Would You Like Fries with Burgernomics? Understanding the Big Mac Index and its Surrounding Studies

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Abstract

In this seminar paper, I explore the Big Mac Index that was first introduced by the Economist. First, I explain the mechanics of the Big Mac index with a simple example and the corrections made over the years to address the shortcomings of the Big Mac Index. Next, I explain how the Big Mac Index fits in with in international economics theory, such as Law of One Price, purchasing power parity (absolute vs. relative), and non-traded goods. Finally, I discuss the surrounding literature that uses the Big Mac Index in exploring the relative purchasing power parity and exchange rates.

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1 Introduction

In 1986, economists from the *Economist* created a lighthearted guide called the Big Mac Index to show whether foreign currencies are at the "correct" level. Since then, the *Economist* have made revisions to the Big Mac Index to address many of its initial shortcomings. In response to this lighthearted guide, many economists in the literature have favored using it in the center of their economic studies. In fact, Economist (1986) claims it is the subject of at least 20 academic studies, two of which will be mentioned in this paper. These studies include exploring the prices of individual ingredients relative to the Big Mac index and measuring the performance of the Big Mac index.

This paper will summarize the Big Mac index and its surrounding studies. Section 2 introduces the Big Mac index and applies it to a particular country. Section 3 explains deviations from purchasing-power parity and non-traded goods. Section 4 covers economic studies done on the Big Mac Index. We then conclude.

2 Introducing the Big Mac Index

Purchasing-power parity (PPP) is the theory that explains the movements in the exchange rate between two countries' currencies by changes in the countries' price levels, usually through a market "basket" approach. Two currencies are in equilibrium when items in a market "basket" are equivalently priced after accounting for the exchange rate. Mathematically, PPP is expressed as $P_{US} = E * P_{Euro}$ where E is the exchange rate of USD/Euro (Krugman et al., 2017). The Big Mac index is based on PPP, where the only item within the basket is a Big Mac.[1] Thus, two currencies are in equilibrium when the price of the Big Mac equalizes after accounting for exchange rate. The Big Mac index is calculated for 48 different countries (including "Euro area").

There are two versions of the Big Mac index: the raw index and the adjusted index. The raw index only accounts for the average price of the Big Mac within a country. The adjusted index uses the relationship between prices and GDP per person. The prices for a Big Mac are given based on the regression between Big Mac prices and GDP per person, shown in Figure 1. This is an attempt to adjust for the differences in input prices, such as labor costs, and income in different countries. For example, richer countries would price the Big Mac to be more expensive due to higher labor costs. Symmetrically, poorer countries would have lower prices of the Big Mac due to lower labor costs.

Absolute PPP tells us that the prices for a Big Mac are equal around the world, but that is not the case. To observe this, let the USD be the base currency. Figure 6 shows the prices of Big

[1] This is also referred to as the Law of One Price, where an identical item should have the same price after accounting for exchange rates and assuming free trade.

Macs around the world relative to the price of a Big Mac in the United States in terms of over- or undervaluation against the dollar when using the raw index. Upon first glance, the Big Mac prices in many countries, especially in East Asia and Eastern Europe, are undervalued relative to the dollar. When we use the adjusted index, half of the countries overvalue the price of the Big Mac relative to the dollar. There are 16 countries that are within $\pm 10\%$ of over-/ undervaluation relative to the dollar. This is seen in Figure 7.

Using the Big Mac Index interactive app, I take a further look into two countries: China and the US.[2] Once again, assume US is the base currency. First, we look into the raw index. In 2018, the average Big Mac price in the US is \$5.28, while the average price of the Big Mac price in China is \$3.17 (or 20.40 RMB). We plug these values into the PPP equation and solve for the implied exchanged rate, $E_{implied}$

$$\begin{aligned} P_{US} &= E * P_{CN} \\ 5.28 &= E * (20.40) \\ E_{implied} &= 0.26 \end{aligned}$$

Here, $E_{implied}$ is the exchange rate (USD to RMB) that we expect to get based on absolute PPP. However, the actual exchange rate is $E_{actual} = 0.16$. Clearly, PPP does not properly predict the actual exchange rate, and the Chinese RMB is undervalued relative to the USD. Looking at Figure 2, the Chinese currency has been undervalued relative to the equilibrium exchange rate for years before 2018 as well. When we adjust for GDP, the price of the Big Mac in China is not as dramatically undervalued relative to the US dollar, as seen in Figure 7.

