for exchange rates for the South African Rand in comparison to the Raw BMI?
- c) Does the adjusted Big Mac Index yield better forecasting estimates compared to the raw Big Mac Index for the rand?

#### **1.4 Methods, Procedures and Techniques**

The study follows a post-positivist paradigm. To achieve the goals of the research, secondary data was collected for all the countries that have the Mc Donald's franchise and for which *The Economist* has collected price data. Annual country level panel data for 40 countries from 2000 to 2022 was collected from *The Economist* online dataset. Terms of trade data for South Africa was sourced from the Reserve Bank. This study examines whether local currencies are overvalued or undervalued by comparing the actual worth of local currencies versus the US dollar with the raw Big Mac index and the adjusted BMI. The question of whether the raw or adjusted BMI is more useful for forecasting future exchange rate movements is investigated by calculating changes in overvaluation and undervaluation over time. After taking into account country-level variations using GDP per capita, a panel Autoregressive Distributed Lag (ARDL) econometric model is also employed to ascertain whether the raw BMI has any predictive power for real exchange rates.

#### **1.5 Significance of the study**

The exchange rate is now a more significant macroeconomic variable that can be used to affect economic growth as a result of globalisation (Perraton, 2019). The interconnectedness of world economies has made domestic economies more susceptible to events occurring in other economies. As a result, Krugman (2017) concluded that exchange rate stability and alignment are crucial since they affect how economic performance is determined. When the real exchange rate diverges from its long-term equilibrium level, this is known as exchange rate misalignment. According to the relative PPP-based method of measuring misalignment and equilibrium, equilibrium is attained when the purchasing power of two currencies is equal (LaFrance, 2002). This implies that the ratio of the two nations' price levels should match the ratio of the two countries. Depending on whether it is overvalued or undervalued, a misaligned exchange rate can have a favourable or negative impact on the ways that exchange rates impact economic growth.

Making PPP comparisons can be done more easily and simply with the Big Mac Index (Loveridge & Paredes, 2018). This is carried out by taking the McDonald's burger prices bilaterally and calculating the price ratio that results, which serves as a gauge for the implied appropriate value of the local currency (Ong, 1997). Since conventional PPP measurement has been observed to have flaws and challenges, the popularity of the BMI has increased. Due to its ease of measurement, the BMI has drawn the interest of macroeconomic experts during the past few decades.

Some studies, including a study by Chen et al (2007), have found that the raw BMI does not hold due to nontradables and productivity biases. It has been found further that the adjusted BMI method provides more consistent misvaluation estimates in contrast to the large differences observed in the misvaluation estimates when using the raw BMI method (Jiawen, 2018). This means the adjusted BMI results in smaller differences from the nominal exchange rates compared to the raw BMI. Therefore, it is worthwhile to investigate if the adjusted BMI, as opposed to the raw BMI, provides a more accurate indicator of suitable exchange rate valuation in South Africa and the global economy.

Furthermore the main contribution to this study is a new perspective into the existing literature on the raw big mac index will be brought into the study. This is to ascertain the predictive power of the raw BMI for RER after factoring in GDP per capita, through the use of a Panel ADRL model to check for short and long run relation of the GDP and BMI variables. This seeks to address the issue of productivity bias which makes the price levels for the burger to be higher in the wealthier countries (Clements et Al, 2012). Looking at the country level differences for the nontradables and catering for the different income levels in the countries could potentially improve the effectiveness of the raw BMI. The study further looks into the South African Rand in detail to explore the exchange rate behaviour of the Rand using the Big Mac index. The success of the applicability of the BMI to the Rand could potentially pave way for more studies into the foreign exchange market and monetary policy.

### **1.6 Structure of the Thesis**

The outline of the thesis is as follows. Chapter 2 covers the conceptual framework and an overview of foreign exchange markets. It reviews, briefly, the existing literature on exchange rates, purchasing power parity and the Big Mac Index. Chapter 3 covers the research methodology, design and data sources. Chapter 4 presents the empirical analysis and findings.

Lastly, Chapter 5 consists of the summary of the study and the discussions of the results and findings.

## CHAPTER 2

### CONCEPTUAL FRAMEWORK, THEORETICAL FRAMEWORK AND LITERATURE REVIEW

#### 2.1 Introduction

This chapter is concerned with the definitions of exchange rates as well as the concepts around exchange rate determination. The definitions, calculations, theoretical and empirical literature pertaining to Purchasing Power Parity, exchange rates, the Big Mac Index and currency misalignment will be discussed to conceptualize the issue of exchange rate determination and long run mean reversion in currency misalignment/ misvaluation. This chapter is divided into three sections. The first section contains the conceptual framework which provides definitions for key concepts related exchange rates. The next section introduces the theoretical framework and provides a brief review of the empirical literature on the Big Mac Index and Purchasing Power Parity. The last section discusses currency misalignment with respect to Purchasing Power Parity and the Big Mac Index.

#### 2.2 Conceptual Framework

##### 2.2.1 The Exchange Rate

The cost of exchanging one currency for another is known as the exchange rate (Taylor, 1995). To put it another way, an exchange rate is the quantity of one currency that can be bought with one unit of another, and vice versa. The exchange rate is a key factor in an open economy since it affects consumer pricing, interest rates, economic growth, and investment decisions.

##### 2.2.2 Nominal Exchange Rate

The nominal exchange rate, also known as the nominal effective exchange rate, is the rate at which one currency is exchanged from another. Lane (1999) defined the nominal exchange as the number of units of country currency per unit of the currency of the benchmark country (US dollar). For example, if the nominal exchange rate between the South African Rand (ZAR) and the US Dollar (USD) is 18.15, then 1 dollar can be exchanged for 18.15 ZAR. The nominal exchange rate is influenced by market and economic factors such as: trade balances, market sentiments, interest rates, economic performance, political influences, and inflation rates (Lane, 1999). It is also worth noting that the nominal exchange rate factors in the relative value of the currencies in the foreign exchange market and it excludes purchasing power between countries (Mussa, 1986).

### 2.2.3 Real Exchange Rate

Unlike the nominal exchange rate which looks at the relative value of one currency in terms of another, the real exchange rate (RER) is a measure of the relative Purchasing Power Parity (Edwards 1989) of two currencies (Hinkle & Montiel, 1999). In other words, the real exchange rate considers the differences in the price levels in different countries. This means the real exchange rate tends to provide a more accurate picture of the purchasing power of all currencies in their respective economies.

The real exchange rate is calculated as follows:

$$RER = \text{Nominal exchange rate} \times \frac{\text{Price of domestic goods}}{\text{price of foreign goods}} \dots\dots\dots (2.1)$$

Where:

- Nominal exchange rate: The rate at which one currency can be exchanged for another currency.
- Price of domestic goods: The average price level of goods and services in the domestic economy (the country where the currency is being measured).
- Price of foreign goods: The average price level of goods and services in the foreign economy (the country of the other currency).

The real exchange rate can be used to evaluate how competitive a country's commodities are in international trade. According to Edwards (1989), a real exchange rate lower than the nominal exchange rate suggests that it is cheaper for foreign consumers to buy goods, which makes exports more competitive. Whilst a lower real exchange rate means imports become more attractive as the price of the goods becomes cheaper for locals to buy and consume.

A real exchange rate close to 1 shows that the purchasing power of a currency is similar whilst a real exchange rate greater/ less than 1 suggests a possible misalignment in the currencies. As a result, the real exchange rate helps when it comes to trade and international investment decisions. Policy makers, investors and businesses are then able to better understand the true economic conditions of countries.

#### **2.2.4 Bilateral and Multilateral Exchange Rates**

The price of one currency in terms of another can also be referred to as the bilateral exchange rate. There are two main types of exchange rates: bilateral and multilateral. A bilateral exchange rate is the rate at which one currency can be exchanged for another single currency (Hamilton, 2018). For example, the exchange rate between the US dollar (USD) and the euro (EUR) is a bilateral exchange rate. Bilateral exchange rates can fluctuate constantly due to various factors, including changes in economic conditions, interest rates, inflation, political stability, and market speculation.

On the other hand, multilateral exchange rate refers to the exchange rate between one country's currency and a weighted average of the currencies of other countries. Kunkler (2023), defined multilateral exchange rates as a broad measure of the value of one nation's currency relative to several other currencies combined. The weightings are typically based on the trade volumes or economic importance of the countries involved in the calculation. Central banks, policymakers, and international organizations may use multilateral exchange rates as a benchmark to monitor and evaluate currency movements and to make informed decisions related to economic policies and international trade. These rates can also influence various aspects of international finance and trade, affecting import and export competitiveness and cross-border investment decisions.

#### **2.2.5 Equilibrium Real Exchange Rate**

The Equilibrium Real Exchange Rate (ERER) is a concept used in international economics and finance to describe the theoretical exchange rate at which a country's currency is in equilibrium, or at a level where the country's international trade is balanced in the long run (Edwards 1989). The equilibrium real exchange rate considers changes in price levels between countries. It is often expressed as the relative price of goods and services between two countries. It is a vital concept for understanding exchange rate movements and the factors that influence a country's trade balance.

When a country's currency is at its equilibrium real exchange rate, it means that its currency is neither overvalued nor undervalued. In this state, the country's exports and imports are in balance, and there are, therefore, no imbalances in the trade account. As a result, there is no tendency for the country to experience persistent trade surpluses or deficits.

However, several factors can influence achieving an equilibrium real exchange rate: relative productivity, fiscal and monetary policy, structural factors, and terms of trade. It's important to note that the nominal exchange rate in the foreign exchange market can deviate, in the short run, from the equilibrium real exchange rate due to various factors, including speculative activity, changes in investor sentiment, and unexpected economic events. However, over time, market forces tend to move the real exchange rate toward the equilibrium real exchange rate as international trade and capital flows adjust to the underlying economic fundamentals.

### **2.2.6 Importance of the Equilibrium Exchange Rate**

The equilibrium exchange rate is very important in international economics and finance for several reasons. Central banks and policymakers often monitor and analyze exchange rate misalignments to make informed decisions about appropriate monetary and fiscal policies to address any imbalances and support the economy's stability and growth.

Overall, the equilibrium exchange rate serves as a reference point for policymakers, businesses, and investors to assess a country's economic health, trade competitiveness, and financial stability, for a country's exchange rate policy and economic decision-making. Maintaining a well-aligned exchange rate is vital for achieving sustainable economic growth and stability in an increasingly interconnected global economy. While achieving the exact equilibrium exchange rate in practice can be challenging, having a clear understanding of the concept helps policymakers lead the economy towards sustainable growth and avoid potential issues that could arise from exchange rate misalignments, which is why it is important to get as close to the real equilibrium exchange rate as possible.

### **2.2.7 Exchange rate determination – Purchasing Power Parity**

The real exchange rate is a measure of purchasing power parity, as was previously mentioned. According to the "Purchasing Power Parity," when two currencies have the same purchasing power in each nation, their exchange rates will be in equilibrium. According to the law of one price, the ratio of the two nations' prices for a set basket of goods and services should be the same as the exchange rate between them. To attain purchasing power parity, a country's exchange rate must also decline when its domestic price level rises. This could be as a result of inflation.

The idea is that, in the short term, exchange rates are driven by the news presenting economic changes. Any economic changes like interest rates and inflation rates will result in immediate changes in the exchange rate. However, when it comes to PPP the long run behaviour of exchange rates comes into play. The market forces which cause shifts in the exchange rate in the short run will eventually equalize and any movements will be corrected, and the purchasing power of currencies is determined.

The subsequent section will examine the theoretical and empirical literature relevant to the study. It will focus on real exchange rate theory and measurement as well as the history, theory and arguments behind Purchasing Power Parity (PPP) in more detail. This section also introduces the Big Mac PPP-Approach and lastly considers several issues related to currency over/under valuation.

## **2.3 Theoretical Framework**

### **2.3.1 The Real Exchange Rate: Concepts and Measurement**

Measuring the real exchange rate is the first step towards determining the long run equilibrium real exchange rate. Hinkle and Montiel (1999) state that there are two primary classifications for the real exchange rate: internal and external. The ratio of the domestic price of tradable to non-tradable products within a single nation is known as the internal terms. An economy's buying and selling operations are influenced by the internal terms, which capture the internal pricing incentives in that economy for producing or consuming tradable products as opposed to non-tradable items. In this scenario, the actual exchange rate turns becomes an indicator of domestic resource allocation incentives. However, when it comes to the external terms, the nominal exchange rate is modified to account for price differences across nations rather than just for one. It is the ratio, expressed in a common currency, of the total international price level to the total domestic price level. The price level in one nation is converted into the other nation's currency using the nominal exchange rate.

Consequently, economists have chosen to focus on the external RER for empirical and analytical purposes for both industrial and developing countries. The RER is calculated as the ratio of the foreign to the domestic values of price indices, such as the Consumer Price Index (CPI) and the GDP deflator. The nominal exchange rate can be used to translate the price level of one country's currency to that of another country and express this as a common currency.

However, there are many complications in the analysis of the RER since different conceptual frameworks would mean different choices of price indexes. Then we are left with many categories of external real exchange rates from which to choose. The three external real exchange rate measures identified are the Mundell-Fleming or aggregate production cost RER, which uses GDP deflators. The traded goods RER, which uses relative unit labor costs in manufacturing, manufacturing sector deflators, export unit values and wholesale prices. Then finally the Purchasing Power Parity based RER, this uses the domestic and foreign Consumer Price Indices. The PPP based RER method has the empirical advantage of price data being widely available and easily accessible for many countries including developing countries. This means that RER country representation can easily be established and computed. For the purposes of this study focus will be given to the PPP based RER due to the reasons discussed below.

## **2.3.2 Purchasing Power Parity**

### **2.3.2.1 History of Purchasing Power Parity**

Purchasing Power Parity is a theory for determining exchange rates. In its common form the theory is that any exchange rate change between currencies over a period is determined by the changes of the relative price levels of those two countries. Other scholars also refer to PPP as the ‘inflation theory of exchange rates’ because attention is drawn towards exchange rate movements being driven by price level changes. Despite the many differing views on PPP, there is a general understanding that PPP provides a useful description of exchange rate behaviour.

PPP theory can be traced back to the Salamanca school in the 16<sup>th</sup> Century as well as writings by Gerrard de Malynes in England in the early 1600s. Over the years, many scholars like Alfred Marshall, Stuart Mill, David Ricardo, Ludwig von Mises, and Viscount Goshen also had more qualified views on Purchasing power parity as an operational theory of exchange rates. However, it was Gustav Cassel (1921,1922) who initiated the development and application of PPP theory post World War 1.

The origin of the purchasing power parity is traced back to the discussions held on how the world financial system could be restored following the collapse that occurred during World War 1. Before the war, many countries followed the gold standard, and had their currencies

convertible to gold at fixed parity. At that time, the exchange rate reflected the relative gold values of the two currencies. Post-war it became near impossible to maintain the gold standard due to devaluation concerns. Thereafter the gold standard was abandoned. The major problem was that countries struggled to find a way to reset the exchange rates back to pre-war status, in a way that caused limited interruptions to government finances and the prices of goods. This was attributed to the differing inflation rates that were experienced during the war. Cassel (1928) encouraged using purchasing power parity to establish parity according to the gold standard. He proposed using the inflation differentials of gold from the 1914s to calculate exchange rates to maintain PPP.

*“The fact that the rate of exchange corresponding to Purchasing Power Parity possesses such a remarkable stability is a sufficient reason regarding Purchasing Power Parity as the fundamental factor determining the rate of exchange and for classifying all other factors that may influence the rate and perhaps make it deviate from the purchasing power parity as factors of secondary importance, most suitably grouped under the head of ‘disturbances’.” – Cassel 1928 (MacDonald, 2007, pg. 110)*

However, Cassel also identified three groups of disturbances which could pose problems to PPP theory. Namely, new hindrances to international trade, shifts in international movements of capital and actual & expected inflation or deflation. He further believed that despite these disturbances being present they were confined between ‘narrow limits’, making them disturbances that did not affect the real exchange rate in the long run. Empirical evidence from the 1920s and data collected from the early 1970s provided support for purchasing power parity and the monetary approach.

### **2.3.2.2 Statement of The Theory**

#### **2.3.2.2.1 Absolute Purchasing Power Parity**

We assume that  $p_i$  and  $p_i^*$  are the price of the  $i^{\text{th}}$  commodity in the domestic and foreign currency, respectively, and we can further assume that  $e$  is the exchange rate. In the same manner  $P_i$  and  $P^*$  represent the price level at the domestic currency and in the foreign currency, respectively. Having this in mind, the exchange rate is then defined as the number of units of domestic currency per unit of foreign currency.

The strong form of PPP which is also referred to as absolute PPP is based on the ‘law of one price’ in a competitive market. The ‘law of one price’ states that holding all else constant goods that are identical should be sold for the same price when expressed in a common currency, which is usually the US Dollar. We can denote this as;  $p_i = ep^*_i$

Assuming that the domestic price index is  $P = f(p_1, \dots, p_i, \dots, p_n)$  , and the foreign price index is  $P^* = g(p_1^*, \dots, p_i^*, \dots, p_n^*)$ .....(2.2)

Absolute PPP would be expected to hold after equalizing the prices of goods across countries through a common currency and assuming that the goods are homogenous, given the same weights. As a result, the ‘law of one price’ will apply to the aggregate price levels and to the individual goods (MacDonald, 2007).

In this case the formula for Absolute PPP can be expressed as;

$$e = \frac{P}{P^*} = \frac{\text{foreign (dollar) price of a standard market basket of goods}}{\text{domestic price of the same standard basket}} \dots\dots\dots(2.3)$$

whereby the right-hand side of the equation is the multiple of the price of each good in the two country’s currencies.

Despite any existing monetary or real disturbances that may be present in the economy, due to costless arbitrage, the prices of a common basket of goods in the market of the two countries, measured in a common currency will be always the same,  $P/eP^*=1$ .

Theoretically, absolute PPP did not receive substantial critique. However, empirically, it was found to be a simplifying assumption which has a number of potential problems. The concern was the spot price of a good will not be the same in different locations at a given period. This was attributed to various factors like non-tradable goods, trade barriers (tariffs and quotas), transportation costs and imperfect competition. These are the same factors that affect the ‘law of one price’. Since the law of one price was driven by international commodity arbitrage, it was believed that the prices of the goods be equal or else there would be unexploited risk-free arbitrage opportunities present (Bleaney 1992). And these opportunities would be difficult to explain if we assumed that traders acted rationally and didn’t capitalize on them.

However, studies have found it is possible for arbitrage to fail due to the above listed factors (Frenkel, 1980). These factors result in currency values deviating from what absolute PPP would predict. In as much as this does not suggest market failure, it shows the inability to move goods with ease and without cost, from one location to another. Instead, they will just not be set at common prices. As a result, the strong form of PPP fails to hold.

### 2.3.2.2.2 Relative Purchasing Power Parity

Dornbusch (1988) further discusses the weak form of PPP which is also known as relative PPP, as it considers the changes in exchange rates and changes in relative price levels (inflation).

This is given as;  $e = \theta P/P^*$ ..... (2.4)

Where:

e is the exchange rate

$\theta$  represents the barriers to trade

P is the domestic price index

P\* is the foreign price index

This means an increase in the domestic price level relative to the foreign price level implies a depreciation of the domestic currency. In other words, if one currency experiences higher inflation than another, then that country's currency should weaken in value relative to the other country's currency. This is done to maintain the relative purchasing power of the two currencies.

The formula for relative PPP is then given as;

$$\hat{e}^2 = \hat{P} - \hat{P}^* \dots\dots\dots (2.5)$$

This is further supported by Cassel's theory of how exchange rates work post World War 1.

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<sup>2</sup> Where the ^ denotes percentage change.

*“The general inflation which has taken place during the war has lowered this purchasing power in all countries, though in a different degree, and the rates of exchange should accordingly be expected to deviate from their old parities in proportion to the inflation of each country. At every moment the real parity is represented by this quotient between the purchasing power of money in the one country and the other. I propose to call this parity ‘Purchasing Power Parity’. As long as anything like free movement of merchandise and a somewhat comprehensive trade between the two countries takes place, the actual rate of exchange cannot deviate very much from this purchasing power parity. “ – Cassel 1918 (MacDonald, 2007, pg.107)*

However, just like absolute PPP, relative PPP has received scrutiny and criticism by scholars, who postulate that despite adjusting for price changes in the determination of exchange rates, relative PPP also does not hold due to the changes in relative productivity, interest rates, market expectations as well as other economic variables. They termed this as the Purchasing Power Parity Puzzle (Frenkel, 1978).

