BIG MAC INDEX AND EFFECTIVE EXCHANGE RATES: THE US DOLLAR, THE EURO, AND THE YUAN

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ABSTRACT

This study is an investigation of currency misvaluation estimates relative to several different effective exchange rate (EER) baskets, given *The Economist's* two Big Mac index methods of intrinsic currency valuation (raw and adjusted). We find that a currency's misvaluation estimates have tended to be relatively consistent across the different EER basket compositions for the adjusted Big Mac method but not for the raw Big Mac method. For the adjusted Big Mac method, the Chinese yuan's estimated undervaluation gradually diminished after January 2011 until the yuan was slightly overvalued as of January 2016.

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The term *effective exchange rate* (EER) refers to an exchange rate between a given currency and a basket of currencies. That is, an EER is essentially a currency index from the perspective of the given currency. An EER is deemed to be a more effective way to measure a given currency's value than a bilateral exchange rate between the given currency and another individual currency (Chinn, 2006). With an EER and a standard of intrinsic foreign exchange (FX) value, like purchasing power parity (PPP) for example, one can estimate a given currency's overall misvaluation versus other currencies in general.

As Chinn (2006) explains, researchers have typically weighted the currencies in EER baskets by relative levels of trade. For example, Cline and Williamson (2008) summarize various Chinese yuan EER misvaluation estimates based on trade-weighted currency baskets. However, Ho (2012) argues that GDP weights are more logical than trade weights for EER baskets in today's globalized economy. Moreover, because a GDP-weighted basket has the same composition from any given currency perspective, a currency's misvaluation estimate is consistent with that of another given currency and the estimated bilateral misvaluation of the two currencies. Equal weighting of currency basket positions also allows this consistency, but trade weighting does not. For example, a Chinese yuan misvaluation versus an EER basket based on China's trade weights would not generally be consistent with a US dollar misvaluation versus an EER basket based on US trade weights and the bilateral misvaluation of the yuan versus the US dollar.[1]

Overview of the Study

This study is an investigation of currency misvaluation estimates versus several EER baskets, based on *The Economist's* two standards of intrinsic FX value: (1) the original Big Mac index, which applies the PPP condition and is now usually called the raw Big Mac index; and (2) the adjusted Big Mac method, which takes into account per capita GDP differences across economies using a regression equation that links Big Mac prices and per capita GDPs.

One EER basket is a simple, equally-weighted basket, where the currency positions in the basket convert to the same amount of the given currency using the bilateral *intrinsic* FX rates versus the given currency. Two other EER baskets use Ho's (2012) idea of nominal GDP weights. One basket is weighted by *per capita* GDP (denoted GDPp), which is used in *The Economist's* adjusted Big Mac analysis and related research (for examples, Rogoff, 1996; Frankel, 2006; Xu, 2009; Zhang, 2012; and Cheung and Fujii, 2014). The other is weighted *by total* GDP (denoted GDPt), which is akin to the wealth-weighted currency index in the O'Brien and Dolde (2000) two-factor international CAPM.[2] The two GDP-weighted baskets assume that the currency positions, after conversion to the given currency using the bilateral intrinsic FX rates with the given currency, have proportions based on per capita and total GDP, respectively. For the adjusted Big Mac method, the regression line serves as a fourth EER basket with implicit currency positions

[1] In order to have the same composition from the perspective of any given currency, GDP- and equally-weighted baskets include a fractional position in the given currency. Trade-weighted baskets do not do this, but the main reason that trade-weighting does not give the consistency is that trade weights vary by economy.

[2] O'Brien and Dolde (2000) simplify the well-known Solnik (1974) – Sercu (1980) special case of the international CAPM by assuming that the representative investor of each economy has the same average degree of relative risk aversion.

determined by the regression. All of the EER baskets use arithmetic weighting rather than the geometric weighting discussed in Chinn (2006).

The study presents findings for each semiannual date that *The Economist* has published the adjusted Big Mac index, which was introduced in July 2011 as a presumed better way to measure intrinsic FX value than the original (raw) Big Mac index. For each date, we construct the EER baskets using 37 different currencies. We use *The Economist's* GDPp estimates for July 2015 and January 2016. These estimates are practically identical, with the July 2015 estimates being exactly identical to the 2014 International Monetary Fund (IMF) estimates. Because of this relationship, and because *The Economist's* earlier GDPp estimates are unavailable, we use the IMF 2010 estimates for July 2011 and January 2012, the IMF 2011 estimates for July 2012 and January 2013, and so forth.[3] IMF estimates of GDPt are used in the same way. The IMF's GDP estimates are for nominal GDP, using current prices and market FX rates to convert from local currency to US dollars.