Both the adjusted and unadjusted Big Mac indices give good insights into a country's exchange rate policies. Turning back to China and the US, it should be no surprise that China undervalues its currency relative to the US dollar, since China is export-oriented. Undervalued currency implies that Chinese exports are cheaper, so China will export more at the cost of more expensive imports, thus running a trade surplus. Similarly, the Big Mac index shows that the Asian "Tigers", such as Hong Kong and Singapore, also undervalue their currencies relative to the US dollar to promote exports and drive growth. In 1986, the hamburger in the US cost 64% more than that in Hong Kong and 23% more than that in Singapore. Figure 4 presents the Big Mac Raw Index from 2000-2018 with the US Dollar as the base currency. Using the Big Mac Index, we also imply that Hong Kong pegs the Hong Kong Dollar to the US Dollar as seen by the lack of change in the Big Mac Index, which is the case today. The Big Mac Index is able to identify currencies that are consistently undervalued, which bring up important policy considerations when addressing currency manipulation, as in the case with China.

[2]You can play around with the data visualization here: `https://www.economist.com/content/big-mac-index`

The Big Mac Index can also be used to give insights into the consequences of macro-prudential policies that alter the exchange rate. In one particular example, during the global financial crisis in 2007, Brazil used capital control policies to shield its currency (the Real) from appreciating too much in order to keep its export-oriented economy competitive (Alfaro et al., 2017). This policy would be implemented from 2008-2012. Using the Big Mac Index, we expect the valuation of Real to increase relative to the dollar, then return to the pre-global financial crisis state. Figure 5 presents the Big Mac Raw Index valuation of the Brazilian Real relative to the US Dollar. Using the Big Mac Index, we see that the Big Mac is undervalued in around 2006, but then suddenly becomes overvalued during the crisis, and finally decline to its normal state starting in 2014. Figure 5 matches this outcome well.

While the Big Mac Index are a friendly way to understand the deviations of currency valuation and potentially present the consequences of macro-prudential policies that control exchange rates, there are many shortcomings that negatively affect the conclusions we draw from using the Big Mac Index.

3 Relative PPP

The *Economist* adjusts the Big Mac index by GDP to account for the violation of absolute PPP, but we can also consider relative PPP as an alternative, expressed mathematically as

$$\frac{E^e - E}{E} = \pi^e - \pi^{e*} \tag{1}$$

where π^e is the expected percentage price change increase (inflation) and E^e is the expected exchange rate change. Intuitively, relative PPP predicts the relationship between changes in prices and changes in exchange rates. In other words, the movements in inflation rates between two countries are able to predict movements in exchange rates and vice-versa. Because we are measuring in changes rather than in levels, relative PPP tends to hold more often than absolute PPP. Since relative PPP is derived from absolute PPP, if absolute PPP holds, then relative PPP must holds.[3]

To illustrate this concept, we consider the following example. Assuming relative PPP holds, if the Big Mac price in the US goes up by 5% and the Big Mac price in China goes up by 3%, it must be true that the exchange rate also goes up by 2%.

[3]The converse does not need to be true. If relative PPP holds, it does not imply absolute PPP holds. To illustrate this, if the inflation rates of Switzerland and the US are the same, then the implied movement of the exchange rate is 0, despite the fact that the Big Mac in Switzerland is much more expensive than that in the US.

4 Violations of Absolute PPP: Non-traded Goods

What accounts for the violations of the PPP theory when looking at the Big Mac index? What are the shortcomings to the Big Mac index? The *Economist* notes many factors that contribute to the shortcomings of PPP: transport costs, government regulations, product differentiation, and non-traded goods. In the case of the Big Mac, non-traded goods include rent and electricity.

Non-traded good can only be consumed domestically and cannot be imported nor exported. Since non-traded goods are priced based on domestic supply and demand, prices of non-traded goods, such as rent or electricity, vary from country to country. The pricing of non-traded goods play a large role in pricing the traded good and change the real exchange rate even though the terms of trade do not change.

To show this, consider the small country case, where the country is a price-taker. Let P_{TG} be the world price of traded goods. Assume P_{TG} consists of two goods A and B, such that

$$P_A = EP_A^*$$
$$P_B = EP_B^*$$

So, $P_{TG} \equiv \frac{P_A}{P_B} = \frac{P_A^*}{P_B^*} \equiv P_{TG}^*$. Therefore, in a price-taking country, $P_{TG} = P_{TG}^*$ (that is the traded good is set by the world price). Although P_{TG} is exogenous and is independent of the exchange rate, exchange rate policy can still affect the relative price of the traded good to the non-traded good, $\frac{P_{TG}}{P_{NTG}}$, where P_{NTG} is the price of the non-traded goods. Consider the domestic currency depreciates against the foreign currency (increase in E). Relating the relative price of traded-goods to non-traded goods domestically to that of the world, we get the following equation