#### **2.3.2.2.3 The ‘Purchasing Power Parity’ Puzzle**

The core assumption is that there should be a correlation in aggregate price levels if the goods market arbitrage maintains parity in prices over a significant range of individual commodities (law of one price). Most economists accept purchasing power parity as an anchor for long-term real exchange rates, even though few take PPP seriously as a short-term idea (Rogoff, 1996). Even though PPP has poor empirical support in the short run, the long run real exchange rate may still be anchored by PPP. Despite the common agreement on the above, some economists believe the short run deviations from PPP are volatile and large and the speed of convergence to PPP is very slow even for the long run (Frenkel, 1978).

There are mixed views on whether PPP holds for real exchange rates. Studies by Frenkel (1980); Rogoff (1996); Taylor & Taylor (2004); O’Connell (1998); Lafrance (2002) and Ong (2003) argue against PPP theory. The main contention here is that, according to asset market theory, there is an inherent distinction between national price levels and exchange rates. This suggests that nominal price levels are less vulnerable to assumptions about future occurrences than exchange rates, similar to the pricing of other assets. This means there will be more volatility for exchange rates caused by ‘news’ than volatility for price levels (Rogoff, 1996). This then creates the phenomenon known as the ‘PPP Puzzle’.

According to Frenkel (1978), changes will be unforeseeable since we are unable to forecast news based on historical pricing data. Therefore, because aggregate price levels represent the cost of less durable goods, they are unable to demonstrate volatility. This indicates that the nominal exchange rate is fluctuating during the adjustment process at a pace that is different from the rate of inflation (Ong, 2003).

Furthermore, the theoretical literature refuting PPP postulates that the 'Law of One Price' (LOOP) is violated. The LOOP, as mentioned, implies that where there are no transaction costs, due to competitive arbitrage, one price should be set for the same goods in all countries in terms of the dollar. However, according to Haidar (2011) and Haskel & Wolf (2001), the theory of PPP will not, in practice, be satisfied between countries due to the factors impacting the trade of currencies. These include interest rate differentials, which means these transactions are based on the capital account of the balance of payments instead of what PPP assumes. The PPP assumption is that foreign exchange transactions are based on current account transactions, an example being terms of trade<sup>3</sup>.

However, there are still strong arguments in favour of PPP theory. The arguments for PPP are that exchange rates and price levels cannot be divorced from each other. Policies which affect the trend of local prices are likely to affect the exchange rate in a similar manner when it comes to macro-economic policy (Weale et al, 2015). The view is that PPP is violated due to overshooting. Overshooting is the idea that markets quickly react to interest rate changes and other economic changes (Bjørnland, 2009). Although it is not an immediate reaction, but it takes some time for market participants to adjust fully to market expectations. Consequently, the exchange rates will exhibit short term volatility and, in turn, overshoot the long term values.

McKinnon (1981) suggests that overshooting is due to a lack of sufficient speculation in the markets for foreign exchange. Dornbusch (1978) and Frenkel (1981) argue that it is due to the process by which asset holders restore portfolio balance during disturbances. But the premise of PPP is that despite these deviations/ disturbances, the exchange rate should revert to the mean in the long run (Cashin & McDermott, 2006) Real exchange rates are found to be stationary despite the highly persistent shocks present. It was found that the persistence of the shocks was because of a country's inflation experience and the extent of nominal exchange rate

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<sup>3</sup> The relative price of exports in terms of imports (Mendoza, 1997).

volatility. So, the arguments against PPP are mostly because of the slow rate that the exchange rates adjust to PPP. This means the essential concept of mean reversion is still valid and applicable to exchange rate measurement.

The PPP puzzle has highlighted the PPP disparities that exist, and there is vast literature on the consequences of a situation whereby exchange rates fail to conform to PPP theory<sup>4</sup>. These issues include, but are not limited to, issues of macroeconomic measurement, linkages and policy which can be investigated further in a different study.

In summary, despite all the issues that have been highlighted in relation to PPP, it remains an essential part of open economy macroeconomics for two main reasons. Firstly, it acts as a benchmark to judge the level of exchange rates and PPP is utilized as a predictive model for the future exchange rates. According to Cassel (1918), without PPP we would not have a meaningful way to discuss issues of mis-valuation (be it over or under valuation). This is further confirmed by the widespread use of PPP by financial institutions, international organisations and governments. They use this to judge the changes in a country's external competitiveness, which assumes that the changes in real exchange rates translate into changes in competitiveness from which to expect change in trade flows and net exports (Ang et al, 2021). Moreover, several empirical results on the study of PPP which are applicable for both developing and developed countries further supports Cassel's theory on Purchasing Power Parity.

### **2.3.3 Big Mac Index**

*The Economist* magazine, in 1986, introduced an informal measure of currency exchange rates for PPP known as the Big Mac Index (BMI). *The Economist* initially humorously created this index and gave caution that it should be taken with a grain of salt. However, over time, the Big Mac Index then piqued the interest of scholars and became a subject of academic study. This paved the way for a theory known as "Burgernomics". The Big Mac Index is a simpler method for making PPP comparisons to establish real exchange rates, compared to using the traditional PPP basket. Like with traditional PPP theory, to get long run equilibrium in the real exchange rate, we expect mean reversion between the deviations between the nominal exchange rate and the BMI implied exchange rate.

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<sup>4</sup> Dornbusch, R., (1985). *Purchasing power parity*.

Lindert, P.H., (2016). *Purchasing power disparity before 1914* (No. w22896). National Bureau of Economic Research.

According to Caetano et al. (2004), the BMI employs the single-good basket theory, which is the basis for calculating absolute PPP. The contents of a Big Mac hamburger from McDonald's include tradeable items such as burger buns, pickles, lettuce, ground beef, cooking oil, onions, and cheese. Most significantly, non-tradeable components like labour, rent, and electricity are also included. The prices of the ingredients and other parts that go into making the Big Mac, which add up to a basket of goods and services, can be utilised to estimate the cost function of the sandwich. Caetano et al. (2004) propose that the BMI avoids issues linked to other measures because of the commonalities of the ingredients across all countries and the expectation that the pricing should be similar locally and internationally. The BMI avoids problems related to other measures (CPI or GDP deflator) of PPP. There are now two versions of the Big Mac Index being studied; the raw BMI and the adjusted BMI.

### 2.3.3.1 Raw Big Mac Index

Making PPP Comparisons can be done more easily and simply using the raw BMI. The raw BMI uses the price ratio that is produced from comparing the local and global costs of McDonald's hamburgers to determine the inferred acceptable value of the local currency. Jiawen (2004) states that this index is based on the idea that as the hamburgers are always the same, their price should be the same everywhere in the world when stated in the same currency. In terms of the law of one price, the BMI seeks to ascertain whether a currency is appropriately valued, or over- or undervalued, by contrasting the burger price ratio with the real exchange rate measure.

The raw BMI is calculated by taking the prices of the McDonald's burger locally and internationally to determine the raw BMI implied exchange rate (Clements et al, 2012).

$$S = \frac{P}{P^*} \dots\dots\dots (2.6)$$

where;

S is the raw BMI implied exchange rate

P is the price of a Big Mac in local currency

P\* is the price of a Big Mac in the US dollar

The raw BMI was supported by the ‘law of one price’ and it utilised the price ratio as a measure of the implied appropriate value of the local currency (Caetano *et al*, 2004). According to Jiawen (2004), the BMI is based on the notion that when expressed in the same currency, the burgers should, because they are identical, be the same price globally. For PPP to hold for the BMI we expect the deviations for BMI exchange rates to be mean reverting towards real exchange rates in the long run.

In this case currency misvaluation (deviation) is measured as the difference between the BMI implied exchange rate and the nominal exchange rate. The formula for currency misvaluation for raw BMI is given as;

$$M_{\text{raw}}^R = X - X_{\text{raw}} \dots\dots\dots (2.7)$$

Where ;

X is the real exchange rate

X<sub>raw</sub> is the raw BMI implied exchange rate

However, studies have challenged the reliability and applicability of the BMI for exchange rate valuation. Empirical studies by Jiawen (2018), Chen et al (2007), and San Vicente & Atal (2014), presented evidence that PPP through the BMI does not hold for real exchange rates. They found that the BMI fails to be a good measure of current and future exchange rates. This is due to varying labour costs and barriers to migration that undermine purchasing power. Pakko and Pollard (2003) suggest that the Big Mac Index can be used for testing purchasing power parity theory. However, they identified that the reasons other scholars found it not to hold is due to non tradables and productivity bias<sup>5</sup>, which gives different results for different countries due to the economic activity of these countries not being the same.

### 2.3.3.2 Adjusted BMI

*The Economist*, in 2011, made an improvement on the raw BMI and introduced the adjusted Big Mac Index for currency exchange rate measurement (The Economist, 2023). The adjusted BMI considers per capita GDP differences across economies, as an improvement on the limitations nontradables and productivity bias placed on the index. The adjusted Big Mac Index

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<sup>5</sup> Stems from the Balassa-Samuelson effect (also known as the Penn effect), which suggests that a relatively more productive economy experiences a real appreciation of its currency.

was then used to predict what Big Mac prices should be after controlling for a country's GDP per capita.

$$A = \frac{aP}{aP^*} \dots\dots\dots (2.10)$$

where;

A is the adjusted BMI implied exchange rate

aP is the GDP adjusted price of a Big Mac in local currency

aP\* is the GDP adjusted price of a Big Mac in the US dollar

**2.3.3.2.1 Currency Misvaluation and the Adjusted Big Mac Index**

In order to calculate currency misvaluation using the adjusted BMI, first we need to get the predicted big mac price by running an OLS regression ;

$$\hat{P} = \alpha + \beta_1 GDP_p \dots\dots\dots (2.11)$$

Where;

$\hat{P}$  = predicted big mac prices

GDP<sub>p</sub> = GDP per capita for local currency

$\alpha$  = the intercept

$\beta_1$  = slope coefficient

A currency misevaluation for the adjusted Big Mac Index is measured by comparing the currency's residual and the estimated line of best fit. A currency's relative residual measures the currency's overall misvaluation. This is relative to the line of best fit and to the basket of other currencies. The currency's residual ( $\epsilon$ ) is the actual price of the Big Mac minus the predicted ( $\hat{P}$ ) Big Mac price. A currency misvaluation after the adjustment for GDP can be found when a positive residual signifies an over valuation and a negative misvaluation means an undervaluation. A correctly valued currency is found when the currency's residual is zero.

Moreover, it is worth noting that the adjusted Big Mac method estimates the bilateral misvaluation between two currencies using the overall misvaluation estimates of two currencies. Clearly distinguishing the difference between the overall misvaluation and bilateral

misvaluation is crucial in the study of the adjusted big mac index. Due to this being a new method with limited literature there tends to be confusion as to how exactly the misvaluation is determined by *The Economist* as they give a very vague explanation on how they did their calculations. Obrien & Vargas (2015), tried to fill in the gaps and provide more clarity.

A bilateral misvaluation is when the exchange rate between two currencies is either over or undervalued relative to its true economic fundamentals. Bilateral exchange rates are used to estimate one country’s currency against another country’s currency in terms of typical applications of the raw PPP-BMI. Whilst overall currency misvaluation is measured between one country’s currency and a basket of a larger number of countries’ currencies. The adjusted Big Mac method uses the bilateral misvaluation to assist with the calculation of the overall misvaluation.

To ascertain currency misvaluation mathematically using the ZAR/USD as an example:

- Find the overall misvaluation of the rand vs the currency ‘basket’

$$m_{Adj}^R = \frac{p - \hat{p}}{\hat{p}} - 1 \dots\dots\dots (2.12)$$

Where: p= big mac rand prices,  $\hat{p}$  = predicted big mac rand prices

- Find the overall misvaluation of the dollar vs the currency ‘basket’ is found as follows:

$$m_{Adj}^{\$} = \frac{p - \hat{p}}{\hat{p}} - 1 \dots\dots\dots (2.13)$$

Then lastly determine bilateral misvaluation of the rand vs the dollar;

$$m_{Adj}^{\$/R} = \frac{1 + m_{Adj}^R}{1 + m_{Adj}^{\$}} - 1 \dots\dots\dots (2.14)$$

Clements and Si (2017) tested the applicability of the adjusted Big Mac Index for a selection of economies to include higher income earning economies as well as low income countries. They found that the adjusted BMI method provides more consistent and effective misvaluation

estimates in contrast to the large differences observed in the misvaluation estimates when using the raw BMI method. That means the adjusted BMI results in smaller differences from the nominal exchange rates compared to the raw BMI. The relative consistency across the BMI basket suggests that one can get a reasonable approximation of a given currency's misvaluation by simply averaging the bilateral misvaluation (O'Brien and Vargas, 2015). This provides evidence of the adjusted BMI working even for emerging economies like South Africa, which suggests that even for these economies PPP does hold with the adjusted BMI and thus meets the current account assumptions of PPP.

The adjusted BMI follows the Balassa-Samuelson Effect theory also known as the Penn-Effect (Balassa, 1964) (Samuelson, 1964). The Penn-Effect speaks to the association between the traditional PPP deviations and per capita GDP. As a model of exchange rate valuation, the Penn Effect assumes that an individual currency may deviate from the estimated relationship, which justifies mean reverting currency misvaluation. The Penn-Effect is further supported by the productivity bias hypothesis (Bahmani-Oskooee & Nasir, 2005) which suggests that a relatively more productive economy will exhibit higher price levels as a result of an increase in wages, which eventually results in changes in the long term exchange rates.

#### **2.3.2.2.2 Adjusted BMI Theories**

##### **2.3.2.2.2.1 Balassa-Samuelson Effect**

The Balassa-Samuelson effect was proposed by economists Bela Balassa and Paul Samuelson in 1964. The Balassa-Samuelson effect is an economic theory that explains the relationship between relative price levels in different countries and exchange rates. It suggests that exchange rates are influenced by the difference in productivity growth in the tradable and non-tradable sector of an economy. The Balassa-Samuelson effect supports the theory that price levels tend to be higher for wealthy countries like Switzerland and Sweden. The Balassa-Samuelson model found that there is a strong positive relationship between price levels and GDP per capita. This theory is sometimes also referred to as the "Penn effect," after two economists, Alan Heston, and Robert Summers, who first documented it at the University of Pennsylvania.

Cross-country differentials are the primary cause of persistent fluctuations in real exchange rates over time and between countries, according to the main theoretical framework for interpreting real exchange rates. This is referred to as the Balassa-Samuelson model. The forces behind this concept are simple: non-tradable goods prices rise as a result of increased

local input costs, such as wage increases, caused by higher productivity development in traded-goods sectors (Balassa, 1964; Samuelson, 1964). This raises the local price level, which is a true appreciation of the exchange rate, since traded-goods prices tend to be equalised across national borders.

The assumption is that differences in the productivity growth between countries exists for the tradable goods sector (goods which are easily good and sold globally like manufactured goods). The understanding is that the difference in the productivity growth is attributed to the wage and price effects. When one country experiences higher productivity growth one of two things could happen. Firstly, the higher productivity could result in higher wages for the tradable goods sector in the country that has higher productivity growth. This is caused by the firms' ability to now pay their workers more wages yet remaining competitive in the international markets as a result of their comparative advantage (Pancaro, 2011).

However, there is a positive relationship between an increase in the wages of the firms' workers and the prices of the goods being produced in that firm. This is because higher wages can lead to an increase in production costs, and the consumers are made to bear the additional costs in the form of higher prices. This may then cause a difference in the price levels of goods which consequently results in the basket of goods having different price levels. This is applicable even in the context of the Big Mac basket, in that despite the same ingredients being used, the differences in the wages could lead to the price of the burger to be different in the different MacDonalds franchises.

The theory suggests that exchange rates will adjust to reflect the differences in the relative price levels between two countries. The currency of the country that has high productivity levels and high inflation will weaken over time in comparison to the currency of a country with a lower productivity growth and inflation level. The rising price levels cause the inflation rate to be higher in the faster growing and more developed countries compared to the slower growing developing countries. This in turn positively impacts the trade balance (Hassan, 2016). The currency with a weakening exchange rate consequently has cheaper exports and the country's imports become more expensive. This leads to an improvement in the trade balance for the country, which also improves its terms of trade ratio.

This model is driven by higher productivity growth in traded- goods which tends to increase local input costs and therefore prices of non-tradable goods. And because the prices of traded goods are equalized across countries this in turn raises the local price level resulting in the real exchange rate appreciating. The argument is that a faster growth of the relative productivity in the domestic currency as compared to the foreign country is what causes the real exchange rate to appreciate. And this has also been the reasoning given to explain the real exchange rate misalignments from Purchasing Power Parity. This is further supported Pancaro (2011) who studied the Balassa-Samuelson effect and the Penn Effect and found similarities which showed that real income ratios between developed and developing countries will be overvalued when converted to market exchange rates because the price level is higher in the wealthier countries. The rising price levels cause the inflation rate to be higher in the faster growing and more developed countries compared to the slower growing developing countries.

The law of one price says that the prices of tradable goods need to be equalized across all countries, but this doesn't apply for non-tradable goods. However, the higher productivity in tradable goods means higher wages for workers in that sector. This will lead to relatively higher prices and possibly wages for the local non- tradable goods purchased by the workers. This also means countries with lower per capita income will have lower domestic prices for services and lower price levels. Therefore, the long run productivity differences between the high- and low-income countries will lead to the deviations between the PPP and exchange rates.

Furthermore, Annaert & De Ceuster (1997) demonstrated the existence of an expectations mechanism, wherein producers of non-tradable items may base their price expectations on the knowledge that there is a relationship between the prices of non-tradable and tradable commodities. Because of this, producers base their pricing adjustments on the real exchange rate when setting their prices. The justifications presented above support the inclusion of non-traded goods in the computation of Purchasing Power Parity, which is then applied to the adjusted Big Mac Index. When calculating Purchasing Power Parity using the Big Mac Index, productivity bias is controlled for by include both marketable and non-tradable commodities.

The Balassa- Samuelson effect is further supported by the productivity bias hypothesis which also says that the differences in productivity growth rates (for tradable goods) leads to changes in the relative price levels which eminently leads to changes in the long-term trends of exchange rates (Bahmani-Oskooee & Nasir, 2005). This is why it is important to incorporate

these productivity differences when analyzing currency movements. Incorporating GDP per capita as a proxy for productivity differences solves the problems that made the raw Big Mac Index PPP not to hold (income differentials) and allows for better measurement of exchange rates.

### **2.3.2.3 Empirical Literature**

#### **2.3.2.3.1 Empirical Literature on Purchasing Power Parity**

Purchasing power parity and exchange rates have been heavily researched by economists all over the world. There are mixed views on the theory of purchasing power parity, some scholars find that PPP theory does not hold because currency misalignment does not revert to parity due to exchange rates following a random walk. However, there are a number of studies that provide support for PPP. In this literature, the empirical findings show that, in the long run, exchange rates are mean reverting and find themselves back towards parity even with the short run deviations observed.

Shively (2001) studied long-term PPP for Canada, Japan, Italy, the United Kingdom, France, and Switzerland using a sample spanning from 1973 to 1997. The study's objective was to determine if the real PPP link—which exists as a long-run equilibrium relationship between nominal exchange rates and domestic and international indices—holds true. The relevance of annual, long-horizon real exchange rates was examined using an exact small-sample, pointwise most powerful invariant (MPI) unit root test. The study's findings unequivocally and consistently supported the existence of the real purchasing power parity relationship. In favour of the trend stationary alternative, which states that the real exchange rate returns to a long-run equilibrium, the random walk null hypothesis link was rejected.

Holmes (2000, 2001) did a study to test for long run relative purchasing power parity for 27 developing African countries from 1974 to 1997. The study used a t-bar test, which allows for one to test for unit roots in heterogenous panel datasets. PPP was rejected using individual unit root tests, but PPP is supported using the t-bar test. The results suggest that PPP is likely to hold for high inflation developing countries and the half-life of deviations to parity is six quarters.

Abuaf & Jorian (1990) carried out a study to reevaluate the data that was previously available on PPP over the long term. Abuaf & Jorian contend that rather than being proof against PPP, the negative results that imply PPP might not hold up over time could be the consequence of

tests with inadequate power. Utilising a set of univariate autoregressions, they limited the autoregressive coefficient, which remained constant across all nations. The goal was to provide parameter estimations that were more accurate than the typical setting based on each country. They employed yearly data for ten industrialised nations (Belgium, Canada, France, Germany, Italy, Japan, Netherlands, Norway, Switzerland, and Britain) spanning the years 1900 to 1972. The theory that real exchange rates exhibit a random walk was called into question by the empirical findings. Thus, even if evidence for short run deviations was discovered, their conclusions—drawn from a Monte Carlo approach to estimation—were that long run PPP might in fact hold.