For the raw Big Mac method, the three different EER basket compositions result in substantial differences in the misvaluation estimates for any given currency. In contrast, for the adjusted Big Mac method, the misvaluation estimates of the four different EER basket compositions are relatively consistent. This finding supports the notion that the adjusted Big Mac method is an improved model of FX valuation versus the raw Big Mac (PPP) method.

Although the general findings apply for any given currency, we feature the results for three currencies: the US dollar, the euro, and the Chinese yuan. We find that the US dollar has effectively

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[3] The only exception is the Eurozone GDP, which is not provided by the IMF, and for which we use World Bank estimates. (*The Economist's* Eurozone GDP estimate seems to be constructed from the individual estimates of Eurozone countries.) We also investigated averaging the most recent two years' IMF estimates for the January dates; the results of the study are not materially affected. Note also: only 36 currencies are used for January 2012, because the data for Peru are missing in *The Economist's* downloadable data spreadsheet.

been less overvalued recently for the adjusted Big Mac index than for the raw Big Mac index. The yuan has been effectively less undervalued for the adjusted Big Mac index than for the raw Big Mac index, and was slightly above fair value for the adjusted Big Mac index in January 2016.

The Raw Big Mac Index

The Economist's original Big Mac index, published semiannually since 1986, views a Big Mac as a composite of traded and nontraded goods. Despite limitations and warnings by *The Economist* to "take it with a grain of salt", the Big Mac index has appealing simplicity and overcomes the problem that CPI baskets are usually different across countries. As a result, the Big Mac index has a history of popularity with practitioners, instructors, and researchers.[4]

The original Big Mac index, now usually called the raw Big Mac index, uses domestic and foreign local Big Mac prices to estimate traditional (absolute) PPP intrinsic FX rates. Let P be the domestic Big Mac price in the domestic currency and $P*$ be the foreign Big Mac price in the foreign currency; the raw Big Mac intrinsic FX rate (in direct terms of the domestic currency) is:

$$X_{Raw} = P/P* \tag{1}$$

For example, for the US dollar as the domestic (reference) currency and the euro as the foreign currency, P = \$4.79 and $P*$ = €3.70 in July 2015. The raw Big Mac intrinsic FX rate, expressed in US dollars per euro, was thus \$4.79/€3.70 = 1.295 \$/€.

A difference between actual and intrinsic FX rates indicates a currency misvaluation. The percentage misvaluation of the foreign currency versus the reference currency in the raw Big Mac

[4] Clements, Lan, and Seah (2010, 2012) provide a review of the Big Mac literature. For examples of research involving the original Big Mac index, see Annaert and De Ceuster (1997), Clements and Lan (2010), Click (1996), Pakko and Pollard (1996, 2003), Cumby (1997), *The Economist* (2006, 2011), Landry (2008), Ong (1997, 2003), Lutz (2002), Parsley and Wei (2007), Rogoff (1996), Taylor and Taylor (2004), and Yang (2004).

approach is m_{Raw} = X/X_{Raw} – 1, where X is the actual FX rate in direct terms of the reference currency. Equivalently, using equation (1), m_{Raw} = $(X \bullet P*)/P$ – 1, where $X \bullet P*$ is the actual foreign Big Mac price expressed in the reference currency.

The euro's bilateral misvaluation versus the US dollar may thus be expressed in terms of the ratio of the Eurozone Big Mac price given in US dollars to the local US Big Mac price. For example, letting P_E and P_U denote the Eurozone and US Big Mac prices, expressed in US dollars, the percentage misvaluation of the euro relative to the US dollar in the raw Big Mac approach is shown in equation (2):

$$m_{Raw}^{\$/€} = P_E/P_U - 1 \quad (2)$$

For example, in July 2015 the raw Big Mac estimate of the euro's misvaluation versus the US dollar was –15.4% (as shown in Table 1), indicating a 15.4% undervaluation of the euro versus the US dollar.

For the July 2015 raw Big Mac analysis, Table 1 shows the individual percentage bilateral misvaluation estimates versus (1) the US dollar, (2) the euro, and (3) the Chinese yuan, as reported by *The Economist*, for 37 currencies (including a zero misvaluation for each currency versus itself.)

Table 1: Misvaluation of Currencies vs the US Dollar, Euro, and Yuan Raw Big Mac Method (July 2015)