$$\frac{P_{TG}}{P_{NTG}} = \frac{EP_{TG}^*}{P_{NTG}} \tag{2}$$

Using (1), an increase in E will cause an increase in P_{TG}. The quantity consumed of the traded good will decrease while the quantity produced of the traded good will increase, which increases $\frac{P_{TG}}{P_{NTG}}$. Consider the real exchange rate

$$q = \frac{EP^*}{P} \tag{3}$$

The real exchange rate can be expressed in terms of traded goods and non-traded goods, so

$$q = \frac{EP_{TG}^*}{P_{NTG}} \tag{4}$$

Intuitively, the the price-taking country takes on the world price of the traded good, while non-traded goods are priced domestically. In conclusion, for a price-taking country, a depreciation of

the domestic currency will cause price of the traded good to increase domestically to the world price. The depreciation also causes the real exchange rate q to increase without changing the terms of trade. Through this example, we see that P_{NTG} influences the pricing of domestic goods.[4] We now apply this analysis to the Big Mac index.

First, the Big Mac itself is a non-traded good. Because there are few close substitutes for the Big Mac, product differentiation gives McDonald's some power to adjust prices based on the local market. The Big Mac exists in an imperfectly competitive market, so arbitrage opportunities through buying and selling Big Macs are hard to capitalize on.

Second, even if the Big Mac were a traded good, it is made up of traded and non-traded inputs. The non-traded inputs will drive the Big Mac to deviate from the PPP price. The ingredients, such as beef, cheese, lettuce, and tomato, are all traded inputs that should obey law of one price, and thus also PPP, assuming that there are no distortions, such as tariffs, imposed on the ingredients. Nonfood inputs such as electricity and rent are non-traded inputs that change the local price of the burger depending on a country's infrastructure and endowment. Labor and wages are other nonfood inputs

Third, government interventions, such as imposing food taxes or setting trade barriers, such as tariffs or import quotas, will influence the local price of the Big Mac. A similar argument can be made for capital control policies, which alter exchange rates, and therefore distorting prices of the Big Mac. These distortions will cause the price of the Big Mac to deviate from the true price of the Big Mac.

5 Further Studies on the Big Mac Index

In the previous section, I mentioned that the Big Mac index is far from perfect, particularly in the deviations from the PPP. In this section, I summarize two studies that addresses the shortcomings of the Big Mac index: Parsley and Wei (2007) and Cumby (1996).

5.1 Summary of Parsley and Wei (2007)

Parsley and Wei (2007) match prices of the Big Mac to the prices of the individual ingredients to study the movement of real exchange rates. They find that the Big Mac real exchange rates are highly correlated with the CPI-based exchange rates. Of the sample of 561 possible real exchange rates in the data set, 61% of them had correlation coefficients greater than 0.65, with a median correlation coefficient of 0.889. This motivated the use of the Big Mac index compared to more traditional ways of measuring real exchange rates (e.g. using CPI-based exchange rates).

[4]There are other cases to consider, such as the semi-small country case or rigid country case. These will not be described in this paper.

Next, Parsley and Wei (2007) regress the price of the Big Mac on eight factors: five traded factors (beef, cheese, lettuce, onions, bread) and three nontraded factors (labor, rent, electricity). Table 1 summarizes the results of the regression. These eight factors account for 86.9% of the price of the Big Mac. Of these factors, the nontraded factors account for 55.3% of the Big Mac prices, which implies that nontraded factors are an important component of Big Mac prices. Parsley and Wei (2007) proves this point through studying the persistence of these cross-country price differences with the following specification

$$\Delta q_{i,j,t} = \beta q_{i,t-1} + \alpha_j + \alpha_t + \epsilon_{i,j,t} \tag{5}$$

for input i, country j at time t, where α_j and α_t are country and time dummies respectively, and the log real exchange rate is defined as $q_t = s + p_t^* - p_t$, where s is the spot or exchange rate and $p_t^* - p_t$ is the difference in foreign and domestic price. Through this specification, they show that the half-life of convergence for nontraded factors is 3.4 years, more than twice that of the traded factors (1.4 years). This specification presents the idea of relative PPP, but at the input level.

Finally, Parsley and Wei (2007) show that the deviations from the law of one price in tradeable goods do not add much to movements in real exchange rates.[5] Many government interventionist policies, such as pegging currencies, trade agreements, and tariffs, weakens the effect between real exchange rate and law of one price deviations.