Cashin & McDermott (2006) examined parity reversion in real exchange rates and, in particular, on whether it is fast, slow or non-existent. The paper tested for PPP using the real effective exchange rate for 90 developing and developed countries (20 industrialised and 70 developing countries) during the Bretton Woods period (1973 to 2002). Least squares estimators and median-unbiased estimation techniques were used to calculate the half-lives of PPP deviations. The study provided support for PPP as the majority of the countries experienced finite deviations of real exchange rates from parity. The speed of parity reversion was found to be faster for countries that had a flexible exchange rate regime compared to countries with fixed nominal exchange rate regimes.

Ngayasu (2002) considered the question of whether the long-run PPP hypothesis holds for Africa, using a panel cointegration study. The paper studied the long-run PPP concept using parallel market exchange rates of 17 African countries (including South Africa) using the panel cointegration method, for the period 1980 to 1994. This was a method best used for analysing the countries which did not have a long time series. The findings of the study were that weak form of the long run PPP hypothesis is supported even in Africa, without the need for homogeneity restrictions on prices.

McNown & Wallace (1989) did a study on national price levels, purchasing power parity and cointegration. They examined the time series properties of PPP for four high inflation countries (Argentina, Brazil, Chile and Israel) for the 1976 to 1985 time period. They used cointegrating regressions to determine the departure from long run equilibrium. They also employed error correction models to describe the mechanism of adjustment to long run equilibrium. The cointegration tests found evidence to support that PPP does hold in the long run. The results

from the error correction model also further supported the results for cointegration in relation to PPP.

#### **2.3.2.3.2 Empirical Literature on the Big Mac Index**

Upon looking into the theoretical background behind the Big Mac Index, it's important to look at the empirical evidence which is in full support of the use of the Big Mac Index as a simpler measure of PPP in the measurement of exchange rates.

Chen et al. (2007) used Big Mac and CPI pricing for 16 nations from 1992 to 1999 to investigate the validity of PPP. Their findings demonstrated that the idea that PPP is a useful inflation metric was disproved when the OLS approach was applied. The results demonstrate that while PPP is acceptable when the dependent variable is the price ratio, it is invalid when the dependent variable is the nominal exchange rate. Using the Big Mac price does not result in PPP being rejected. When CPI prices are used, PPP is still rejected even after removing productivity bias; however, when Big Mac prices are used, PPP is accepted.

Another study was done by Ong (2003) to investigate the economics of the Big Mac standard. They did a study to test whether the Big Mac Index can be used to track exchange rates over the long term. Regression tests were run which confirmed that relative and absolute purchasing power parity holds with the Big Mac index over a 9-year time horizon. The data used in the study was of the Big Mac burger prices for 34 countries from 1986 to 1994. The regression results showed that the BMI seems to model short-term and long-term PPP very well. The results found that even though individual currencies were deviating from PPP, there was a tendency for the deviations to offset one another so that the rest of the currencies were in parity for any one year. The study further found that geographical influences play an important role in currency valuation. The study found that PPP comparisons could be enhanced by factoring in productivity differentials between countries and by introducing the 'no frills' index which considers these differentials between countries.

Clements et al (2011) conducted an evaluation on the "Burgernomics" theory and its evolution. The study set out to assess the 'true value' of 24 countries from 1994 to 2008. A regression line of best fit was plotted, and a regression was run to measure exchange rate disparity. A Root Mean Squared error (RMSE) test was done to establish the predictive power of the BMI. The paper found that the BMI suffers from productivity bias, but once that bias is allowed for the

index tracks exchange rates well over the long term in line with PPP theory. The study also found that the random walk model predicts future currency values for the longer time horizons.

Clements & Si (2016) also conducted a study looking into simplifying the Big Mac Index. This study was done upon the amendment *The Economist* (2023) made when they introduced the adjusted Big Mac Index. They then suggested a third alternative which they believed to be a simplification of the adjusted BMI. They suggested for a change in the functional form of the pricing equation from a linear model to a logarithmic model. The log-model still maintains the purpose of testing whether the Big Mac Index can be used to explain PPP and exchange rates. The study used data for 49 countries for 2015. The study ran regressions using *The Economist's* "line of best fit" but in log form to test its hypothesis. They found that the adjusted big mac index and their simplified method produced similar results and they found that the two were a better forecaster in comparison to the raw BMI.

Wee & Lee (2022) tested the validity of purchasing power parity using a panel cointegration approach with the Big Mac Index. The study looked at PPP using the Big Mac Index, from 1999 to 2021 for 27 countries. The study used panel unit root and panel cointegration tests. The results showed strong evidence of weak form (absolute PPP or adjusted BMI) PPP and inconclusive evidence for the strong form (raw BMI or relative PPP) PPP. Which led them to conclude that these findings help market participants in the foreign exchange market find direction with regards to future fluctuations of exchange rates. This meant they found that PPP holds for the BMI, which meant it could be used to determine whether long term investments could be made or not.

Fujiki & Kitamura (2004) also examined the 'Big Mac Standard'. The study evaluated a statistical procedure best suited to test PPP based on the BMI. Data was collected for 23 countries from 1996 to 2002. A fixed effects estimator regression was run for an unbalanced set and for a balanced set, and the observations were plotted against a 45-degree line of best fit. The results found supporting evidence for purchasing power parity based on the Balassa Samuelson effect. They found the main conditions for BMI-PPP to hold being the selection of appropriate models, sample periods and the countries used for estimation. However, the study ignored certain measurement problems like how the data used was collected only at one time in the year. This could mean any transitory exchange rate fluctuations may not be reflective of the exchange rates throughout the year.

Jiawen (2004) did a study disproving BMI-PPP theory. The study was based on non-tradables and the valuation of the Chinese Renminbi (RMB) according to the BMI. The study looked at the Chinese currency and 28 other countries for the time period 1992-2003. A BMI misalignment calculation was done to determine how over/undervalued these 29 currencies were. A correlation graph was also presented to compare the Big Mac valuation against GDP per capita. The study found that the RMB is being overvalued by the index due to the per capita income of China being lower than that of the United States. It was also found that BMI fails to account for the nontradable aspect in its pricing. Jiawen further found that the BMI is a misleading measure for currency valuation for countries whose income levels are different from benchmark currencies like the Dollar and the Pound.

A study identifying the purchasing power of Indonesia Rupiah (IDR) based on the BMI was done by Naban (2016). The aim of the study was to compare the purchasing power of the Rupiah to the US dollar against the BMI exchange rate behaviour of other countries. The study further went on to investigate the income inequality amongst Indonesia and four Association of Southeast Asian Nations (ASEAN) countries. A raw BMI misalignment calculation and a Big Mac affordability index were done. It was found that between 1988 and 2015, the exchange rate of the IDR/USD weakened and was undervalued. The affordability index showed that a disparity of real income exists between Singapore and five other ASEAN countries.

Portes & Atal (2013) studied the BMI as a shortcut to inflation and exchange rate dynamics. The study tested the price tracking and predictive properties of the BMI. Statistical analysis was done using data collected for 54 countries from 1986 to 2012. BMI misalignment calculations were done. An exchange rate movement tracking exercise was also done to assess whether big mac prices reflect price movements that move together with CPI. The results found that big mac prices show a lag in the overall inflation patterns and some stickiness was found at a 1-year horizon. Evidence for some forecasting power of the BMI was found. The study further concluded that developed countries gravitated towards BMI parity but not the emerging markets.

Another study on the BMI by Pakko & Pollard (1996) was done looking at 15 countries. Data was collected from 1986 to 1995. The study ran misalignment calculations as well as a comparison between inflation differentials vs the exchange rate. They stated that with the

inferential differential, if the exchange rate equals to the inferential differential, it means PPP using BMI holds. The results showed that PPP generally doesn't hold in the short run for relative and absolute PPP. It was further concluded that the BMI-PPP theory acts a useful benchmark for long term equilibrium in the foreign exchange markets, but it does poorly as a predictive tool for future exchange rates.

Click (1996), did a study on the PPP on the BMI. The study looked at 26 countries for a time period 1986 - 1995. A logarithmic regression model of the price ratio onto the exchange rate. the regression considered simple pooling, country specific fixed effects and country specific random effects. A logarithmic regression was run, and it was found that BMI-PPP does not hold over an annual basis but over a longer term of ten years it was found to hold. A logarithmic plot of the big mac price ratio onto the exchange rate was further plotted to see if the line of best fit is achieved. The study concluded that PPP holds for the BMI. The time series dimension and the country effects were found to be linked to income as suggested by the Balassa-Samuelson effect.

Based on the review of the above literature there are views both in favour of the BMI working for Purchasing Parity and studies opposing the effectiveness of BMI-PPP. The studies that have opposed the applicability of the BMI have cited concerns with country specific income effects. They found that the BMI fails to be a simpler method of PPP because it fails to account for income differences amongst the different countries with different economic standings. However, there has been a large number of studies that have found that BMI-PPP holds, and any country specific deviations are explained by the Balassa-Samuelson effect, which states that the Big Mac tends to cost more where income is higher. Therefore, controlling for income effects improves the BMI's measure of exchange rates and this makes BMI-PPP theory to hold and calls for further investigation and mastering of the theory.

#### **2.4 Over/undervaluation with respect to PPP and the Big Mac Index**

The dynamics of currency rates should be taken into consideration after talking about PPP and the BMI. The purchasing power of one currency against another is what determines the exchange rate. Exchange rates may be either floating or fixed. Emerging nations may occasionally have government-controlled or pegged currency rates. The government has the authority to control the exchange rate by choosing to buy or sell its own currency.

Exchange rate misalignment can occur due to various factors, including speculative activities in the foreign exchange market, central bank interventions to influence the exchange rate, differences in interest rates between countries, capital flows and investment decisions, government policies and trade barriers and market expectations and sentiment.

It's important to note that exchange rate misalignments are not uncommon, and exchange rates in the foreign exchange market can be subject to significant short-term fluctuations that do not necessarily reflect misalignment. However, persistent, and significant deviations from the equilibrium exchange rate can have significant implications for a country's trade balance, economic growth, and overall macroeconomic stability (Hinkle, Monteil 1999).

The PPP/BMI can be used to measure an exchange rate and determine if a currency is overvalued or undervalued. When the real exchange rate exceeds the predicted Purchasing Power Parity/Big Mac Index exchange rate, the currency is said to be overpriced (Rodrik, 2008). This indicates that, generally speaking, domestic prices for goods and services are higher than those of foreign countries. For instance, products are more expensive in the US than in South Africa if the US dollar is overpriced in relation to the South African Rand.

Imports are less expensive when a currency is overvalued, which benefits nations that mostly rely on imports for their goods and services since it helps to regulate prices and inflation. However, exports cost more to international buyers. An overpriced currency also discourages foreign direct investment, according to Jensen et al. (2013), since investors will deem the nation too costly to invest in and the rewards will be inferior to those in other places. The labour market will suffer from these results, and economic development will eventually slow down.

A currency that is undervalued is one in which the cost of a basket of products in the undervalued nation is less than the cost of those commodities elsewhere in the world. According to Rodrik (2008), this results in a rise in exports since the products made there are more affordable outside. When a currency is devalued, more investments and jobs are created. Additionally, imports are consumed less since they increase in price, which helps local businesses by increasing the amount of their products that are consumed. A depreciating currency will raise demand for locally produced items and drive down the cost of local goods. This is the influence on consumption.

Politically speaking, a depreciating currency benefits exporting businesses and permits the nation to tax imports without violating any international trade regulations. Undervaluation, however, might cause issues such as a reduction in the labour supply, an overabundance of demand for employment, and a rise in salaries that could cause inflation (Goldfain and Gupta, 1999). The Big Mac Index or Purchasing Power Parity can be used to determine if exchange rates are fairly priced. Nevertheless, due to governmental activities, political influences, and other factors affecting the exchange rate markets, purchasing power parity may not always persist, particularly over an extended period of time (Chen et al., 2007).

## **2.5 Conclusion**

In summary, Purchasing Power parity theory has been a topic of great discussion amongst academics. There are mixed views on whether purchasing power parity can be used to determine exchange rates. This has been based on the uncertainty of the disturbances that cause the PPP exchange rates to be different from real exchange rates. However, it has been established that even exchange rates may follow a random walk in the short term. Over the long term these deviations have been found to be mean reverting (at parity 1) which is the basis of the PPP theory.

The PPP theory was taken a step further by *The Economist* when they humorously created the Big Mac Index which was said to be a simpler method of exchange rate determination, using a single homogenous basket of goods, which helped to solve the arguments that people had regarding the CPI basket which is commonly used to establish PPP and exchange rates. The idea for the Big Mac Index gained popularity when scholars decided to put it to the test. They wanted to see if, indeed, a simpler measure of PPP would address the main problems that have been identified with PPP using price levels.

This chapter also introduced the theory behind the Big Mac Index as well as the two types of the Big Mac Index: the raw Big Mac Index and the adjusted Big Mac index. The former being based on the difference between the price of the burger in the local currency against the price in dollar terms. The latter uses the same logic but incorporates productivity differentials to establish whether adjusting for income levels in the different countries would provide a better estimate of the BMI. Therefore, the study will hinge on the effect productivity bias (Balassa-Samuelson effect) has on the determination of the BMI implied exchange rates. It will outline

the difference that incorporating income differentials between countries makes on the effectiveness of the Big Mac Index in determining exchange rates.

The following chapter will outline the methodology that will be followed to test which of the two BMI approaches are appropriate measures of exchange rate valuation.

## CHAPTER THREE

### RESEARCH METHODOLOGY, DESIGN AND DATA

#### 3.1 Introduction

This chapter serves to provide an outline of the empirical analysis that will be undertaken in the study. The objective of this chapter is to provide an overview of the research design, data sources, and empirical strategy. The chapter is structured as follows, research paradigm, research design and estimation techniques.

#### 3.2 Research Paradigm

A post-positivist paradigm is followed in this research. This paradigm suggests that researchers bring their values, beliefs, and biases into the research process, and that these factors can influence the way knowledge is consumed and interpreted. The post-positivist paradigm challenges the positivist claims about absolute truth being proved/shown through generalisation and laws. Post-positivist researchers are more likely to use mixed methods (quantitative and qualitative data) in their studies. Researchers using a post-positivist paradigm try their best to work as objective researchers. However, unlike positivists, post-positivists believe that an objective reality is not fully possible, because human intellect is flawed.

According to post-positivism, the aim of research is to test a hypothesis, find the relationship between variables and thereafter predict results. Hence, the aim of this study is to test a hypothesis and predict results to determine the usefulness of the adjusted BMI for PPP as a measure of appropriate exchange rate valuation over the long term. This is done by testing whether the adjusted Big Mac Index provides a better exchange rate valuation as compared to the Raw Big Mac Index.

A quantitative methodology is applied in this study, to answer the research questions. The study will be able to report on comparisons and comment on the statistical significance of the findings. This makes it easier to make the study as objective as possible, whilst producing results that are reliable and backed up with both theoretical and empirical literature.

#### 3.3 Research Design

Panel data is used in this study as it is one of the approaches used when there is a combination of cross sections and time series. This makes it the ideal data type to use in a financial markets

study. Studies by Bruer et al (2002), Alba & Papell (2007), Nayaran (2005) and Bahmani - Oskooee (1995) have found that cross sectional and panel data give more powerful evidence of long run PPP than time series data. This is because panel data allow one to estimate mean reversion with greater precision than the short-term time series regression. Oh (1996), suggests that the advantage of panel data is that it avoids concerns about the use of long-term time series data because it includes potentially serious structural shifts. It would be difficult to find the same results using short term time series approach and at least a century worth of data would be required. Findings by Mokoena (2007), show that there is a moderate tendency for real exchange rates to converge towards long run equilibrium.

Panel data includes observations collected at different time points for the same units, allowing researchers to study changes and trends over time. Each time point includes observations on multiple entities, enabling researchers to analyze differences between entities at a specific time. Panel data captures the individual variation within entities over time, which provides more precise estimates compared to cross-sectional data alone. Researchers can conduct analysis to explore how trends change over time, making it possible to study dynamic processes and results. Panel data can lead to more efficient estimation and stronger statistical power compared to cross-sectional or time-series data alone, especially when studying specific phenomena. This is relevant to the study because it allows for identification and quantification of econometric and statistical techniques, such as fixed effects models and random effects models.

### **3.3.1 Sample and sampling methods**

Secondary data was collected for all countries that have the Macdonald's franchise and for which *The Economist* has published price data. Annual country level panel data for 36 countries from 2000 to 2022 was obtained from *The Economist's* publicly available online dataset.

The key variables included in the dataset are:

- Big Mac prices (measured in both local and dollar currencies)
- GDP adjusted Big Mac prices (measured in both local and dollar currencies)
- Foreign exchange rates
- Terms of trade for goods for South Africa
- GDP per capita (measured in both local and dollar currencies)

*The Economist* refers to the following sources for compiling their data. The Big Mac and GDP-adjusted Big Mac prices are collected from McDonald's franchises directly. The historical exchange rate information was sourced from Thomson Reuters (up until January 2022) and Refinitiv DataStream (from January to July 2022). GDP per capita<sup>6</sup> data is from the IMF World Economic Outlook reports. Terms of trade data for South Africa was sourced from the South African Reserve Bank. The Big Mac calculations constructed by *The Economist* were done through Jupyter notebook.<sup>7</sup> All of this data was collected as annual data.

The data used in this study is an unbalanced panel data set. This means that some of the variables has more observations in one specific class than others. This called for the removal or omission of some countries in the data sample. 35 countries<sup>8</sup> are evaluated out of a dataset of 52 countries. The selection process on the countries to keep for this study is based on the availability data for all the necessary variables from at least 2000 till 2022.

Out of the 35 countries evaluated, the study will focus on 6 countries: Brazil, Sweden, China, Russia, South Africa, and Britain from the years 2000 to 2022. Random selection was used to decide on a fair selection of low- income, middle-income and high- income countries that have the McDonalds franchise.

### **3.3.2 Estimation techniques**

#### **3.3.2.1 Unit root stochastic process**

A unit root stochastic process refers to a stochastic (random) process where the underlying variable has a unit root. A unit root implies that the variable's value is not stationary over time, which can lead to various statistical issues and challenges in analysis. Conducting estimations on non-stationary data could result in spurious and unreliable results. This makes interpretations and forecasting to be incorrect and misleading.

Stationarity is an important concept in time series analysis. A stationary time series has statistical properties, such as mean and variance, that do not change over time, this is also

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<sup>6</sup> GDP per capita is calculated using GDP and population data for the countries of interest.

<sup>7</sup> Big Mac data generator.ipynb

<sup>8</sup> The 35 countries are; Argentina, Brazil, Britain, Canada, Chile, China, Colombia, Czech Republic, Denmark, Egypt, Euro Area, Hong Kong, Hungary, Indonesia, Israel, Japan, Malaysia, Mexico, New Zealand, Norway, Pakistan, Peru, Philippines, Poland, Russia, Saudi Arabia, Singapore, South Africa, South Korea, Sweden, Switzerland, Taiwan, Thailand and Turkey

referred to as a stochastic process with a purely random or white noise process. This is statistically depicted as;  $E(Y_t) = 0$  and  $\text{Var}(Y_t) = 1/(1 - \rho^2)$ .

On the other hand, a non-stationary series may display tendencies that complicate the analysis process. When two non-stationary variables seem related but are not causally related, the result of non-stationarity is a spurious regression. A random walk is followed by random shocks that permanently affect a series with a unit root. This suggests that when performing a regression analysis with a time series that contains a unit root, the results could be erroneous. For instance, a series with a unit root has no tendency to revert to the long-run deterministic path, and its variance is time-dependent.

Researchers and analysts often use techniques like differencing or transforming the data to make a time series stationary before doing any further analysis. This can help remove trends and stabilize the variance of the series. The commonly used unit root tests include the Dickey-Fuller test (DF) and the Augmented Dickey-Fuller (ADF) test and Phillip-Peron (PP) test. These tests help determine whether a unit root is present in a time series and whether differencing is necessary to achieve stationarity.

#### **3.3.2.1.1 Augmented Dickey-Fuller test**

The Augmented Dickey-Fuller test was developed to improve the issues the DF test had. The ADF test is an extension of the Dickey-Fuller test that includes additional lagged differences of a time series variable to account for possible serial correlation in the error terms. This modification makes the ADF test more powerful and suitable for a bigger dataset of time series data.

The test involves estimating the autoregressive model and calculating a test statistic, which is then compared to critical values from statistical tables to determine whether to reject the null hypothesis. If the test statistic is more negative than the critical value, the null hypothesis is rejected, indicating that the data is likely stationary.