ECONOMY	$m^{\$/C}_{Raw}$ (%)	$m^{€/C}_{Raw}$ (%)	$m^{¥/C}_{Raw}$ (%)	GDPp ($)	GDPt ($bn)
Argentina	–36.0	–24.4	12.0	12,873	540
Australia	–18.1	–3.2	43.3	61,219	1,444
Brazil	–10.6	5.6	56.4	11,604	2,353
Britain	–5.8	11.3	64.8	45,653	2,945
Canada	–5.3	11.9	65.7	50,398	1,789
Chile	–31.8	–19.4	19.4	14,477	258
China	–42.8	–32.5	0.0	7,589	10,380
Colombia	–39.1	–28.1	6.5	8,076	385
Czech Republic	–40.8	–30.1	3.5	19,563	206
Denmark	6.0	25.3	85.5	60,564	341
Egypt	–54.9	–46.7	–21.0	3,304	286
Eurozone	–15.4	0.0	48.1	40,028	13,410
Hong Kong	–48.3	–38.9	-9.5	39,871	290
Hungary	–33.6	–21.5	16.2	13,881	137
India	–61.7	–54.8	–33.1	1,627	2,050
Indonesia	–52.3	–43.6	–16.5	3,534	889
Israel	–3.3	14.3	69.2	36,991	304
Japan	–37.7	–26.4	9.0	36,332	4,616
Malaysia	–58.0	–50.4	–26.6	10,804	327
Mexico	–35.0	–23.2	13.7	10,715	1,283
New Zealand	–18.4	–3.6	42.8	43,837	198
Norway	17.9	39.4	106.3	97,013	500
Pakistan	–28.2	–15.1	25.7	1,343	250
Peru	–34.4	–22.5	14.7	6,458	203
Philippines	–24.7	–11.1	31.7	2,865	285
Poland	–46.9	–37.2	–7.1	14,379	547
Russia	–60.7	–53.5	–31.2	12,926	1,857
Saudi Arabia	–33.2	–21.1	16.9	24,454	752
Singapore	–28.2	–15.2	25.6	56,319	308
South Africa	–56.3	–48.3	–23.5	6,483	350
Korea	–21.5	–7.2	37.3	28,101	1,417
Sweden	7.0	26.5	87.3	58,491	570
Switzerland	42.4	68.3	149.2	87,475	712
Taiwan	–46.8	–37.2	–7.0	22,598	530
Thailand	–33.9	–21.8	15.7	5,445	374
Turkey	–19.1	–4.4	41.5	10,482	806
United States	0.0	18.2	75.0	54,597	17,419
Equally-Weighted AVG	**–27.3**	**–14.1**	**27.2**		
GDPp-Weighted AVG	**–11.0**	**5.1**	**55.7**		
GDPt-Weighted AVG	**–20.8**	**–6.4**	**38.6**		

Table 1 shows misvaluation percentages for the raw Big Mac method for 37 currencies versus the US dollar, the euro, and the Chinese yuan. $m^{\$/C}_{Raw}$ = currency C's percentage misvaluation versus the US dollar; $m^{€/C}_{Raw}$ = currency C's percentage misvaluation versus the euro; $m^{¥/C}_{Raw}$ = currency C's percentage misvaluation versus the yuan; GDPp ($) = estimated per capita GDP in US dollars. GDPt ($bn) = estimated total GDP in billions of US dollars. Data sources: *The Economist's* downloadable data spreadsheet and the International Monetary Fund (IMF).

Effective Exchange Rates and the Raw Big Mac Method

Estimates of bilateral misvaluation between individual currencies are useful, but we also are interested in estimates of a currency's effective misvaluation, relative to a basket of other currencies in general. Based on the raw Big Mac index and three types of EER baskets of 37 currencies, this section reports effective misvaluation estimates over time for the US dollar, the euro, and the Chinese yuan.

The last rows of Table 1 indicate the following results for the raw Big Mac index in July 2015: (1) All three EER baskets were undervalued versus the US dollar; by 27.3% for the equally-weighted basket, by 11% for the GDPp-weighted basket, and by 20.8% for the GDPt-weighted basket. (2) Versus the euro, the equally-weighted basket was undervalued by 14.1%, the GDPp-weighted basket was overvalued by 5.1%, and the GDPt-weighted basket was undervalued by 6.4%. (3) All three EER baskets were overvalued versus the yuan; by 27.2% for the equally-weighted basket, by 55.7% for the GDPp-weighted basket, and by 38.6% for the GDPt-weighted basket.

For each given currency, the misvaluation estimates of the different EER basket types are substantially different. The estimates for the GDPp-weighted basket being the highest, reflecting the tendency for high-GDPp economies to have overvalued currencies, and low-GDPp economies to have undervalued currencies, given the raw Big Mac (PPP) standard of FX valuation. So the GDPp-weighted basket has a higher FX value than the equally-weighted basket, versus a given currency. This tendency is much less pronounced with weighting by total GDP, particularly given

China's very low GDPp and high GDPt, so the misvaluation estimates for the GDPt-weighted basket are between those of the other two baskets.[5]

To reciprocate a basket's misvaluation versus a currency to the misvaluation of the currency versus the basket, we make use of the relationship between the percentage misvaluation of two currencies, C and D, versus each other. The percentage misvaluation of currency C versus currency D, denoted $m^{\mathrm{D/C}}$, is equal to $1/(1 + m^{\mathrm{C/D}}) - 1$, where $m^{\mathrm{C/D}}$ is the percentage misvaluation of currency D versus currency C. For example, if the euro is undervalued versus the US dollar by 15.4% ($m^{\$/€} = -0.154$), as shown in Table 1, the US dollar's misvaluation versus the euro is $1/(1 - 0.154) - 1 = 0.182$, or an 18.2% overvaluation, as shown in Table 1.