In conclusion, the results of Parsley and Wei (2007) suggest that the PPP "violations" mentioned earlier are largely affected by non-tradeable inputs, such as labor, rent, and electricity, and trade barriers and distortions. The regression of Big Mac prices on eight input factor prices is an important innovation to the Big Mac index model.

5.2 Summary of Cumby (1996)

Cumby (1996) study the usefulness of the deviations from the Big Mac parity, like in Parsley and Wei (1996). Primarily, Cumby (1996) aims to answer three questions:

(i). Do the deviations from the Big Mac parity tend to return to the Big Mac parity?

(ii). Do deviations from the Big Mac parity forecast future exchange rates?

(iii). Do deviations from the Big Mac parity forecast changes in the local currency prices of the Big Mac?

Cumby (1996) answers these questions with four different empirical specifications. In all four specifications, Cumby (1996) Big Mac parity, defined as $EBMP_{i,t} = P_{i,t}/P_{US,t}$, adjusts for cur-

[5]The movement of the real exchange rate are attributed to the deviations from the law of one price is called the Engel effect.

rency and time effects. Cumby (1996) uses a sample of 14 countries with 13 exchange rates and 10 time series observations of the Big Mac Index.

First, Cumby (1996) explores the deviations from the Big Mac parity, through the auto-regression:

$$\Delta q_{i,t} = \theta_i + (\rho_i - 1)q_{i,t-1} + \sum_{j=1}^{k_i} \gamma_{ij} \Delta q_{i,t-j} + v_{i,t} \tag{6}$$

where $q_{i,t} = ln(EBMP_{i,t}/E_{i,t})$.[6] Here, the variable of interest is ρ_i, where the null hypothesis is $rho_i = 0$. Table 2 presents the results of the auto-regression. We see that the estimates for ρ_i are far from 1 and insignificant due to the small sample size in his data.

To get better estimates, Cumby (1996) pools the data and estimate the regression

$$ln\left(\frac{EBMP_{i,t}}{E_{i,t}}\right) = \theta + \lambda_t + \rho\ ln\left(\frac{EBMP_{i,t-1}}{E_{i,t-1}}\right) + u_{i,t} \tag{7}$$

where λ_t are time fixed effects. The results of the regression are presented in Table 3. Focusing on the OLS results, the estimates of ρ are now significant, bringing us to the first main result. Cumby (1996) find that a half-life of deviations from the Big Mac parity is around 1 year, suggesting that these deviations are not permanent.

Next, Cumby (1996) explores whether deviations from Big Mac parity can forecast future exchange rates with the regression

$$ln\left(\frac{E_{i,t}}{E_{i,t-1}}\right) = \delta_i + \phi_t + \beta\ ln\left(\frac{EBMP_{i,t-1}}{E_{i,t-1}}\right) + v_{i,t} \tag{8}$$

where ϕ_t are time fixed effects and β is the variable of interest. Table 4 presents the result of this regression. Cumby (1996) find that a 10% undervaluation in the Big Mac standard is associated with a 5% appreciation in the following year. Adjusting for bias, (Cumby, 1996) find that a 10% undervaluation in one year leads to a 3.5% appreciation in subsequent year.

Finally, Cumby (1996) explores if current deviations from the Big Mac parity are useful in forecasting changes in relative Big Mac prices with the regression

$$ln\left(\frac{EBMP_{i,t}}{EBMP_{i,t-1}}\right) = \mu_i + \psi_t + \pi\ ln\left(\frac{EBMP_{i,t-1}}{E_{i,t-1}}\right) + \eta_{i,t} \tag{9}$$

where ψ_t are time fixed effects and π is the variable of interest. Table 5 presents the results of this regression. Cumby (1996) find that when U.S. dollar price of Big Macs is high in a country, local currency price of Big Macs in that country is likely to fall during the following year. The results

[6] This is also known as the Dickey-Fuller (1979) test. The downsides of using this auto-regression is its low power, but it is a key first step.

from Cumby (1996) imply that the deviations from the Big Mac index, and therefore PPP, are only temporary and are helpful in forecasting future exchange rates.

Both Parsley and Wei (2007) and Cumby (1996) use relative PPP in their analyses of the Big Mac Index, particularly through exploring the deviations and convergence to the Big Mac Index. Cumby (1996) makes this argument by considering the product as a whole, and goes on to make claims of forecasting future exchange rates. Parsley and Wei (2007) makes this same argument, but through decomposing the Big Mac into its tradeable and non-traded inputs.