#### **3.3.2.1.2 Panel unit root test**

While effective in a temporal series, standard unit root tests like the Dickey Fuller, Augmented Dickey-Fuller, and Phillips Peron unit root tests are weak in their ability to differentiate the unit root null from stationary alternatives. As a result, panel unit root tests have gained popularity among empirical researchers who have access to panel data sets in recent years.

Since the first generation panel unit root is the only approach offered by EViews, it was the only available method of this study.

The first generation panel unit root tests are the Levin, Lin and Chu test (2002), Im, Pesaran and Shin test (2003) and Fisher-type tests(Maddala & Wu, 1999). These tests are based on the assumption that the data is independent and identically distributed across individuals (Barbieri, 2006).

The panel unit root test was done to determine whether or not BMI PPP holds by determining the stationarity of the BMI (raw and adjusted) implied exchange rates using the panel unit root test. Weak form BMI implied PPP holds when the panels are stationary. The following equation tests validity of BMI implied PPP;

$$\ln E = \alpha \ln P_i - \beta \ln \beta^*_i \dots\dots\dots (3.1)$$

Where;

$\ln P_i$  is the logarithm of local Big Mac price

$\ln \beta^*_i$  is the logarithm of the US Big Mac price

The panel unit root test was a very vital part of analysis as it shows the number of times a variable had to be differenced for it to be stationary in order to allow for further tests to be done.

The *priori* expectation for a panel unit root test is that the variables will be stationary either at level terms or 1<sup>st</sup> difference, it can also be a combination of the two. Further estimations can be conducted when the null hypothesis is non-stationarity is rejected and stationarity is found either at level terms or 1<sup>st</sup> difference or of mixed order of integration.

**3.3.3.4 Cointegration test**

The concept of cointegration was first formalised by Granger (1981) and Engle & Granger (1987). Cointegration is a statistical concept that refers to a long-term relationship between two or more non-stationary time series variables. it implies that while individual variables might not be stationary, a linear combination of these variables is stationary, indicating a stable equilibrium relationship between them. Cointegration tests are particularly useful for

understanding the long-term relationships between economic variables and for constructing appropriate models that capture the interdependencies among non-stationary variables.

One of the most widely used cointegration tests is the Johansen cointegration test. There are two main versions of the Johansen test: The trace test, tests the null hypothesis that there are at most "r" cointegrating vectors against the alternative that there are "r+1" cointegrating vectors. The maximum eigenvalue test tests the null hypothesis that there are exactly "r" cointegrating vectors against the alternative that there are "r+1" cointegrating vectors. Other cointegration tests include the Engle-Granger cointegration test, which is simpler but limited to two variables, and various tests based on the concept of Vector Error Correction Models (VECMs).

Determining whether a model empirically demonstrates a substantial long-term relationship requires testing for cointegration. In the event that there is no cointegration among the underlying variables, working with differenced variables must be done; nevertheless, this will result in missing long-run data. The Johansen and panel cointegration tests will be the main emphasis of the study.

### **3.3.3 Model Specification**

#### **3.3.3.1 Panel ARDL model**

An expansion of the ARDL (Autoregressive Distributed Lag) model for time series data in panel data format is the Panel ARDL model. When variables of different orders are integrated, Pesaran & Shin (1995) presented the ARDL model as a solution to the cointegration analysis problem. The panel model used in this study was further improved by Pesaran & Pesaran (1997), Pesaran et al. (1999), and Pesaran et al. (2001). It is employed to examine both the short- and long-term relationships among the variables in a panel dataset. Panel data consists of observations made on several cross-sectional units (such as nations, businesses, and people) during various time periods.

The key feature of the Panel ARDL model is that it allows for both heterogeneous and cross-sectional dependence, making it ideal for analyzing the dynamics of variables that may have different behaviors across different units and over time.

Therefore the following model is specified;

$$\Delta RER_{it} = \Phi_i RER_{i,t-1} - \beta'_i X_{i,t} + \beta'_i \Delta GDP_{it} + \sum \alpha_{ij} \Delta RER_{i,t-j} + \sum \delta'_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_i \dots \dots \dots (3.2)$$

Where:  $X_{it}$  is the raw BMI for country  $i$  in time  $t$ .  $\Phi_i$  is the group-specific speed of adjustment coefficient (expected that  $\Phi_i < 0$ ).  $\beta'_i$  is the coefficient of misvaluation, which measures the long run relationship between BMI and the real exchange rate. The error correction term is given as  $ECT = [RER_{i,t-1} - \beta'_i X_{i,t}]$ . Finally,  $\alpha_{ij}$ ,  $\delta'_{ij}$  are the short run dynamic coefficients and  $p$  and  $q$  are optimal lag orders and  $\mu_i$  is the constant.

The panel ARDL model was run to check for the short and long run relation of the GDP and BMI variables relative to the real exchange rate. The aim was to determine whether the raw BMI has short or long-run predictive power for real exchange rates after controlling for GDP per capita and country level (unobservable and time invariant) fixed effects.

Due to the lack of sensitivity to sample size and ability to estimate the model's long- and short-term components simultaneously, the ARDL is a useful model. According to Pesaran & Pesaran (1997), the ARDL methodology is more adaptable and may be used regardless of whether the variables have a different order of integration. Additionally, the t-test sizes from an estimator that employs an ARDL approach are significantly more dependable. Pesaran & Pesaran (1997) also found that the ARDL method has an advantage over other cointegration strategies since it can adequately compensate for both the endogenous regressor issue and residual serial correlation at the same time.

For this study the expectation is that a long run relationship be found to be present and significant for the raw BMI and GDP per Capita. The expectation is that the variables will be found to be bound together in the long run due to equilibrium forces, despite how the variables would move individually. Moreover, a high statistically significant ECM is expected as that would show how quickly the disequilibrium present in the short run is corrected. This study makes use of the panel ARDL model in order to remove the time consistent unobservable differences which exist between countries.

### 3.3.4 Forecasting

Forecasting involves predicting future values of a variable using information from multiple entities (cross-sectional units) observed over time. Based on the above estimation techniques,

and the nature of this research which is largely centered on the cointegration between the variables a VECM is used to forecast the future real exchange rates for the South African Rand.

A long-term equilibrium relationship is also said to be a cointegrating relationship. This is because the cointegrating variables may deviate from their relationship in the short run, but equilibrium is restored in the long run. Due to this cointegrating relationship that potentially exists the VECM becomes the model of choice used for forecasting. If no cointegrating relationship is found a VAR model would be the best way to forecast future exchange rates.

A 5-year in-sample forecast is done to test which Big Mac Index between the raw BMI and the adjusted BMI will provide forecasting estimates closest to the real exchange. The index that closest tracks the real exchange rate will be deemed as the better forecasting technique for BMI implied purchasing power parity.

### **3.4 Conclusion**

The research approach used for this study was covered in this chapter. It described the data collection process as well as the statistical and economic techniques applied to achieve the main objective of evaluating the Adjusted BMI's effectiveness in comparison to the Raw BMI for PPP as a long-term indicator of suitable exchange rate valuation. The explanation of the research's outcomes and conclusions is presented in the following chapter.

## CHAPTER FOUR

### PRESENTATION AND DISCUSSION OF RESULTS AND FINDINGS

#### 4.1 Introduction

The analysis conducted to determine whether the Big Mac Index is a good indicator of exchange rate value is presented in this chapter. It will also explore whether the adjusted Big Mac index is a better measure of exchange rate valuation compared to the raw big mac index after accounting for the productivity differentials between different countries. This chapter is broken down into four sections; the first section presents a global analysis of the behaviour of the real exchange rate, raw BMI, and the adjusted BMI. The following section will present a panel data analysis which will conclude with a panel ARDL model to examine the long run behaviour of the raw BMI and GDP per Capita on the real exchange rate. Then the study will narrow the focus onto a time series analysis of the South African rand. The relationship between terms of trade data and the exchange rates will be determined. Lastly, forecasting estimates will be presented to establish whether the raw BMI or the Adjusted BMI is a better predictor of future exchange rates.

#### 4.2 Global economy

##### 4.2.1 Exchange rates and BMI measures for 2000 to 2022

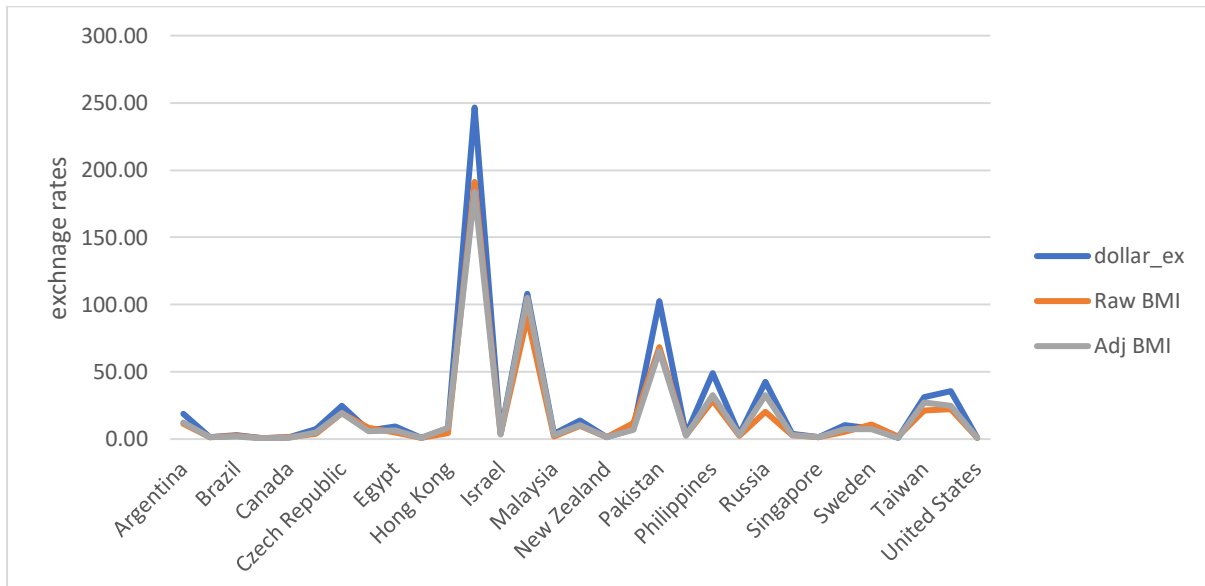


Figure 4.1: Global annual exchange rates over the 2000 to 2022 period

Source: Own calculations from *The Economist's* (2023) Big Mac database.

Figure 4.1 above presents a graphical analysis of the relationship between the RER, raw Big Mac Index and the adjusted Big Mac Index globally for the countries with the McDonald's franchise. Globally we see that when we get an average of the global exchange rates for the 20 years of data for 37 countries, the three variables all follow the same pattern, and they move together, this thereby suggests that the variables could be correlated. This will be established through further correlation tests later in the chapter. If a correlation is established, this would suggest that there is a form of mutual connection between the variables.

The signs of possible correlation seen from figure 4.1 are consistent with the theory that the BMI implied exchange rates can be used as a simpler measure of exchange rate valuation due to the similar pattern that the BMI implied exchange rate and the real exchange rate have in the graph.

Figure 4.1 above shows that 9 countries; Turkey, Switzerland, Sweden, Norway, Israel, Euro area, Denmark, Canada and Britain had a raw BMI implied exchange rate that was higher than that of the real exchange rate. For example, in Denmark, the RER had an average of 6.35 DKK/USD whilst the raw BMI exchange rate was 8.32 DKK/USD. Most of these countries were noted to be high income countries which is why the raw BMI implied exchange rate was higher than the RER suggesting that the raw BMI may not be a useful measure of exchange rates for the rich countries.

Whilst countries 19 Countries like Australia, Thailand, Taiwan, South Africa, Russia, Poland, Philippines, Saudi Arabia, Mexico, Malaysia, Japan, Indonesia, Hong Kong, Egypt, China, and Argentina saw the adjusted BMI exchange rates averages track closer to the average real exchange rates. In Russia, the average real exchange rate stood at 42.44 RUB/USD, the adjusted BMI average exchange rate was at 32.80 RUB/USD and the raw BMI average exchange rate was 20.30 RUB/USD. This shows that the raw BMI over values the Russian Ruble much more than the adjusted BMI exchange rate does, a similar behaviour is observed with the other 18 countries.

Countries like South Korea, Peru, Pakistan, New Zealand, Hungary, Colombia, Chile and Brazil recorded an adjusted BMI exchange rate lower than that of the raw BMI and the real exchange rate. This may challenge the effectiveness of the adjusted BMI for these countries or it may suggest that these currencies have been largely undervalued over the past 20 years. For

instance, for Chile the real exchange rate lies at 609.72 CLP/USD, the raw BMI exchange rate average being 527.21 CLP/USD and the adjusted BMI exchange rate average was 443.39. factoring for income country specific income differentials through the adjusted BMI has significantly improved the Chilean Peso’s purchasing power.

#### 4.2.2 Graphical analysis of 6 economies 2000 to 2022

The figures below show the exchange rate patterns for the real exchange rate, raw BMI implied exchange rate and the adjusted BMI implied exchange rate for 6 countries: Brazil, Sweden, China, Russia, South Africa, and Britain from the years 2000 to 2022. These 6 countries consist of a combination of low-income, middle-income and high-income countries around the world. When looking at the 6 graphs, the one thing that draws attention is how the raw BMI implied exchange rate dips for all 6 countries in 2021, which could be attributed to the appreciation of the US dollar in the same year. Another thing worth noting is that the real exchange rate and the adjusted BMI implied exchange rate follow a similar pattern, which could be an indication that they are cointegrated.

#### Brazil

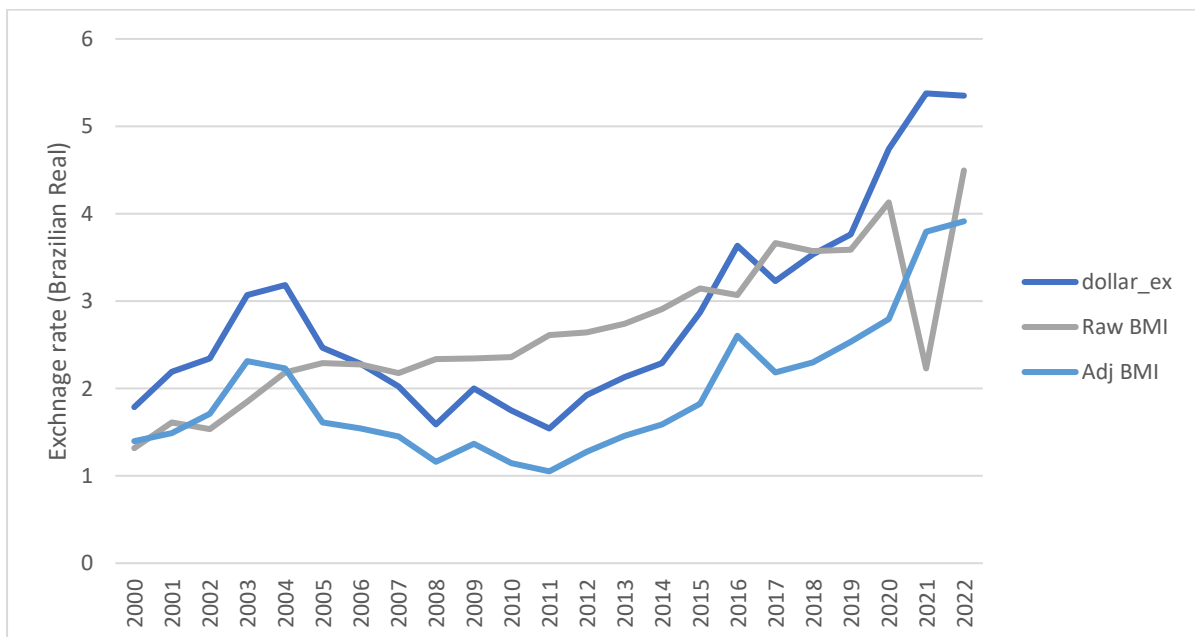


Figure 4.2: Exchange rate patterns for Brazil 2000 to 2022

Source: Own calculations from *The Economist’s* (2023) Big Mac database.

## Britain

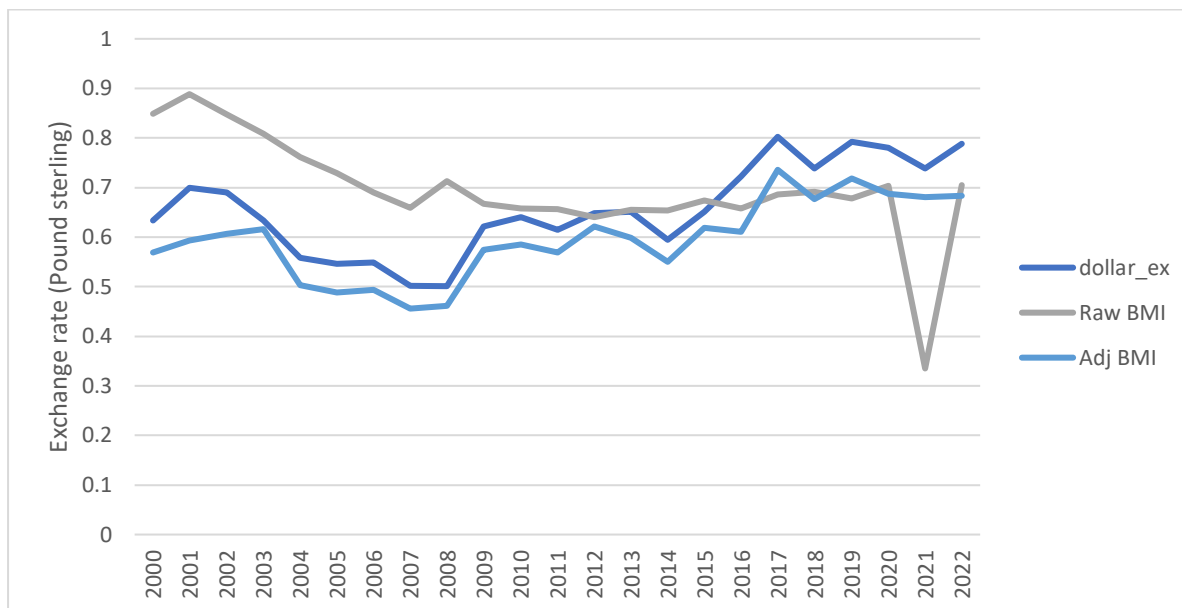


Figure 4.3 Exchange rate patterns for Britain 2000 to 2022

Source: Own calculations from *The Economist's* (2023) Big Mac database.

## China

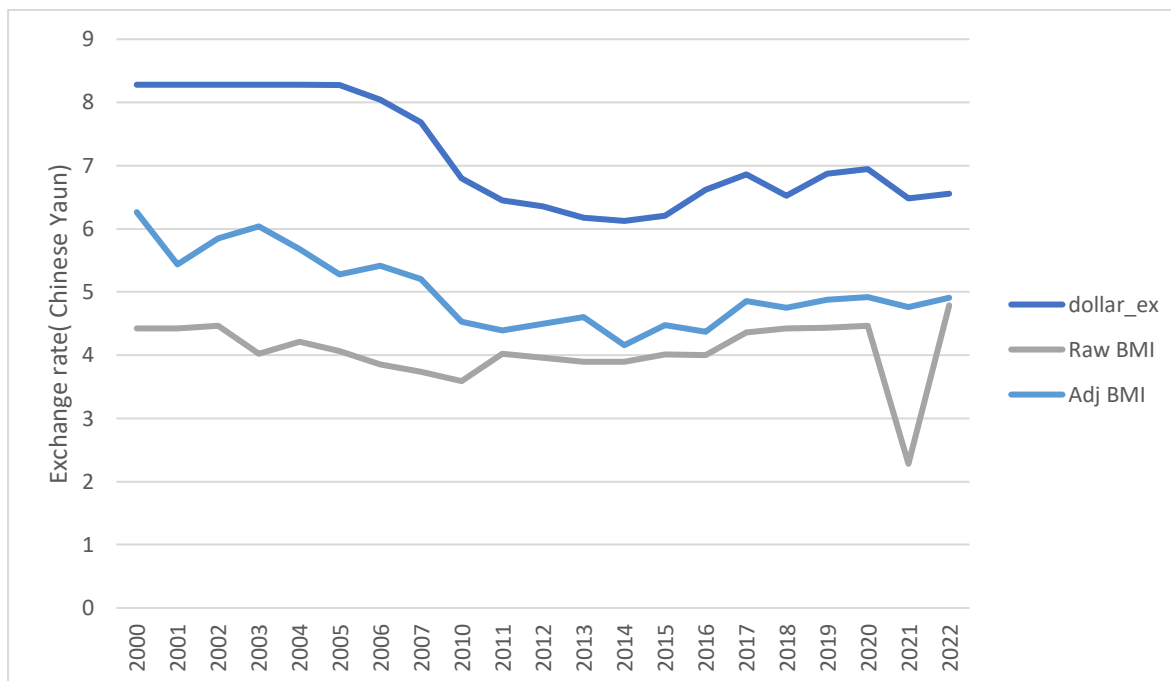


Figure 4.4: Exchange rate patterns China 2000 to 2022

Source: Own calculations from *The Economist's* (2023) Big Mac database.

## Russia

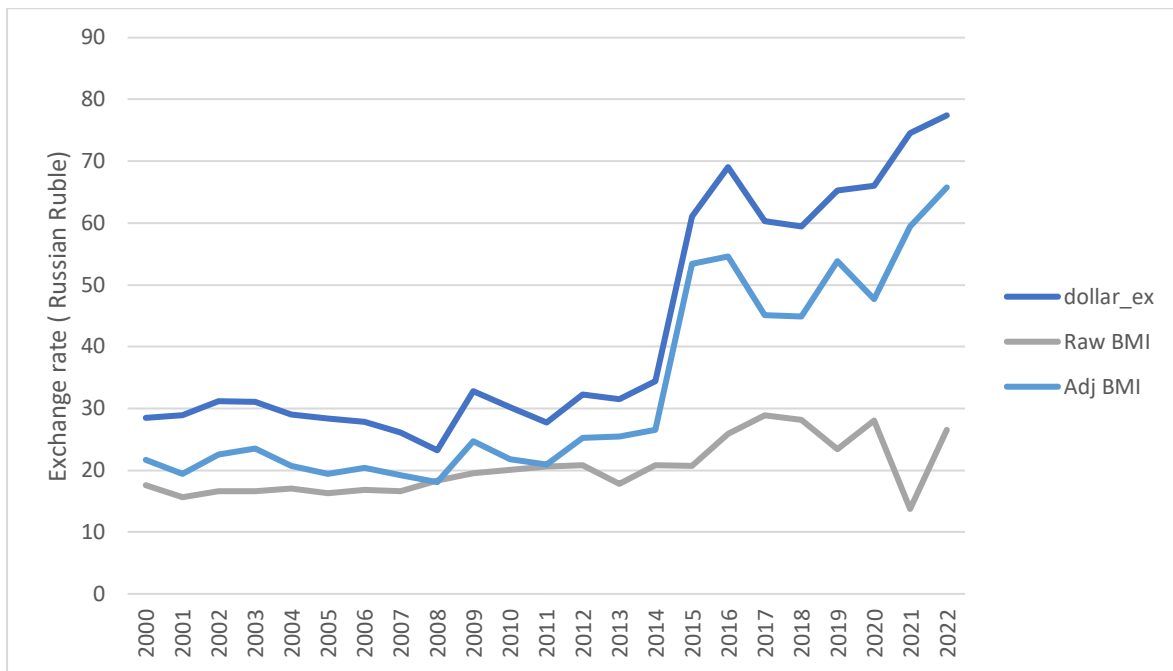


Figure 4.5: Exchange rate patterns Russia 2000 to 2022

Source: Own calculations from *The Economist's* (2023) Big Mac database.

## South Africa

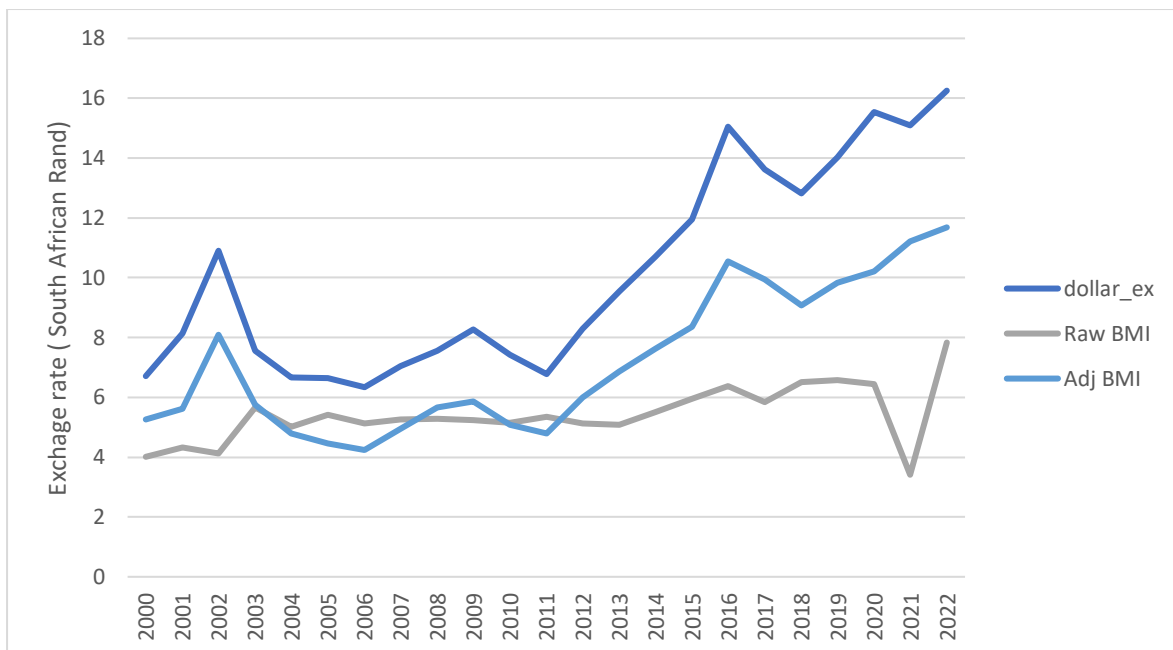


Figure 4.6: Exchange rate patterns 2000 to 2022

Source: Own calculations from *The Economist's* (2023) Big Mac database.

## Sweden

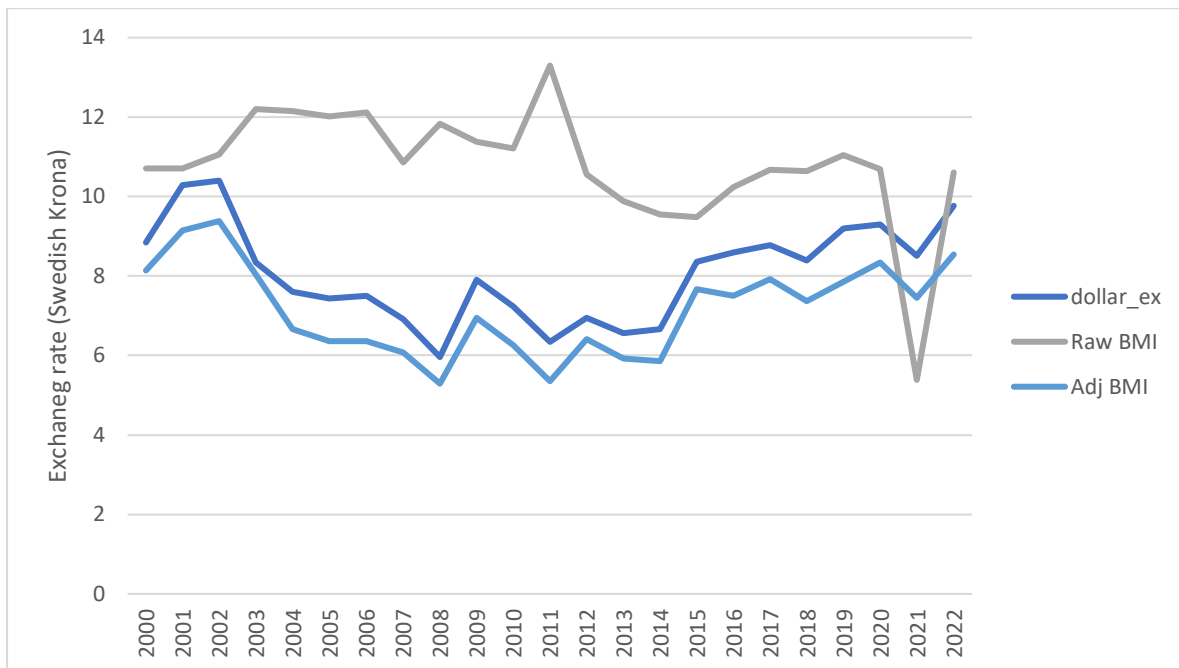


Figure 4.7: Exchange rate patterns for Russia 2000 to 2022

Source: Own calculations from *The Economist's* (2023) Big Mac database.

The patterns of the 3 exchange rates differ according to each country's economic position. Looking at figure 4.7, Sweden has a raw BMI implied exchange rate tracking higher than the real exchange rate and the dollar exchange rate. The raw BMI implied rate for Sweden in 2010 was 11,21, whilst the real exchange rate and the adjusted BMI implied exchange rates are 723 and 6,26. This can be attributed to the country having a high GDP and low unemployment. This makes the case to show how incorporating the productivity bias in a country's exchange rate could help in attempting to value a currency correctly. There is a difference of over 4 Swedish Krona between the raw BMI implied exchange rate and the adjusted BMI implied exchange rate which could suggest that the raw BMI exchange rate is undervalued compared to the real exchange and the adjusted BMI exchange rate. This gives evidence to suggest that the adjusted BMI is a better measure of real exchange rates compared to the raw BMI.

China, Russia and South Africa follow a slightly different pattern compared to Sweden as shown in the figures above. These 3 countries have their raw BMI exchange rate lower than the real exchange rate whilst the adjusted BMI and real exchange rates continue to move together. In Russia for example, the raw BMI, adjusted BMI and the real exchange start the period with similar values but, from 2012, the adjusted BMI and real exchange rate start to drift

away from the raw BMI and they track higher than the raw BMI. A similar movement can be noted for the South African Rand. This could imply that the raw BMI overvalued these countries' currencies, whilst the adjusted BMI continues to be a better measure of exchange rates.

Furthermore, Britain and Brazil are the two economies where the raw BMI, adjusted BMI and real exchange rate movements are intertwined. In Britain over the 20 year period, the pound sterling has had a steady and consistent real exchange rate which tracks together with the adjusted BMI. Whilst the raw BMI exchange rate starts off higher in 2000 than the real and adjusted BMI exchange rates, by 2022, it becomes lower showing that the raw BMI unlike the adjusted BMI overvalues the pound sterling at first but then becomes undervalued in 2022. It is worth noting that Brazil and Britain are two of the economies which were found to have the least misalignment for both the raw BMI and adjusted BMI.

#### **4.2.3 Exchange rate misalignment**

In determining currency misalignment globally, this component of the study adopts the methodology of Jiawen (2004) and San Vicente Portes & Atal (2014). This section involves figuring out the percentage difference between the real exchange rate (all represented in dollars) and the implied exchange rate for the raw and adjusted BMIs. The currency's overvaluation or undervaluation in a given year is determined by the difference between the real exchange rate and the BMI indicated exchange rate. This raises questions about whether the implied exchange rate implied by the BMI is significant in estimating a currency's PPP value and whether future movement towards BMI parity can be predicted when a currency appears undervalued or overvalued at a given moment. This evaluation technique is applied to the 37 countries being studied for a 20 year average.

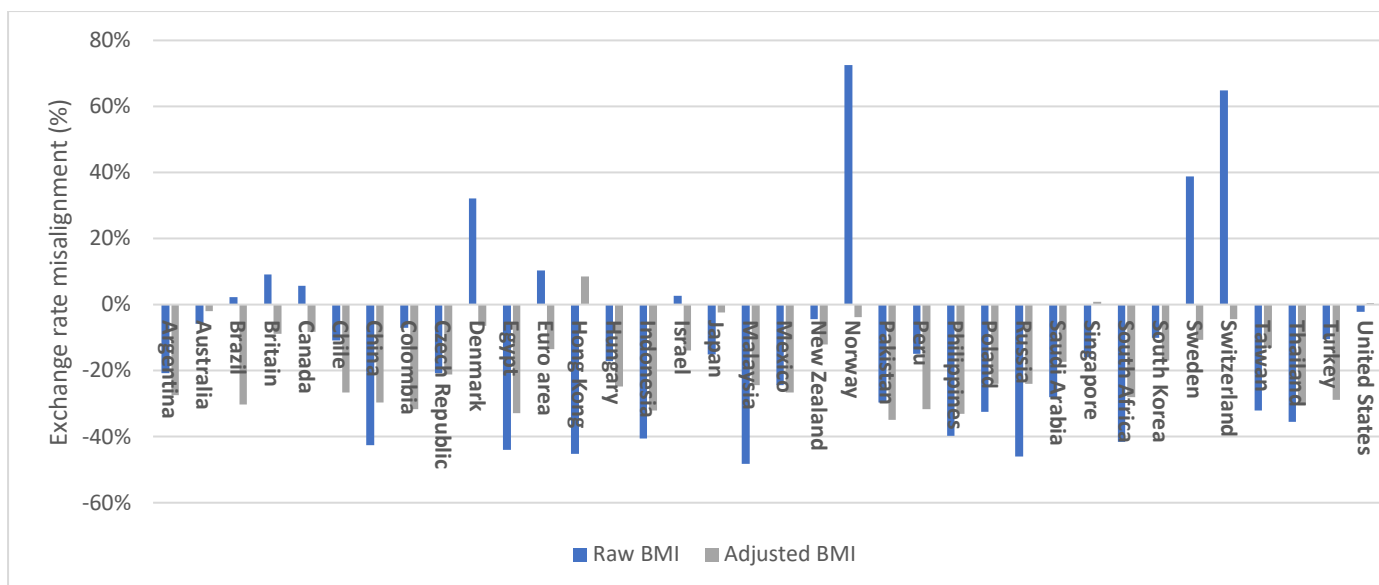


Figure 4.8: Percentage differences of the real exchange rate to BMI exchange rates averages between 2000 and 2022 (negative implies undervaluation, positive implies overvaluation)

Source: Own calculations from *The Economist's* (2023) Big Mac database.

The results from figure 4.8 above show that for most of the 37 countries over the period 2000-2022, the real exchange rates are undervalued relative to the BMI implied exchange rates. There are exceptions such as Norway, Switzerland, Sweden, Denmark Britain and Canada where there is an overvaluation of their respective currencies for the raw Big Mac Index. This finding is in line with the Big Mac theory as well as findings from other studies that have found that the raw BMI will find currencies from higher income countries to be overvalued to a large degree. For example, as shown by table C in [Appendix C](#), the Norwegian currency was found to be overvalued by an average of 75% over the past 20 years. This has been attributed to the failure to incorporate the productivity bias in the raw BMI. Once the valuation is adjusted for productivity bias, the adjusted BMI shows an undervaluation of all currencies except the Hong Kong dollar. This could be explained by the fact that Hong Kong is a highly developed free market economy with high factor productivity growth, so it is not surprising to see that including productivity differentials improves the BMI implied exchange rate valuation.

Worth noting however, is that the RER is higher than the raw BMI and adjusted BMI for all 37 countries. This could suggest that the RER could be misvalued. The table in the appendix shows the calculation for currency misvaluation for the real exchange rate. For example, the Argentine Peso is found to be undervalued by 13% in 2022 according to the raw BMI and the adjusted BMI found that the Argentine peso is undervalued by 25%. This means that, according to the

raw BMI, the exchange rate should be \$88,32 or \$78,52 according to the adjusted BMI. In comparison, the rate \$117,07 as per the real exchange rate.

#### **4.2.4 Econometric findings**

This section of the paper provides results from the econometric tests that were run to answer the research questions of the study. The section begins with a brief discussion of the descriptive statistics and then further discusses the results from the estimation techniques described in the previous chapter.

##### **4.2.4.1 ARDL model**

The next section looks into the analysis of the panel ARDL model to tests for the short run and long run effects of using raw BMI after controlling for GDP per Capita to determine exchange rates. Before this can be done preliminary tests for statistical significance and stationarity for the individual variables need to be done before the model can be run.

###### **4.2.4.1.1 Unit root test**

Tables 4.5, 4.6 and 4.7 show the first generation panel unit root test results for the variables RER, raw BMI, adjusted BMI and GDP Per Capita. The panel unit root test is done to determine whether the variables are stationary in level form  $I(0)$  or if they are stationary at 1<sup>st</sup> difference  $I(1)$ . As discussed in the previous chapter in order for a panel ARDL model to be run all variables need to be stationary either at the level terms or first difference or a combination of the two. Therefore a unit root test is done to check that none of the variables are stationary at 2<sup>nd</sup> difference  $I(2)$ . After testing for stationarity for variables with an intercept only and for the variables with an intercept and trend, the results were given as follows.

The results were obtained through panel unit root tests like the IPS (Im et al, 2003), LLC (Levin et Al, 2002), and ADF Fisher Chi-Square (Maddala & Wu, 1999). A variable is termed as non-stationary when it is found to contain a unit root. This means when any one of the above tests is run the null hypothesis is that the series has a unit root (it is non-stationary).

Table 4.2: First-generation panel unit root tests (Level) (Intercept and no Trend)

Variables	Model	LLC	IPS	ADF Fisher chi-square
Adjusted BMI	Intercept and no Trend	-23.7215*** (0.0000)	-18.8312*** (0.0000)	407.271*** (0.0000)
Real exchange rate	Intercept and no Trend	-23.7473*** (0.0000)	-18.8457*** (0.0000)	407.557*** (0.0000)
GDP per Capita	Intercept and no Trend	-23.5733*** (0.0000)	-20.9804*** (0.0000)	429.303*** (0.0000)
Raw BMI	Intercept and no Trend	-23.8937*** (0.0000)	-19.0086*** (0.0000)	411.641*** (0.0000)

Notes: Statistically significant at the: 10% level (\*), 5% level (\*\*) and 1% level (\*\*\*)

Source: EViews output, data from *The Economist* (2023)

Table 4.3: First-generation panel (Level) (Intercept and trend)

Variables	Model	LLC	IPS	ADF Fisher chi-square
Adjusted BMI	Intercept and Trend	-21.4989*** (0.0000)	-16.1535*** (0.0000)	326.898*** (0.0000)
Real exchange rate	Intercept and Trend	-21.5359*** (0.0000)	-16.1830*** (0.0000)	327.654*** (0.0000)
GDP per Capita	Intercept and Trend	-21.4258*** (0.0000)	-18.3928*** (0.0000)	337.595*** (0.0000)
Raw BMI	Intercept and Trend	-21.8002*** (0.0000)	-16.4674*** (0.0000)	337.238*** (0.0000)

Notes: Statistically significant at the: 10% level (\*), 5% level (\*\*) and 1% level (\*\*\*)

Source: EViews output, data from *The Economist* (2023)

The results from table 4.1 show the unit root test for level terms where there is an intercept and no trend. At level terms, the results show that RER, raw BMI, adjusted BMI and GDP per Capita are stationary at level terms for the LLC, IPS ADF Fisher chi-square and PP Fisher chi-square. For a model with an intercept and trend table 4.2, the 4 variables are also found to be stationary at level terms at the 1% level. This means based on the results from the unit root

tests we reject the null hypothesis and conclude that raw BMI, adjusted BMI, RER and GDP per capita have no unit root. Overall, the variables appear to be stationary at the 1% level.

#### 4.2.4.1.2 Panel ARDL model

Based on the regression results as well as the unit root tests presented above a panel ARDL model is done. The study uses the Pooled Mean Group panel ARDL model with an intercept and no trend to test for short run and long run effects. The results from the unit root tests showed that the variables are stationary at level terms for a model with an intercept only and no trend. Now that the preliminary tests have been done and factored for the results for a panel ARDL model are given below.