6 Conclusion

The Big Mac index is a reader-friendly way to explain whether the exchange rate is in equilibrium between two countries. In other words, it is easy to tell whether the currency in question is over- or undervalued relative to the base currency. While it is tempting to conclude that the PPP does not hold in real life and arbitrage opportunities arise from the Big Mac index, the raw index does not reflect the factors that contribute to the over- or undervaluation of currency. These factors include transport costs, government regulations, product differentiation, non-traded goods, and ingredient prices. There has been an ongoing effort to correct the shortcomings of the Big Mac Index, such as adjusting the raw index based on the GDP per capita to reflect a country's income or using relative PPP.

Economists have further studied the Big Mac index. Studies, such as Parsley and Wei (2007) and Cumby (1996), explained the deviations from the Big Mac index and further adjusted the Big Mac index through accounting input factors and fixed effects. On one hand, the deviations from law of one price of tradeable inputs do not play a huge role in affecting the real exchange rates. On the other hand, the deviations from the Big Mac parity are helpful in predicting future exchange rates. As economists dig deeper into the Big Mac index question, there are more caveats to consider, and the Big Mac index becomes harder to digest.

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Figures and Tables

Figure 1: Big Mac prices vs GDP per person in 2016. Source: *Economist*

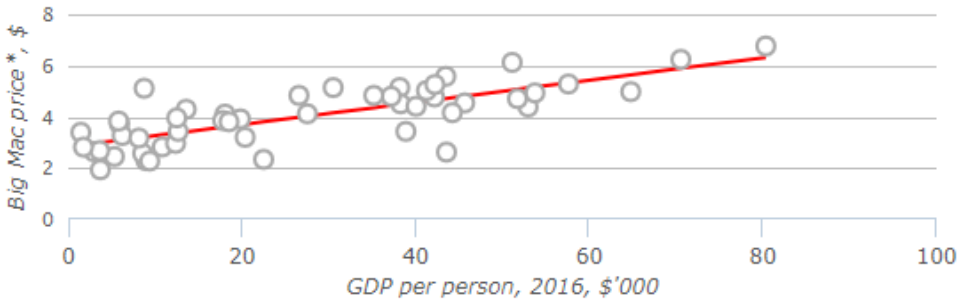

Figure 2: The undervaluation of the Big Mac in RMB relative to USD in Jan 2018. Raw index. Source: *Economist*

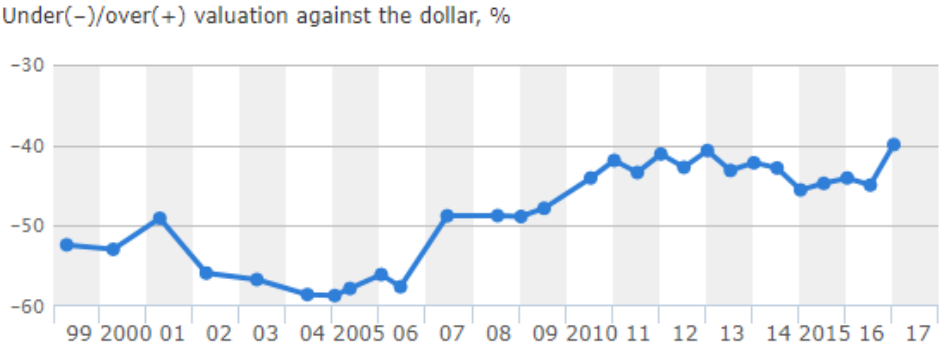

Figure 3: The valuation of the Big Mac in RMB relative to USD adjusted for GDP in Jan 2018. Adjusted index. Source: *Economist*

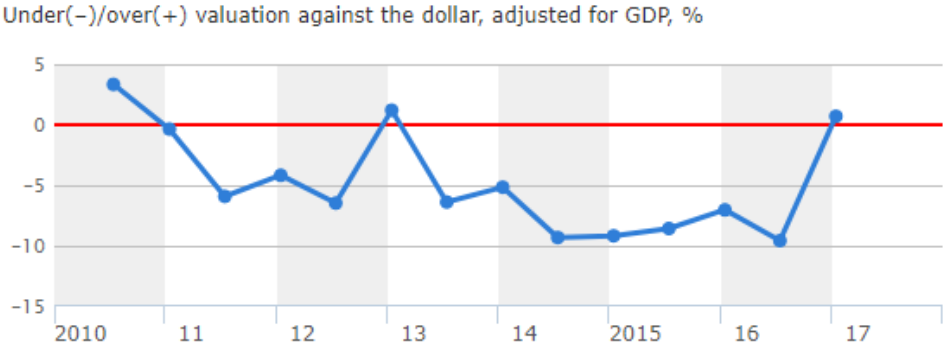

Figure 4: The valuation of the Big Mac in HKD relative to USD adjusted for GDP from 2000-2018. Raw index. Source: *Economist*