Table 4.4: Panel ARDL estimation results

Variable	Coefficients	Std. Error	Probability
	Long run equation		
RAW_BMI	1.244657	0.024312	0.0000***
GDP_PER_CAPITA_DOLLAR	-0.001845	0.001559	0.2371
	Short run equation		
ECT	-0.708513	0.215730	0.0011**
D(DOLLAR_EX(-1))	-0.300560	0.148416	0.0433**
D(DOLLAR_EX(-2))	-0.176213	0.071697	0.0142**
D(DOLLAR_EX(-3))	-0.124527	0.025407	0.0000***
D(RAW_BMI)	0.769305	0.357030	0.0315**
D(RAW_BMI(-1))	0.735809	0.260002	0.0048***
D(RAW_BMI(-2))	0.394691	0.119934	0.0011***
D(RAW_BMI(-3))	0.243646	0.043897	0.0000***
D(GDP_PER_CAPITA_DOLLAR)	0.002384	0.000602	0.0001***
D(GDP_PER_CAPITA_DOLLAR(-1))	0.002577	0.000818	0.0017**
D(GDP_PER_CAPITA_DOLLAR(-2))	0.003000	0.000800	0.0002***
D(GDP_PER_CAPITA_DOLLAR(-3))	0.002431	0.000836	0.0038***
C	53.64156	15.67025	0.0007***

Notes: Statistically significant at the: 10% level (\*), 5% level (\*\*) and 1% level (\*\*\*)

Source: EViews output, data from *The Economist* (2023)

The study used a pooled mean group (PMG) estimator for the panel ARDL model so we can establish the association between the raw BMI and GDP per Capita and the real exchange rate

over the last 20 years for the 37 countries using the real exchange rate as the dependent variable. This is to ascertain if the raw BMI will have any predictive power for real exchange rate determination after controlling for income differentials. GDP per Capita is used as a proxy for income differentials that exist between countries and are found to influence global exchange rates.

The model consists of 675 observations out of a sample of 767. The maximum dependent lag chosen for this study was four based on automatic AIC selection. The selected model is an ARDL PMG (4,4,4). In the long run, raw BMI is found to be statistically significant at the 1% level whilst GDP per Capita is found to be statistically insignificant. The raw BMI coefficient is positive whilst the coefficient for GDP per Capita is negative. Since GDP per Capita is statistically insignificant it has no impact on real exchange rates using the raw BMI in the long run. The conclusion drawn from this is that even after controlling for GDP per Capita, and within country differences, the raw BMI's effectiveness as a measure of real exchange rates is not improved.

In the short run, the error correction term is negative and statistically significant at the 1% level. This suggests that the RER moves out of equilibrium in the short run, but there is convergence in the long run. The rate of return to equilibrium is found to be -0.708513. This means 71% of the correction of the disequilibrium happens within the current year.

Moreover, the variables are all statistically significant at the 5% level. The results show that the lagged values of the dependent variable are negative and statistically significant, which is a good indicator as we expect the short run effects of the raw BMI and GDP per Capita to have an inverse relationship since we expect deviations in the short run in the exchange rates. This implies that any misalignment/ mis valuation that exists in the raw BMI implied exchange rate will, after factoring for GDP per Capita, be found to be mean reverting in the short run. But the GDP per Capita was found to be statistically insignificant in the long run, this shows that the raw BMI and real exchange rate share no statistically significant relationship with GDP per Capita. This leads to the conclusion that the raw BMI's predictability is improved by controlling for productivity bias once income differentials are taken out between countries in the short run however over the longer-term GDP per capita does not improve the measurement of the raw BMI implied exchange rates.

### 4.3 South African Rand exchange rate patterns

When narrowing the results and focus on the South African exchange rates, it is possible to examine the country-level relationship between the real exchange rate, raw BMI and adjusted BMI. This section seeks to evaluate whether the BMI meets the current account assumptions of PPP for the South African rand using terms of trade data as a benchmark. Furthermore, forecasting estimates will be presented to establish if the adjusted BMI provides better forecasting estimates compared to the raw BMI.

Table 4.5: The valuation of the rand based on Big Mac Prices and actual Rand/US\$ exchange rates (annual averages)

Date	Price of Big Mac in Rands	Price of Big Mac in Dollars	Real exchange rate	Raw BMI	Over / under valuation	GDP per Capita Dollar	GDP per Capita Local	GDP adjusted Dollar Price of Big Mac	GDP adjusted local Price of Big Mac	Adjusted BMI	Over/under valuation
2022	39,90	5,10	16,25	7,83	-52%	3423,60	20929,01	4,61	53,81	11,68	-24%
2021	33,50	9,82	15,09	3,41	-77%	2964,03	25499,54	4,79	53,64	11,21	-28%
2020	31,00	4,82	15,53	6,43	-58%	4209,22	31842,05	4,67	51,24	10,22	-29%
2019	31,00	4,71	14,02	6,58	-53%	6033,21	38382,78	4,53	45,44	9,83	-29%
2018	30,50	4,62	12,81	6,50	-48%	6276,17	42471,91	4,68	42,43	9,07	-26%
2017	28,16	4,50	13,61	5,85	-54%	6776,47	47804,01	4,36	43,38	9,95	-29%
2016	29,00	4,40	15,04	6,37	-56%	6552,27	55282,01	4,24	44,76	10,55	-33%
2015	25,75	4,29	11,95	5,94	-50%	8130,19	59529,95	4,36	36,49	8,36	-27%
2014	24,00	4,27	10,70	5,51	-47%	8799,48	63823,34	4,88	37,16	7,62	-30%
2013	21,70	4,11	9,55	5,09	-45%	8207,06	67379,28	4,71	32,34	6,87	-24%
2012	19,95	3,89	8,30	5,14	-38%	7458,04	71973,19	4,46	26,73	5,99	-26%
2011	19,45	3,64	6,77	5,34	-21%	6984,93	75748,03	5,07	24,31	4,80	-29%
2010	18,20	3,48	7,42	5,16	-30%	6256,67	79787,63	4,25	21,58	5,08	-30%
2009	17,95	3,43	8,28	5,23	-37%	6256,67	79787,63	3,94	23,09	5,86	-29%
2008	16,95	3,21	7,56	5,28	-30%	5750,79	84611,30	4,27	24,17	5,66	-25%
2007	15,50	2,95	7,04	5,26	-25%	6678,29	88938,16	3,64	18,01	4,94	-30%
2006	13,95	2,73	6,34	5,12	-19%	6984,47	92470,36	3,29	13,93	4,24	-30%
2005	13,95	2,58	6,65	5,41	-19%	6984,47	92470,36	3,38	15,05	4,46	-33%
2004	12,40	2,47	6,66	5,02	-25%	6598,88	95364,27	2,92	13,97	4,79	-28%
2003	13,95	2,46	7,56	5,67	-25%	6598,88	95364,27	2,47	14,18	5,74	-24%
2002	9,70	2,35	10,90	4,13	-62%	5624,50	92601,31	2,47	19,96	8,08	-26%
2001	9,70	2,24	8,13	4,33	-47%	5624,50	92601,31	2,39	13,44	5,63	-31%
2000	9,00	2,24	6,72	4,02	-40%	6950,43	102744,78	2,40	12,61	5,26	-22%

Source: Own calculations from *The Economist's* (2023) Big Mac database.

When looking at the South African rand graphically as shown by figure 4.6, the adjusted Big Mac index and the real exchange rate follow the same trend as they move in a similar style or

pattern compared to how the raw BMI tracks. This shows that incorporating productivity differentials in the BMI significantly improves how close it tracks the real exchange rate and it also could be evidence to show that the Rand is overvalued according to the RER. Again, the adjusted Big Mac Index provides better estimates or is the closest to mirroring the RER which suggests that the adjusted BMI is a better measure of exchange rates even for a middle-income country like south Africa compared to the raw BMI. This shows that factoring for labour costs improves the accuracy of the big mac index thus makes it a potentially useful method of determining exchange rates.

### 4.3.1 Exchange rate misalignment

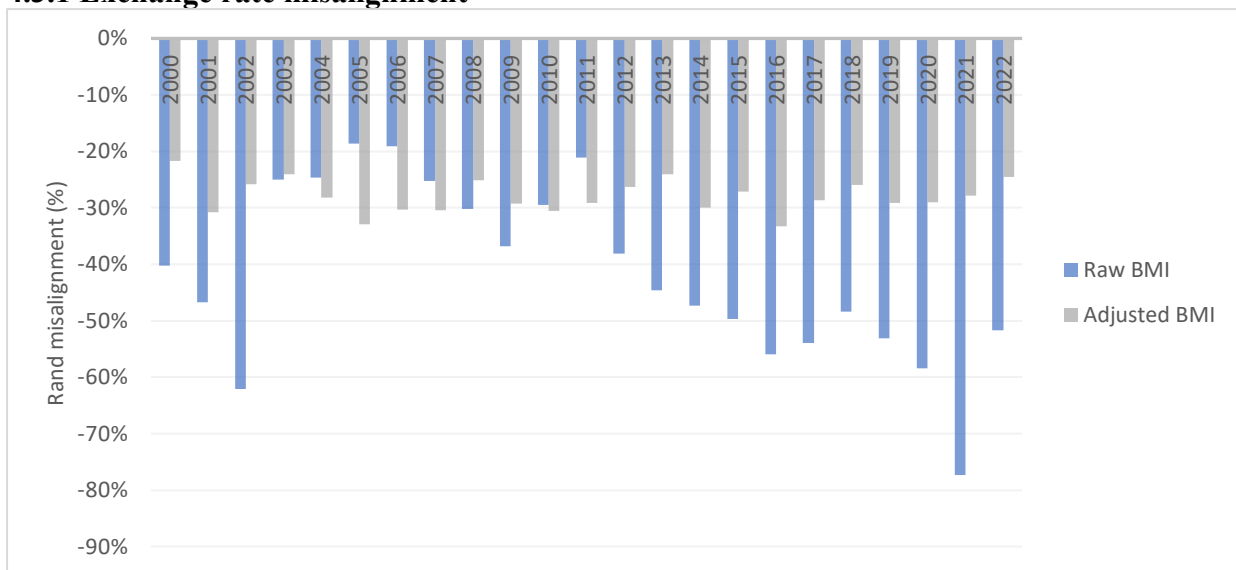


Figure 4. 9: South African exchange rate misalignment  
 Source: Excel output, data from *The Economist* (2023)

When looking at figure 4.9 above showing exchange rate misalignment for the raw BMI and the adjusted BMI we see that the raw BMI has had fluctuating levels of misvaluation over the past twenty years with the lowest value of misalignment being around 2006 at -20% misvaluation and the highest level of misvaluation being recorded in 2021 at -78%. So, between 2006 and 2021 we see the gap widening rather than contracting. For the raw BMI to be applicable as a predictor of future exchange rate measures, we would expect the gap to contract over the years rather than widen as we have seen. Although for the period 2021 to 2022 we do see a contraction in the gap between the BMI implied exchange rate in 2021 and 2022 of around 14%, but that is weak evidence in support of the raw BMI.

On the other hand, we see that for the adjusted Big Mac Index the misalignment for the rand is steady. The highest level of misalignment recorded being in -33% in 2005 and 2016. The lowest level of misalignment was recorded in 2000 at -22%. The trend for the adjusted BMI suggests that the adjusted BMI is mean reverting which is one of the requirements for PPP to hold. This provides further evidence that even in developing countries we can expect PPP to hold for the adjusted BMI.

### 4.3.2 Correlation matrix

The results from the correlation matrix serve as further evidence of what was noted on the trend analysis of these raw and adjusted BMI. There is high positive correlation of 0.992859 between the dollar exchange rate and the adjusted Big Mac Index. The raw BMI and the RER have a weak positive correlation of 0.493959, which is similar to the strength of the correlation between the adjusted BMI and the raw BMI. This aligns with the graphical trend analysis which showed that the adjusted Big Mac Index and the real exchange rate track together.

Table 4.6: Correlation matrix results for 2000 to 2022

	Real exchange rate	Raw BMI	Adjusted BMI
Real exchange rate	1.000000		
Raw BMI	0.493959	1.000000	
Adjusted BMI	0.992859	0.445935	1.000000

Source: EViews output, data from *The Economist* (2023)

### 4.3.3 Cointegration test

#### 4.3.3.1 Unit root test

This section looks at the results of the unit root tests run on the time series data to establish if the series is stationary or not. The results shown below in table 4.6 and table 4.7 show that the adjusted big mac and the real exchange rate are stationary at 1<sup>st</sup> differences at the 1% level for a model with an intercept and no trend. Whilst the raw BMI was found to be stationary at level terms at the 1% level.

Table 4.7: Unit root test results (Level)

Variables	Model	Test	T-statistic	Probability
-----------	-------	------	-------------	-------------

Adjusted BMI	Intercept and No Trend	ADF	-0.302511	0.9067
Real Exchange rate	Intercept and No Trend	ADF	-0.394323	0.8940
Raw BMI	Intercept and No Trend	ADF	-3.974405	0.0064***

Notes: Statistically significant at the: 10% level (\*), 5% level (\*\*) and 1% level (\*\*\*)

Source: EViews output, data from *The Economist* (2023)

Table 4.8: Unit root test results (1st Difference)

Variables	Model	Test	T-statistic	probability
Adjusted BMI	Intercept and No Trend	ADF	-4.380534	0.0027***
Real exchange rate	Intercept and No Trend	ADF	-4.86733	0.0022***
Raw BMI	Intercept and No Trend			

Notes: Statistically significant at the: 10% level (\*), 5% level (\*\*) and 1% level (\*\*\*)

Source: EViews output, data from *The Economist* (2023)

#### 4.3.3.2 Johansen Cointegration test

The Johansen cointegration test was performed to determine whether the real exchange rate, raw BMI and adjusted BMI have a linear combination that is stationary, which would suggest that there exists a long-term relationship between the real exchange rate, raw BMI and adjusted BMI. The null hypothesis for the trace test is that there are at most  $r$  cointegrating vectors.

Table 4.9: Johansen Cointegration test results for the South African Rand for the real exchange rate and the two BMI measures.

Trace test				
Hypothesized	No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value
None		0.778414	42.89164	29.79707
At most 1		0.398306	11.24569	15.49471

At most 2	0.027133	0.577667	3.841465
Max-Eigen Test			
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value
None	0.778414	31.64585	21.13162
At most 1	0.398306	10.66812	14.26460
At most 2	0.027133	0.577667	3.841465

Source: EViews output, data from *The Economist* (2023)

The results in the table above show that there is evidence for at most 1 cointegrating relationships in the series. This means that we reject the null hypothesis and concluded that indeed between the real exchange rate, the raw BMI and the adjusted BMI, there are at most 1 cointegration relationships. This suggests a stable equilibrium relationship exists between the variables.

The Max- Eigen test results also show that the critical value is greater than the max statistic. which means the null hypothesis that there are exactly ‘r’ cointegrating vectors is rejected. The conclusion is that there exists at most 1 cointegrating vectors. This further shows evidence of the long-term relationship which exists between 2 variables. Based on the results above we can safely conclude that either the raw BMI or the adjusted BMI show evidence that they move in the same direction as the real exchange rate. This means that they are bound together in the long term. As a result, more support is given in favour of the use of the BMI as a simpler method of PPP for use in the valuation of exchange rates when it comes to the South African rand.

#### 4.3.4 Terms of Trade

Two variables that are occasionally used as stand-ins for one another are the terms of trade and exchange rate. A currency's value expressed in terms of another is determined by its exchange rate. The quantity of foreign goods that can be bought with a single unit of domestic commodities is measured by the terms of commerce.

To some extent, terms of trade depend on exchange and inflation rates and prices. For PPP, using the consumer price index, if the ratio of the CPIs in local currencies is unchanged, the terms of trade and exchange rates will move in the same way. The terms of trade and exchange

rates will move in the same direction for PPP which uses the consumer price index, if the ratio of the CPIs in local currencies remains constant. According to PPP, changes in a nation's current account balance have an impact on the foreign currency market's exchange rate's value. The interest rate parity theory, on the other hand, makes the assumption that investor behaviour, as represented by transactions on the capital account, influences the exchange rate.

For this reason it is important to examine whether PPP, as proxied by the Big Mac Index, is correlated with terms of trade. This will determine whether the BMI meets the current account assumptions of PPP for the South African rand. If the BMI is correlated with the terms of trade then the BMI would work as a suitable proxy for PPP. However, if there is no correlation, or if the correlations is negative, then this would mean that the BMI fails to meet the current account assumptions of PPP. Thus making the BMI a poor proxy for PPP.

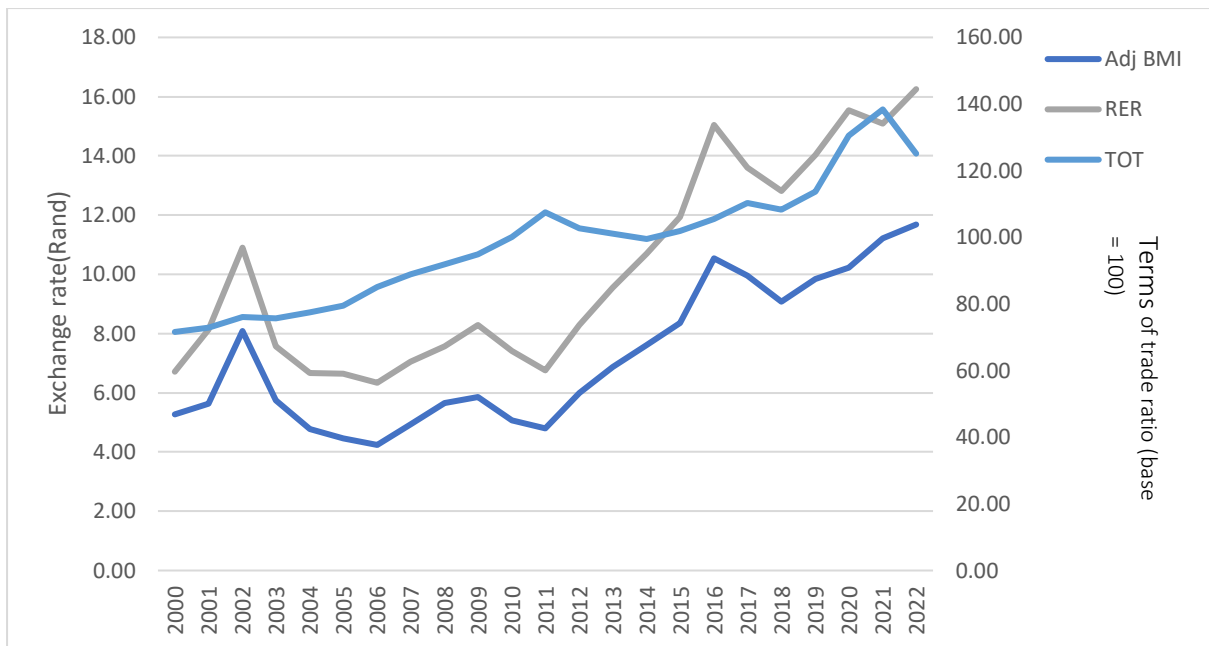


Figure 4.10 Exchange rate patterns South Africa 2000 to 2022

Source: Excel output, data from The Economist (2023)

The results in table 4.10 above show the terms of trade data for goods plotted against the adjusted BMI implied exchange rate and real exchange rate. As already established in the discussions above, the adjusted BMI exchange rate and the real exchange rate are correlated and move in the same direction and pattern. From the year 2000 to 2010, the Rand was highly valued which gave it a higher purchasing power, the terms of trade during those times was

below a 100. A terms of trade ratio below 100 suggests that more capital is leaving the country than is entering the country. This could imply that the country was importing more than it was exporting due to the highly valued Rand. Post 2010 the Rand begins to depreciate and this is met by an improvement in the terms of trade as the trade ratio between 2011 and 2022 ranges from 107 to 125. This suggests that a higher terms of trade correlate with a currency with lower purchasing power as this makes it more favorable for other countries to buy goods produced in South Africa, thus increasing the number of exports in South Africa. 2014 is an exception as the terms of trade fell to 99.42 as a possible response to the rand depreciating to 7.62 ZAR/USD from 6.87 in 2013. This suggests that the exchange rate and the terms of trade are correlated. An inverse relationship between the terms of trade and the exchange rate. As seen in the figure above, a higher exchange rate (implying currency depreciation) is met with higher/positive terms of trade ratio (implying more goods are being exported than those imported).

#### **4.4. Forecasting estimates**

##### **4.4.1 Forecasting results**

Lastly, based on the unit root tests and the cointegration tests done on the Rand's real exchange rate and the BMI implied raw and adjusted exchange rates, forecasting estimates were conducted. There is strong evidence in favour of the adjusted BMI implied exchange rates being used as a measure of exchange rate valuation as they were found to be bound together in the long run. Despite whatever misalignments may exist in the short run, in the long run the BMI implied exchange rates move back to parity and an equilibrium is achieved such that they track close to the real exchange rates being used and applied globally today.

Based on the above results, forecasting estimates were produced from a VECM model for the real exchange rate using the raw BMI and Adjusted BMI. The VECM model was chosen based on the presence of cointegration in the 3 variables from the Johansen cointegration test. In-sample forecasting was done to forecast the exchange rates for 2018 to 2022 for the rand. The forecast was calculated using a dynamic forecast. The real exchange rate values from 2018 to 2022 were predicted using the raw BMI. The real exchange rate was also predicted using the adjusted BMI. In the graphs below, the blue line denotes the raw BMI and the adjusted BMI forecasts of the real exchange rate. the orange line denotes the actual values of the real exchange rate. the BMI measure with the least deviation from the real exchange rate will be deemed as the best BMI measure and predictor of future exchange rates. The results are shown below.