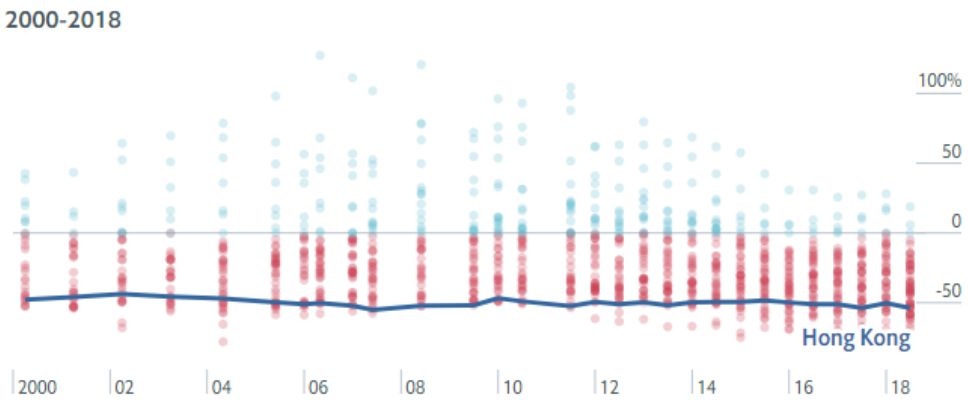

Figure 5: The valuation of the Big Mac in Brazil Real relative to USD adjusted for GDP from 2000-2018. Raw index. Source: *Economist*

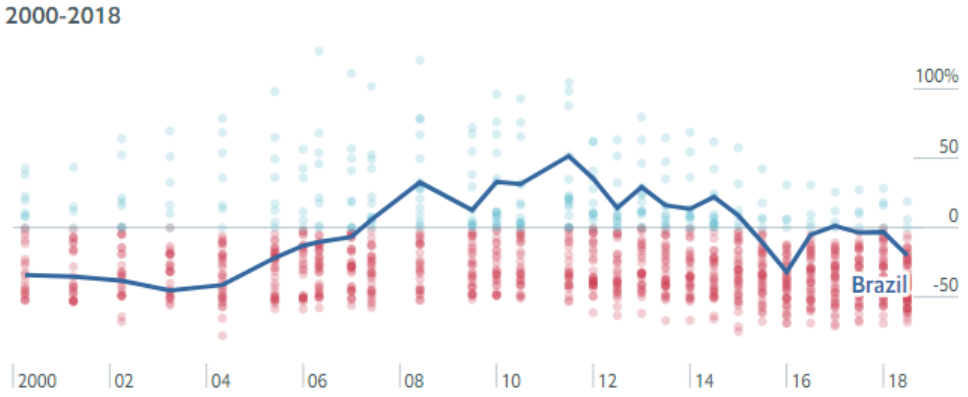

Figure 6: The over-/ undervaluation of the Big Mac relative to USD in Jan 2018. Raw index. Source: *Economist*