Table 4.10 Forecasting estimates for the South African rand

Date	RER	Raw BMI	Raw BMI forecast	Difference		RER	Adjusted BMI	Adjusted BMI forecast	Difference
2000	6.72	4.017857	6.72	0		6.72	5.262003	6.72	0
2001	8.13	4.330357	8.13	0		8.13	5.627817	8.13	0
2002	10.9	4.12766	10.9	0		10.9	8.081205	10.9	0
2003	7.56	5.670732	7.56	0		7.56	5.742469	7.56	0
2004	6.66	5.020243	6.66	0		6.66	4.785644	6.66	0
2005	6.6482	5.406977	6.6482	0		6.6482	4.456444	6.6482	0
2006	6.33865	5.119266	6.33865	0		6.33865	4.239606	6.33865	0
2007	7.040375	5.263158	7.040375	0		7.040375	4.944455	7.040375	0
2008	7.56325	5.280374	7.56325	0		7.56325	5.664538	7.56325	0
2009	8.2805	5.233236	8.2805	0		8.2805	5.859819	8.2805	0
2010	7.4205	5.158046	7.4205	0		7.4205	5.076791	7.4205	0
2011	6.76885	5.343407	6.76885	0		6.76885	4.799619	6.76885	0
2012	8.29935	5.135135	8.29935	0		8.29935	5.992555	8.29935	0
2013	9.547125	5.091352	9.547125	0		9.547125	6.869991	9.547125	0
2014	10.69608	5.509965	10.696075	0		10.69608	7.618903	10.696075	0
2015	11.94665	5.944056	11.94665	0		11.94665	8.359951	11.94665	0
2016	15.04375	6.370876	15.04375	0		15.04375	10.54831	15.04375	0
2017	13.61125	5.848889	13.61125	0		13.61125	9.947311	13.61125	0
2018	12.81003	6.500542	13.87540298	-1.065377981		12.81003	9.071908	13.29924374	-0.48922
2019	14.02125	6.581741	13.88470653	0.136543469		14.02125	9.831574	13.94168798	0.079562
2020	15.53175	6.431535	14.81261558	0.719134425		15.53175	10.21648	14.00814274	1.523607
2021	15.0925	3.411405	16.28426728	-1.191767281		15.0925	11.20849	15.98824406	-0.89574
2022	16.25313	7.831207	15.36775966	0.885365336		16.25313	11.68167	15.66668801	0.586437

Source: Excel output, data from *The Economist* (2023)

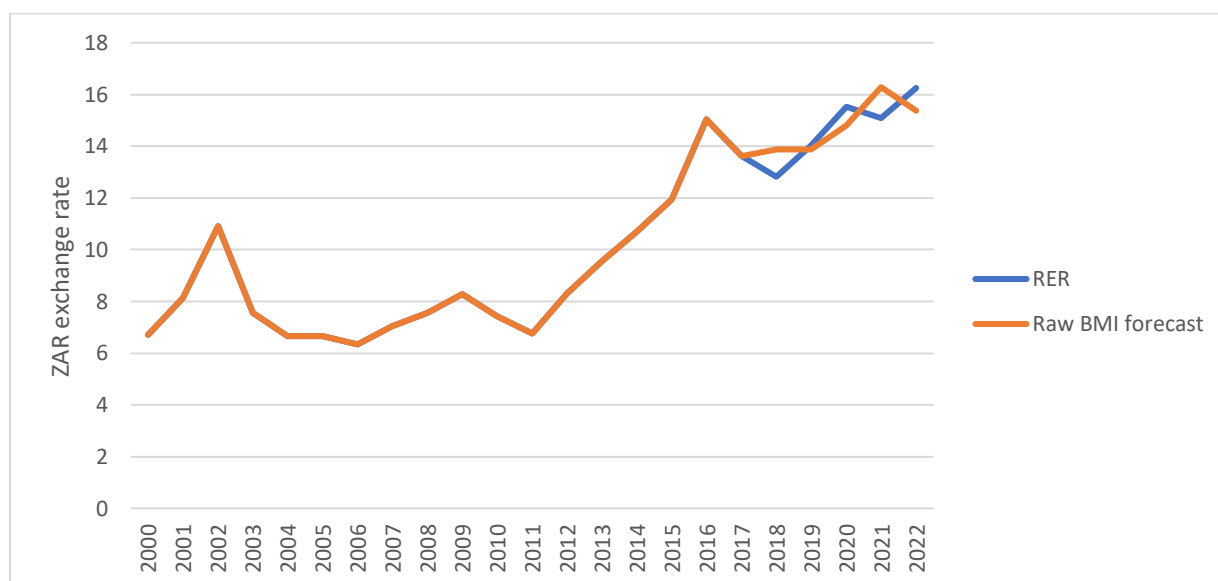


Figure 4.11: Forecasting estimates- Real exchange rate vs Raw BMI implied exchange rate forecast

Source: EViews output, data from *The Economist* (2023)

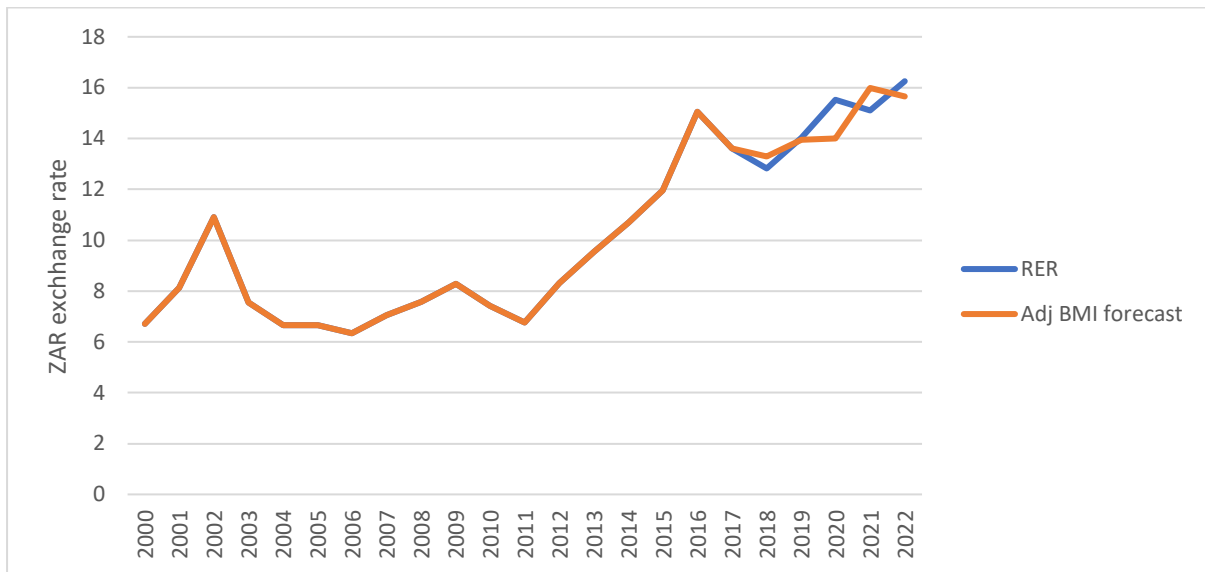


Figure 4.12: Forecasting estimates- Real exchange rate vs Adjusted BMI implied exchange rate forecast

Source: EViews output, data from *The Economist* (2023)

Looking at figure 4.11 and 4.12 above, we can see that the forecasting estimates for the adjusted BMI track closer to the actual adjusted BMI values, compared to the raw BMI forecasts. The graph for the actual raw BMI shows that in 2022 there is a sharp decline in the value of the rand, whilst the forecast shows a steady growth in the value of the rand over the years. Yet for the adjusted BMI the difference between the actual BMI and the forecasted BMI, they more or less move in a similar upward trend and towards the end we see them steadily move together, even though it is possible that over the years they will start to move away from each other but the existing trend is promising with regards to the forecasting power that the adjusted BMI has over the raw BMI. Based on the above results it can be concluded that, again, the adjusted BMI has been shown to be a better measure of exchange rate valuation compared to the raw BMI.

#### 4.4.2 Forecast evaluation

Table 4.11: Forecast evaluation results

Variable	RMSE	MAE	MAPE	Theil
Raw BMI	0.880342	0.799638	5.452890	0.029677
Adjusted BMI	0.861778	0.714914	4.747855	0.029302

Source: EViews output, data from *The Economist* (2023)

Table 4.10 above shows the results from the forecast evaluation checks to determine if the results from the VECM forecast are accurate. For the Root Mean Square Error (RMSE) to be applicable we apply the rule of thumb that the lower the RMSE, the better the forecasting. As shown in the results above the adjusted BMI has a lower RMSE of 0.861778 compared to the raw BMI's RMSE of 0.880342. This means for the adjusted BMI the difference between the actual BMI and the forecasted BMI is smaller, which makes it a better forecasting model. Looking at the mean absolute error and mean absolute percentage error, the results show that these values for the adjusted BMI are also lower compared to those of the raw BMI.

The Theil inequality coefficient is a good indicator in support of the adjusted BMI being a better forecasting technique compared to the raw BMI. Theil's U statistic shows how good a forecast is. When  $U = 0$  the forecast is perfect. If  $U > 0$  the forecast is not perfect. Table 4.14 shows the Theil coefficient is closer to zero for the adjusted BMI compared to the Theil coefficient for the raw BMI. In summary, the forecasting evaluation measures provide more evidence in favour of the adjusted BMI being a better predictor of future exchange rates compared to the raw BMI.

#### **4.5 Conclusion**

This chapter presented the empirical findings which were in line with the objectives of this study. The chapter began by illustrating, graphically, the exchange rate patterns of the 3 exchange rate measures; real exchange rate, raw BMI and the adjusted BMI for the countries with the McDonald's franchise. The misalignment patterns of the global exchange rate were evaluated and discussed. The raw BMI was found to have a higher degree of misvaluation in comparison to the adjusted BMI. Correlation analysis found that there is a mixed relationship between the variables of interest, with a high correlation being found between the real exchange rate and the adjusted BMI.

Firstly, the aim was to check the predictive power of the real exchange rates for the raw BMI, after accounting for GDP per Capita differences between countries, for real exchange rates in a cross-country longitudinal sample. A panel unit root test was done and raw BMI, real exchange rate and adjusted BMI were found to be stationary at the 1% level at level terms. The pooled mean group panel ARDL estimation results found that in the long run, the GDP per

Capita has no impact on the raw BMI in estimating the real exchange rate. However, in the short run it was found that the raw BMI does have predictive power after accounting for GDP differences and within group heterogeneity. In the short run the problem of income differentials affecting the raw BMI acting as a good measure of Purchasing Power Parity has been addressed.

Secondly, the South African rand was investigated in more detail. Graphical analysis as well as the correlation results confirmed that the adjusted BMI and the real exchange rate have a strong positive correlation over the past 20 years. The results from the Johansen cointegration tests found evidence of at least one cointegrating relationship present between the real exchange rate, raw BMI and the adjusted BMI. In other words, a cointegrating relationship exists between the adjusted BMI and the real exchange rate. Evidence to support the PPP assumptions of the current account was found since the terms of trade for goods and the adjusted BMI were found to have a positive relationship. Lastly, forecasting estimates were done using a VEC model to predict the real exchange rate for the Rand using the raw BMI and the adjusted BMI. The results from the 5 year holdback sample showed that the adjusted BMI produced a better forecast compared to the raw BMI.

This study concludes that the adjusted Big Mac Index is a better exchange rate valuation measure compared to the raw BMI. The study also found that factoring for GDP differences within group heterogeneity improves the effectiveness of the BMI as a method of establishing PPP. The results from this study come as no surprise as previous studies by Pakko & Pollard (1996); Wee & Lee (2022); Clements & Si (2016); O'Brien & Vargas (2015); Clements et al (2011) and Chen et al. (2007) found similar results that support the use of the BMI as an effective method of Purchasing Power Parity and exchange rate determination. They were also in support of the forecasting power that the adjusted Big Mac Index possesses.

## CHAPTER FIVE

### DISCUSSION AND SUMMARY OF RESULTS AND FINDINGS

#### 5.1 Summary of the study

This study analyzed the use of the BMI implied exchange rate as a potentially simpler method of measuring purchasing power parity for exchange rate determination. The Big Mac Index was lightheartedly created by *The Economist* magazine as a variant of PPP. It calls for the use of the law of one price just like PPP. However, rather than the use of a basket of household goods, the BMI calls for the use of the price of the Big Mac burger to determine the exchange rate. The theory is that the Big Mac burger is made using the same inputs. No matter which McDonalds franchise you purchase the burger from in the world you expect to consume the same good.

Two methods of the Big Mac Index were identified: the raw BMI and the adjusted BMI. The raw BMI implied exchange rate is found from the resultant ratio of the price of the Big Mac burger in the local currency against the price of the Big Mac in the US dollar. The adjusted BMI implied exchange rate incorporates GDP per Capita in the prices of the Big Mac. Just like with the raw BMI the adjusted BMI implied exchange rate is found from taking the resultant GDP adjusted price of the Big Mac Burger against the GDP adjusted price of the Big Mac burger in the US dollar.

This study was aimed at establishing whether the adjusted BMI is found to be the best measure of PPP, for determining exchange rates, compared to the raw BMI. To achieve the goal of this study several evaluations were done. Firstly, the review of the conceptual and theoretical framework on exchange rate theory, PPP theory and BMI theory was done. Reviewing the literature on PPP and the BMI provided a basis for understanding the process of exchange rate determination through purchasing power parity and the Big Mac Index. Secondly, the empirical literature was explored to see what other scholars found with regards to the Big Mac Index and PPP for currency valuation. This assisted in framing the possible outcomes expected from making use of 'Burgernomics'. Moreover, empirical analysis was done to answer the research questions and aims of the study. Mixed views were found on the Big Mac Index, the studies that disputed the applicability of the BMI cited income and labour differentials as factors to prevent BMI-PPP to hold. But there is a growing number of studies which have been seen to

support the usefulness on the BMI for exchange rate valuation especially upon the incorporation of GDP per capita into the BMI implied exchange rate.

The main aim of the study was to determine the usefulness of the adjusted BMI as a measure of appropriate exchange rate valuation at a given point in time. A further objective was to determine whether future exchange rate movements can be better forecast using the adjusted BMI than the raw BMI.

The study used quantitative data analysis. Secondary data was collected for the countries that have the McDonald's franchise and for which *The Economist* has collected price data. The variables of interest for this study were raw BMI, adjusted BMI, GDP per capita, terms of trade for goods and the exchange rates in dollar terms. Annual country level panel data for 37 countries from 2000 to 2022 was collected from The Economist online dataset. The terms of trade data was collected from the South African Reserve Bank. The raw BMI and the adjusted BMI were calculated using Microsoft Excel. And all econometric estimations were done through EViews.

Three research questions were answered by this paper. The first research question was to determine whether the raw BMI and the adjusted BMI are useful measures of appropriate global exchange rate valuations globally. If so, which one is the better measure: the raw BMI or the adjusted BMI. This was carried out through graphical analysis of the trends for the real exchange rate, raw BMI and adjusted BMI over a 20 year period (2000 to 2022) for the 35 countries. Summary statistics on global exchange rates, their changes overtime and over/undervaluation were provided. Misvaluation calculations were done to see if the over/undervaluation gap widens or closes over the years. The BMI is found to be applicable if the misvaluation gap closes over time and the exchange rates are closer to parity.

Furthermore, the predictive power of the raw BMI as a replacement for traditional PPP for real exchange rates in a cross-country longitudinal sample was evaluated. This was done by investigating whether correcting for productivity bias using GDP per Capita as a proxy improves raw BMI being a measure of exchange rate valuation. A panel ARDL model was used to determine the short run and long run relation of the raw BMI and GDP per capita. This was done to check for short and long run relation of the GDP and BMI variables. The panel

ARDL model further went on to determine if the raw BMI has any predictive power for real exchange rates after factoring GDP per capita and other cross country differentials.

The second research question zeroed in on the South African Rand to determine whether the raw or adjusted BMI is a better measure for the currency. This entailed a cointegration test to establish if the raw BMI, adjusted BMI and real exchange rate move together. In addition, terms of trade data were compared against the adjusted BMI to ascertain if the adjusted BMI meets the current account assumptions of purchasing power parity.

Lastly, a VECM model was estimated to generate forecasts for a 5 year holdback sample for both the raw BMI and the adjusted BMI for the rand. The index with the closest in sample forecast to the real exchange rate was deemed as the better forecaster of future exchange rates.

## **5.2 Discussion of results**

### **5.2.1 Global exchange rate dynamics**

With regards to the first research question, the evidence was in support of a cointegrating relationship between the adjusted BMI and the real exchange rate. The graphical analysis of a sample of 6 countries; Brazil, Britain, China, Sweden, Russia and South Africa showed that the adjusted BMI was a better measure of exchange rates. This showed that the adjusted BMI theory that accounted for productivity differentials like labour positively influences the applicability of the adjusted BMI. Thus making it a more favourable method of exchange rate valuation compared to the raw BMI.

The misvaluation observed over the years was found to be moving towards parity more for the adjusted BMI compared to the raw BMI. The raw BMI exchange rate dynamics saw more deviation from parity as it had higher levels of convergence and divergence compared to the adjusted BMI. The raw BMI has higher currency misvaluation compared to the adjusted BMI. The currency misvaluation identified could have spill over effects into investments done in the foreign exchange market. The foreign exchange market is the largest financial market in the world plays an important role in facilitating for cross border trade and investment as well as financial transactions. Consequently any possible currency over/undervaluation hinders the forex market from performing its main purpose of establishing a clear market based exchange rate which will act as a benchmark for the rest of the global economy. This means that global

investment banking firms like JP Morgan, Barclays and Citigroup could find themselves making investment decisions on incorrectly valued exchange rates.

In the same manner, any currency misvaluation impacts the performance of other financial markets like the bond market. Suppose the Egyptian government decides to issue a bond of 1 Million Egyptian pounds with a 8% coupon rate maturing after 3 years, which means the return expected would be EGP1 240 000. Table C in the appendix shows that for the raw BMI EGP was found to be undervalued by 50% whilst the adjusted BMI found that the Egyptian pound was undervalued by 27%. Therefore, according to the real exchange rate in 2022 in dollar terms the returns should be \$21 489 200 ( $17.33 * 1\,240\,000$ ). The raw BMI found that the returns should be \$10 343 474 ( $8,34151129 * 1\,240\,000$ ) and for the adjusted BMI the returns are \$14 210 400 ( $11,4558855 * 1\,240\,000$ ). These are large differences observed which cannot be ignored. As it could show how much money an investor should be getting but due to incorrectly valued currencies the government may find themselves paying more than they should pay, which has more spill over effects onto that governments economic activity.

The raw BMI appears to be useful in painting a general picture on the buying power of a currency because it incorporates aspects which are often overlooked in other measures of parity, including the valuation of a homogenous good which incorporates tradeable goods like the buns, lettuce and ground meat and the non-tradeable goods like electricity, rent and labour costs into the price of a Big Mac burger. Moreover, while a few countries moved closer to PPP/BMI parity over the time periods examined, the majority moved further from parity. Thus it is concluded that the raw BMI is a poor measure of appropriate exchange rate valuation or of future movements. The results showed that for some of the rich countries there is some forecasting power in the BMI as these countries moved closer to BMI parity. But, for most emerging markets the currencies moved further away from parity. This was attributed to the productivity bias inherent amongst the different economy types as developed countries like Sweden and Canada are seen to be high earning countries compared to countries like South Korea and South Africa.

This links to the second part of the first research question, which was to determine whether the raw BMI has predictive power for exchange rates in the short or long run after controlling for GDP per Capita and other country level fixed effects. The results from the panel ARDL model showed that attempts made to improve the effectiveness of the raw BMI by controlling for GDP

per capita failed to achieve the desired outcome. The results found that the disequilibrium present between the real exchange rate and the raw BMI is corrected by 71% within the year. However, even after controlling for GDP per capita and the country level fixed effects raw BMI still performs poorly as a measure of exchange rates over the long term despite is significant in the short run. The findings above further cement the hypothesis that the adjusted Big Mac Index is a better predictor of exchange rates.