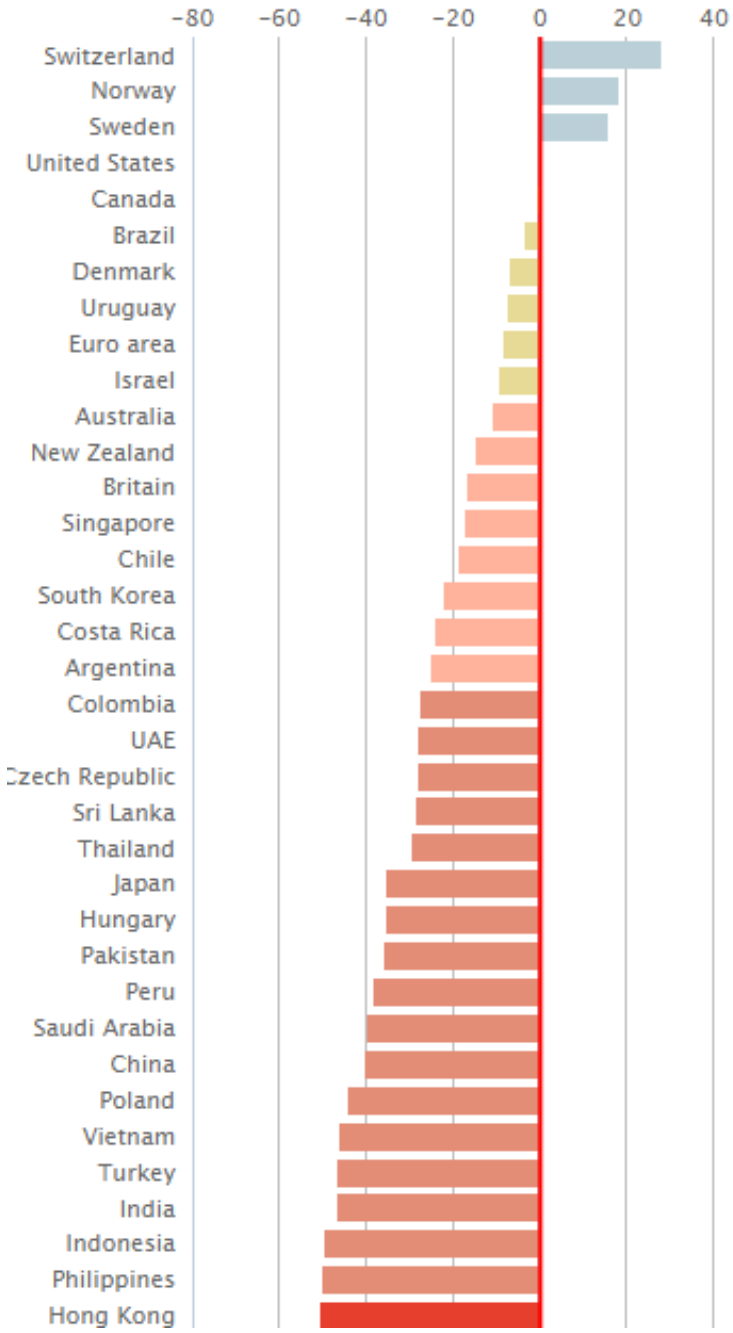

Figure 7: The over-/ undervaluation of the Big Mac relative to USD in Jan 2018. Adjusted index. Source: *Economist*

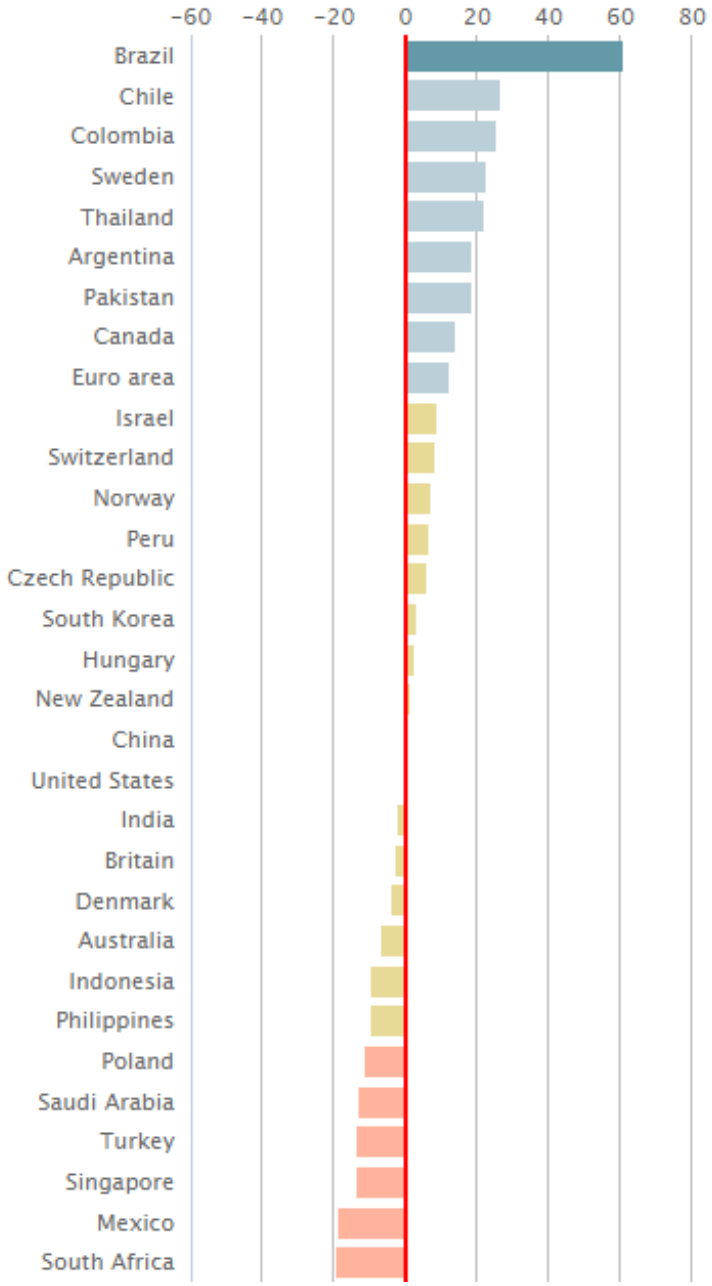

Table 1: Regression of Big Mac prices on prices of eight factors. Source: Parsley and Wei (2007)