This assists in answering the question on whether the Big Mac Index has any predictive power of exchange rates and further supports the idea of the BMI being considered as a replacement for traditional PPP for real exchange rates in a cross-country longitudinal sample. This adds to the growing literature on the Big Mac Index and why it is worth consideration as a simpler measure of purchasing power parity rather than a humorous metric as per its initial introduction into the economic theory by *The Economist* magazine.

### **5.2.2 South African exchange rate dynamics**

In Africa there are 4 countries with the McDonalds franchise: South Africa, Morocco, Egypt and Tunisia. South Africa acts as a good proxy for developing African countries especially in Southern Africa, as it is an anchor economy for many Southern African countries. This makes analysing the rand significant as it can act as an indicator on how the other currencies in the developing countries will react with the BMI. Similar to the patterns of the developed countries, the real exchange rate closely tracks the movements of the adjusted BMI exchange rate. Even for the Rand, the adjusted BMI is found to be a better predictor of exchange rates in comparison to the raw BMI.

The adjusted BMI was found to have lower level of over/undervaluation compared to the raw BMI. The adjusted BMI has shown a constant level of undervaluation over the past 20 years. The fact that the Rand has a constant undervaluation against the adjusted BMI over a long period of 20 years suggests that the adjusted BMI is a good indicator of appropriate Rand exchange rate valuation. When adopting the BMI implied exchange rate into the real world, the exchange would be 5.71 ZAR/USD instead of 16.25 ZAR/USD in 2022.

Using the manufacturing industry in South Africa as an example, BMW South Africa is a producer of vehicles that are sold to markets in North Africa, the Middle East, the United States, Australia, New Zealand, Singapore, Hong Kong, and Canada. It produces about 76,000 X3

automobiles a year, with a retail price of about R1 063 278. According to the raw BMI implied exchange rate of 5.10 ZAR/USD, the car would cost \$208 485.88, making it less competitive globally as it is more expensive and would likely be met by far fewer sales.

Assuming a true exchange rate of 16.25 ZAR/USD in 2022, the automobiles' global selling price would be \$65 432.49. The car would sell for \$91 034.08 based on the adjusted BMI estimated exchange rate of 11.68 ZAR/USD. This demonstrates that, in comparison to utilising the raw BMI inferred exchange rate, employing the modified BMI implied exchange rate increases the vehicle's competitiveness in the worldwide market. Using the corrected BMI indicated exchange rate would boost revenue earned, as can be seen when comparing the prices of the X3 versus the real exchange rate. This is explained by the rand's current undervaluation. It implies that the current balance of payments could be higher than it presently is.

In addition, the study found evidence in support of the adjusted BMI meeting the current account assumptions of PPP for the Rand. The study found evidence of a positive relationship between terms of trade and the adjusted BMI-PPP. This means if the adjusted BMI value is correct, it would be expected that at the current exchange rate SA exports should be highly competitive globally whilst imports are said to be very expensive due to rand being undervalued. This would mean that there should be a surplus in the current account of the balance of payments, and in line with PPP theory the exchange rate should have strengthened. However, in reality, the current account has recorded deficits for most of the 2000-2022 period and the rand exchange rate has weakened. This implies that the value of the exchange rate is either driven by factors other than the current account of the balance of payments, or the BMI is a poor measure of the rand exchange rate, or it could be both scenarios are correct.

Lastly, the adjusted BMI exchange rate has been found to yield better forecasting estimates than the raw BMI exchange rate for the rand. The adjusted BMI has proven to provide forecasting estimates that track the closest to how the real exchange rate patterns are for the 5 year in sample forecast. This suggests that the adjusted BMI could be considered as a simpler method of exchange rate valuation as it not only has predictive power, but it also follows the movements of the current real exchange rate which is universally adopted.

In summary, the main aim was to determine the usefulness of the adjusted BMI as a measure of appropriate exchange rate valuation at a given point in time. The results of this study found

that indeed the adjusted BMI is a useful measure of exchange rate valuation compared to the raw BMI. The study further confirmed that future exchange rate movements can be better forecast using the adjusted BMI. This assists in answering the question on whether the Big Mac Index has any predictive power of exchange rates and further supports the idea of the BMI being considered as a replacement for traditional PPP for real exchange rates in a cross-country longitudinal sample. This adds to the growing literature on the Big Mac Index and why it is worth consideration as a simpler measure of purchasing power parity rather than a humorous metric as per its initial introduction into the economic theory by The Economist magazine. The findings from this study were in line with the findings from a study done by O'brien and Vargas (2015, 2017). They found that the adjusted BMI worked better for exchange rate determination. Thereby it is worth considering the Big Mac theory as more than just lighthearted hypothetical PPP theory. Rather, it could be adopted as one of the effective ways of measuring exchange rate. The simplicity of the model being its strongest attribute.

The use of the BMI for Purchasing Power Parity rather than the use of a CPI basket of goods simplifies the PPP theory and could result in the theory performing better contrary to the views of several scholars. The main problem noted with using a market basket of goods that are supposedly purchased by an average household during a specified period is that geographically the same basket of goods is not consumed. Thus, making cross-country international comparisons difficult to conduct. This is where the simplicity of the Big Mac Index comes into effect as it is a homogenous good produced using identical resources cross-country. This allows for easier cross county comparisons especially after factoring for labour and wages differentials with which the adjusted Big Mac Index has sufficiently captured.

### **5.3 Key findings of the study**

This study analyzed the use of the Big Mac Index (BMI) as a potentially simpler method for measuring purchasing power parity (PPP) and determining exchange rates. The BMI, originally created by The Economist magazine, is a variant of PPP theory that uses the price of a Big Mac burger to determine exchange rates, based on the law of one price.

Two methods of the Big Mac Index were identified: the raw BMI and the adjusted BMI. The raw BMI calculates the implied exchange rate based on the price of a Big Mac burger in local currency compared to the price in US dollars, while the adjusted BMI incorporates GDP per capita into the calculation.

The study aimed to determine whether the adjusted BMI is a better measure of PPP compared to the raw BMI and whether it has better predictive power for future exchange rate movements. Quantitative data analysis was conducted using annual country-level panel data for 35 countries from 2000 to 2022, collected from *The Economist* dataset. The study evaluated the trends of real exchange rates, raw BMI, and adjusted BMI, and assessed misvaluation over time. It also investigated the predictive power of the BMI for exchange rates using econometric models. The results showed that the adjusted BMI was a better measure of exchange rates compared to the raw BMI, particularly for predicting future exchange rate movements. The adjusted BMI accounted for productivity differentials, such as labor costs, which improved its applicability as an exchange rate valuation method. Countries that used the adjusted BMI showed closer convergence to PPP parity over time. In the case of the South African Rand, the adjusted BMI was found to be a better predictor of exchange rates compared to the raw BMI. It demonstrated lower levels of over/undervaluation and provided better forecasting estimates for future exchange rate movements.

Overall, the study concluded that the adjusted BMI is a useful and simpler method for measuring exchange rate valuation and predicting future exchange rate movements compared to the raw BMI. The findings support the consideration of the Big Mac Index as a viable alternative to traditional PPP measures for real exchange rates. The findings of this study were in line with a study by O'Brien & Vargas (2017). They found that the adjusted Big Mac Index and its theory on cross-country income differentials (Balassa-Samuelson effect) works best in determining exchange rates. They also found evidence to support that the adjusted Big Mac Index possesses better forecasting ability as did this study.

#### **5.4 Policy implications**

While the Big Mac Index is not a definitive tool for policymaking, it serves as a useful reference point for policymakers to assess currency valuation, international competitiveness, and global economic trends. By incorporating insights from the index into their decision-making processes, policymakers can potentially improve policy effectiveness and contribute to economic stability and growth. For this to happen though, the Big Mac Index theory would need to be adopted as an actual economic theory rather than it being just a light-hearted way to illustrate exchange rate theories and economic principles.

The index can be useful in providing insight on trade policies. Upon applying the BMI to exchange rate behavior patterns, policy makers can consider adjusting exchange rate policies to address any identified significant currency misvaluations. It can show the competitiveness of domestic goods and services in comparison to those in other countries. Policy makers may then use this information to create trade policies that are aimed at addressing trade deficits in the countries. For example, in the study the Rand was found to be undervalued from 2000 to 2022. This implies that the country's terms of trade could have been higher than they presently are if the BMI implied exchange rate was used. This means the South African government would have to find the ideal trade policy to implement to solve this issue of the currency being valued lower than it should be. An example of a possible implementation could be exchange rate pegs or bands to a stronger currency than the Rand like the Chinese Yuan (CNY). The Yuan has an exchange rate of 1:12 CNY. This would help to stabilize the Rand and prevent excessive depreciation or undervaluation.

### **5.5 Areas of future study**

This study compared the effectiveness of the raw BMI and the Adjusted BMI for the valuation of exchange rates. However, it would be interesting to look into the applications of the Big Mac Index. The Big Mac Index can be used for affordability index tests for many countries and regions. The Index can be used to evaluate the real-income inequality across countries. This would entail establishing how many big mac burgers a household can afford and this would give an idea of how the purchasing power is like in each country to determine their affordability of buying a certain good. Researchers may also conduct comparative studies using the Big Mac Index to compare the cost of living, standard of living, and economic development across different countries and regions. The selling point the simplicity in which these tests may be conducted using the BMI.

Secondly, overtime a similar study may be done with more data available. The predictive power of the BMI for future exchange rates can be improved with a larger dataset and analysis using monthly or bi-monthly data rather than annual data. Using monthly data will mean that forecasting can be conducted with more frequent observations which can better capture the exchange rate behaviours in the short run and provide more useful and accurate results. This can improve the significance of the study.

## **5.6 Limitations of the study**

The study attempted by all means to ensure that the findings are valid and reliable. The main limitation, however, was that the Big Mac dataset that the study uses may be considered small due to the establishment of the different franchises in different years. This reduced the sample size of the study.

Another challenge faced in conducting the study is the limited literature available regarding the Big Mac Index. There are a few recent studies on the index, this can make it difficult to conduct up to date research. This could be attributed to the Index being just a hypothetical theory and not one that has been formally adopted. However, the success of the BMI shows that there is great potential for further studies to be done on the Big Mac Index.

## **5.7 Conclusion**

This chapter discussed the study's main findings. Policy recommendations, areas of future study and the limitations of the study were also presented. In short, this study found that the adjusted Big Mac Index acts as a better measure of purchasing power and exchange rate determination compared to the raw BMI globally as well as in South Africa. A panel ARDL model was done, and it was found that the performance of the raw BMI is improved by incorporating country specific differentials. This supports the Penn effect theory which is the founding theory for explaining why it's important to include productivity differentials in countries in the determination of exchange rates. Furthermore, the adjusted BMI was found to be a better predictor of future exchange rates. Overall, the study has found the Big Mac index as an effective and simpler method of using the Purchasing Power Parity theory to determine exchange rates.

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## 7. APPENDICES

### Appendix A

Table A: Summary of studies done on PPP

<b>Study</b>	<b>Countries Covered</b>	<b>Period Covered (annual data)</b>	<b>Estimation method</b>	<b>Methodology</b>	<b>Summary of findings</b>
Shively (2001)	6 countries	1973 -1997	Pointwise most powerful invariant (MPI) unit root	Test for unit root and stationarity	True long run PPP hold for exchange rates
Holmes (2000, 2001)	27 countries	1974 -1997	t- bar tests	Testing for unit root	PPP hold for high inflation developing countries
Abuaf & Jorian (1990)	10 countries	1990 - 1972	Monte Carlo estimation methods	A system of univariate autoregressions used	Long run PPP holds despite short run deviations found
Cashin & McDermott (2006)	90 countries	1973 - 2002	Least squares estimator	The half lives of PPP deviations were calculated	Speed of mean reversion faster for countries with flexible exchange rates than fixed.
Ngayasu (2002)	17 countries	1980-1994	Panel cointegration tests	Studied the long run PPP using parallel market exchange rates of African countries	Weak form long run PPP is supported in Africa.
McNown & Wallace (1989)	4 countries	1976 - 1985	Cointegrating tests	Examined time series properties of PPP for high inflation countries	PPP holds in the long run.

Appendix B

Table B: Summary of studies done on the BMI

<b>Study</b>	<b>Countries Covered</b>	<b>Period Covered (annual data)</b>	<b>Estimation method</b>	<b>Methodology</b>	<b>Summary of findings</b>
Chen <i>et al</i> (2007)	16 countries	1992 - 1999	OLS regression	Examined the validity of BMI vs CPI for PPP	PPP is not rejected for BMI but rejected for PPP
Ong (2003)	34 countries	1986 - 1994	OLS regression	Regression tests run to determine whether relative and absolute PPP hold with BMI	BMI models short run and long run PPP well
Clements <i>et al</i> (2011)	24 countries	1994 - 2008	Root Mean Square Error (RMSE) test OLS regression	The predictive power of the BMI was examined	The random walk model predicts future currency values for longer time horizons.
Clements & Si (2016)	49 countries	2015	OLS regressions	The predictive power of the adjusted BMI was assessed	Adjusted BMI found to be a better forecaster compared to raw BMI

<b>Study</b>	<b>Countries Covered</b>	<b>Period Covered (annual data)</b>	<b>Estimation method</b>	<b>Methodology</b>	<b>Summary of findings</b>
Wee & Lee (2022)	27 countries	1999 - 2021	Panel cointegration test	The validity of the PPP with the BMI was tested	They found that the BMI for PPP holds
Fujjiki & Kitamura (2004)	23 countries	1996 - 2002	Fixed effects estimator regression	A statistical procedure best suited to test PPP based on	Evidence supporting BMI-PPP was found

				the BMI was discussed	based on the Balassa-Samuelson effect
Jiawen (2004)	29 countries	1992 -2003	BMI misalignment calculation Correlation test	To establish if the BMI is a misleading measure of currency valuation	BMI fails to account for non-tradables
Naban (2016)	5 countries	1988 - 2015	BMI misalignment calculation BMI affordability index	The BMI used to compare the purchasing power of Indonesia rupiah  The big mac affordability index is used to investigate the disparity of real income among ASEAN countries.	exchange rate of IDR against the US weakened and was undervalued. affordability index shows that there is an income disparity between Singapore and five other ASEAN countries.

<b>Study</b>	<b>Countries Covered</b>	<b>Period Covered (annual data)</b>	<b>Estimation method</b>	<b>Methodology</b>	<b>Summary of findings</b>
Portes & Atal (2013)	54 countries	1986 -2012	BMI misalignment Exchange rate movement tracking	Tracking exercise done to assess to what extent big mac prices reflect overall price movements using CPI vs GDP deflator to see if they move together.	There is some forecasting power in the BMI as countries gravitate towards parity, but not for emerging markets.
Pakko & Pollard (1996)	15 countries	1986 - 1995	BMI Misalignment calculation	With the inflation differential, if exchange rate =	The study found that PPP generally does not hold in the short

			Inflation differential vs exchange rate	inflation differential it means PPP using BMI holds	run for either absolute or relative PPP.
Click (1996)	26 countries	1986 - 1995	OLS Regression	A log regression model was run on BMI- PPP to see if it holds	PPP holds in the time series dimension and the country effects are linked to income, as suggested by Balassa Samuelson effect.

## Appendix C

Table C: Average global BMI calculations over 2000 – 2022 for 37 countries

Name	local_price	Price of Big Mac in dollars (US base country)	dollar_ex	dollar_price	Raw BMI	over / under valuation	GDP per Capita Dollar	GDP per Capita Local	adj_dollar_price	adj_dollar_price (US base currency)	adj_local_price	Adj BMI	over/under valuation
Argentina	66,67	3,84	18,62	2,92	11,17	-21%	10329,27	253542,06	2,85	3,95	56,62	12,48	-27%
Australia	4,54	3,84	1,34	3,56	1,21	-6%	51172,15	65312,03	3,89	3,95	4,99	1,30	-2%
Brazil	10,91	3,84	2,83	3,85	2,65	2%	8349,02	24851,52	2,75	3,95	7,87	1,94	-30%
Britain	2,55	3,84	0,66	3,88	0,70	9%	41762,69	28061,23	3,60	3,95	2,37	0,60	-9%
Canada	4,81	3,84	1,24	3,96	1,29	6%	43183,08	52644,88	3,60	3,95	4,40	1,14	-8%
Chile	1970,11	3,84	609,72	3,24	527,21	-11%	12390,32	7708404,88	2,90	3,95	1753,66	443,39	-27%
China	15,38	3,89	7,16	2,23	4,06	-42%	6419,34	43125,79	2,77	3,93	19,24	5,01	-30%
Colombia	9000,00	4,16	2572,55	3,59	2215,53	-7%	6070,65	16115596,43	2,92	4,27	7547,40	1746,55	-32%
Czech Republic	68,92	3,89	24,67	2,97	19,10	-21%	18900,07	419212,97	3,11	3,93	72,66	19,35	-21%
Denmark	28,79	3,84	6,35	4,65	8,32	32%	54426,43	355168,15	3,74	3,95	23,07	5,92	-6%
Egypt	20,84	4,07	9,50	2,15	4,79	-44%	2827,97	28858,06	2,82	4,18	27,43	6,33	-33%

Euro area	3,48	3,97	0,86	4,12	0,93	10%	35352,35	29143,39	3,46	4,01	2,92	0,74	-14%
Hong Kong	15,68	3,84	7,79	2,01	4,27	-45%	38348,57	298465,01	4,30	3,95	33,65	8,46	9%
Hungary	714,24	3,84	246,54	2,98	191,22	-17%	13327,68	3396158,94	2,97	3,95	726,86	183,74	-25%
Indonesia	23712,02	3,84	10998,74	2,13	6290,05	-41%	3090,99	37998633,83	2,68	3,95	29968,86	7427,94	-32%
Israel	16,10	4,49	3,71	4,40	3,83	3%	36526,42	133452,50	3,80	4,40	13,85	3,19	-14%
Japan	323,43	3,84	108,19	3,05	90,47	-15%	39509,89	4191834,67	3,83	3,95	408,36	105,28	-2%
Malaysia	7,01	3,84	3,72	1,89	1,90	-48%	9027,00	34125,75	2,99	3,95	11,09	2,82	-24%
Mexico	37,42	3,84	14,05	2,64	9,87	-24%	9196,26	141342,24	2,89	3,95	42,26	10,26	-27%
New Zealand	5,18	3,84	1,53	3,56	1,42	-4%	35667,83	51506,68	3,48	3,95	5,11	1,34	-12%
Norway	44,80	4,07	7,19	6,38	11,80	72%	78720,07	578021,78	4,04	4,18	28,87	6,86	-4%
Pakistan	302,90	4,16	102,66	2,80	68,20	-30%	1371,39	145908,91	2,78	4,27	287,77	65,34	-35%
Peru	9,97	3,99	3,20	3,14	2,67	-15%	5422,79	17364,49	2,80	4,09	8,89	2,18	-32%
Philippines	110,63	3,91	48,81	2,30	28,85	-40%	2589,14	124454,07	2,69	4,02	129,07	32,55	-33%
Poland	8,61	3,84	3,53	2,48	2,31	-33%	12413,46	43964,90	3,01	3,95	10,45	2,67	-24%
Russia	81,00	3,84	42,44	1,92	20,30	-46%	10331,96	454669,15	3,03	3,95	137,05	32,80	-24%
Saudi Arabia	10,83	4,16	3,75	2,89	2,67	-0,28	20674,89	77530,85	3,51	4,24	13,18	3,10	-0,17
Singapore	4,47	3,84	1,47	3,15	1,23	-16%	50845,85	70605,15	4,02	3,95	5,72	1,47	1%
South Africa	21,09	3,84	10,13	2,08	5,42	-42%	6353,18	69452,45	2,84	3,95	29,64	7,21	-28%
South Korea	3658,70	3,84	1137,62	3,23	1014,09	-10%	26021,37	29283241,29	3,29	3,95	3720,56	938,24	-17%
Sweden	40,00	3,84	8,08	5,07	10,79	39%	50474,10	406750,38	3,52	3,95	27,87	7,17	-11%
Switzerland	6,41	3,84	1,13	5,96	1,87	65%	77045,59	79449,21	3,80	3,95	4,04	1,06	-5%
Taiwan	73,33	3,84	31,28	2,35	21,42	-32%	21862,85	675805,46	3,46	3,95	106,90	27,10	-13%
Thailand	84,80	3,84	35,41	2,48	22,44	-35%	5453,34	180430,90	2,74	3,95	94,29	24,60	-30%
Turkey	557151,51	3,99	212193,57	3,19	229797,42	-11%	9407,37	31126,34	2,92	4,09	381166,71	145532,12	-29%
United States	3,62	3,84	1,00	3,62	0,97	-2%	#DIV/0!	#DIV/0!	3,95	3,95	3,96	1,01	0%