	Regression in Levels		***Change Regression***
Ingredient	Coefficient Estimates[1]	Implied Cost Share (%)[2]	Coefficient Estimates[3]
Traded:			
Beef	3.010	9.0	2.257
	(0.645)		(0.669)
Cheese	2.530	9.4	1.995
	(0.592)		(0.625)
Lettuce	1.546	0.7	6.017
	(3.645)		(3.476)
Onions	1.156	0.5	4.411
	(3.610)		(3.239)
Bread	13.428	12.1	11.256
	(3.053)		(3.200)
Nontraded:			
Labor	9.245	45.6	11.823
	(0.832)		(1.069)
Rent	0.008	4.6	0.010
	(0.003)		(0.004)
Electricity	0.085	5.1	0.078
	(0.027)		(0.039)
		Total = 86.9%	
# of observations	318		284
Adjusted R-squared	.95		.66

Table 2: Regression of Tests for Deviations from Big Mac Parity. Source: Cumby (1996)

Country	$\bar{q}_i$	$\hat{\theta}_i$	$\hat{\rho}_i$	ADF Test	k_i
Australia	-0.257	-0.160	0.303	-2.112	0
		(0.096)	(0.330)		
Belgium	0.302	0.175	0.412	-1.674	0
		(0.112)	(0.351)		
Great Britian	0.134	0.072	0.539	-1.529	0
		(0.055)	(0.302)		
Canada	-0.125	-0.089	0.251	-2.063	0
		(0.060)	(0.363)		
Denmark	0.595	0.569	0.038	-2.549	0
		(0.226)	(0.377)		
France	0.384	0.484	-0.306	-4.917	0
		(0.105)	(0.266)		
Germany	0.209	0.168	0.150	-2.256	0
		(0.084)	(0.377)		
Holland	0.251	0.204	0.181	-2.160	0
		(0.098)	(0.379)		
Hong Kong	-0.671	-0.882	-0.284	-4.486	0
		(0.196)	(0.286)		
Italy	0.254	0.247	-0.051	-3.275	0
		(0.091)	(0.231)		
Japan	0.323	0.278	0.104	-2.249	0
		(0.154)	(0.398)		
Spain	0.215	0.132	0.392	-4.913	2
		(0.083)	(0.347)		
Sweden	0.473	0.270	0.448	-1.663	0
		(0.162)	(0.332)		

Table 3: Pooled Estimates of the Rate of Convergence to Big Mac Parity. Source: Cumby (1996)

	$\hat{\rho}$ OLS	$\hat{\rho}$ GLS
Pooled Estimate	0.904	0.907
$(\theta_i = \theta, \lambda_t = 0)$	(0.042)	(0.037)
Time Dummies Only	0.948	0.968
$(\theta_i = \theta)$	(0.028)	(0.022)
Fixed Effects	0.276	0.242
(Time and Currency Dummies)	(0.121)	(0.079)

Table 4: Predicting Exchange Rate Price Changes. Source: Cumby (1996)

	$\hat{\beta}$ OLS	$\hat{\beta}$ GLS
Pooled Estimate	0.016	-0.000
$(\delta_i = \delta, \varphi_t = 0)$	(0.022)	(0.007)
Time Dummies Only	0.020	0.012
$(\delta_i = \delta)$	(0.021)	(0.020)
Fixed Effects	0.483	0.523
(Time and Currency Dummies)	(0.077)	(0.068)

Table 5: Predicting Local Currency Price Changes. Source: Cumby (1996)

	$\hat{\pi}$ OLS	$\hat{\pi}$ GLS
Pooled Estimate	-0.080	-0.074
$(\mu_i = \mu, \psi_t = 0)$	(0.039)	(0.039)
Time Dummies Only	-0.032	-0.029
$(\mu_i = \mu)$	(0.015)	(0.011)
Fixed Effects	-0.241	-0.179
(Time and Currency Dummies)	(0.074)	(0.044)