Applying this idea, the misvaluation of the US dollar versus the equally-weighted basket, denoted $m^{EQ/\$}$, is equal to $1/(1 + m^{\$/EQ}) - 1$. Thus, given the equally-weighted basket's estimated misvaluation versus the US dollar for the raw Big Mac index in July 2015, $m_{Raw}^{\$/EQ} = -27.3\%$, the US dollar's estimated misvaluation versus the equally-weighted basket was $m_{Raw}^{EQ/\$} = 1/(1 - 0.273) - 1 = 0.375$, or 37.5%. Similar calculations show that the US dollar was overvalued by 12.4% versus the GDPp-weighted basket and by 26.2% versus the GDPt-weighted basket. These results for July 2015 are highlighted in Table 2 along with the analogous results for the euro and the yuan.

Table 2 summarizes the effective misvaluation estimates for the semiannual raw Big Mac analyses from July 2011 through January 2016. Generally, the differences between the effective misvaluation estimates for the three different baskets tend to be substantial. Every misvaluation

[5] For the US dollar for example, the economies with the 10 largest undervaluation estimates have a lower overall weight (12.0%) than using an equal weighting (27.0%). (These countries are India, Poland, Korea, Singapore, Egypt, Indonesia, Hong Kong, Philippines, Taiwan and China.) These countries tend to have below-average GDPp, $12,311 versus $27,632 for the 37 countries. Using GDPt-weighting however, these countries represent an overall weight of 24.5%, close to that for the equal-weighting. Their average of GDP total ($1,751 bn) is much closer to the average over the 37 countries ($1,927 bn).

estimate for the GDPp-weighted basket is substantially lower than the corresponding equally-weighted estimate. The misvaluation estimates for the GDPt-weighted basket are closer to those of the equally-weighted basket but still substantially different. The reasons for these patterns are explained above.

The raw Big Mac method indicates that over time, the US dollar became effectively stronger versus all three EER baskets. The equally-weighted and GDPt-weighted baskets show the US dollar was overvalued after January 2011, but the GDPp-weighted basket shows the US dollar was undervalued until it became overvalued in January 2015. The euro showed no clear trend over time; the euro tended to be overvalued for the equally-weighted and GDPt-weighted baskets and slightly undervalued for the GDPp-weighted basket. The yuan was undervalued throughout the period for all three EER basket types and became gradually less undervalued throughout the period.

Note that the misvaluation estimates of two given currencies versus the same basket must be consistent with the bilateral misvaluation estimate between the two given currencies. For example, given that the US dollar was overvalued by 26.2% versus the GDPt-weighted basket, and that the euro was overvalued by 6.8% versus the same basket, it follows that the US dollar's misvaluation versus the euro was $(1 + 0.262) \div (1 + 0.068) - 1 = 0.182$, or 18.2%, consistent with the highlighted estimate in Table 1. This consistency condition dictates that the dispersion of the effective misvaluation estimates for other given currencies adhere to the same pattern across the different EER basket types.

Table 2: Effective Misvaluation Estimates for the US Dollar, Euro, and Yuan: Raw Big Mac Method (July 2011 – January 2016)

US DOLLAR			
DATE	$m_{Raw}^{EQ/\$}$ (%)	$m_{Raw}^{GDPp/\$}$ (%)	$m_{Raw}^{GDPt/\$}$ (%)
Jul-11	3.3	–19.1	–0.1
Jan-12	14.7	–7.7	7.1
Jul-12	19.1	–3.6	11.3
Jan-13	12.8	–9.5	7.3
Jul-13	21.6	–2.0	15.3
Jan-14	22.8	–2.5	14.8
Jul-14	22.7	–1.2	14.3
Jan-15	33.5	7.4	23.1
Jul-15	37.5	12.4	26.2
Jan-16	52.5	22.4	33.0

EURO			
DATE	$m_{Raw}^{EQ/€}$ (%)	$m_{Raw}^{GDPp/€}$ (%)	$m_{Raw}^{GDPt/€}$ (%)
Jul-11	25.2	–1.9	21.1
Jan-12	21.0	–2.6	13.1
Jul-12	19.6	–3.3	11.7
Jan-13	26.0	1.1	19.9
Jul-13	24.3	0.2	17.9
Jan-14	31.8	4.6	23.2
Jul-14	26.7	2.0	18.1
Jan-15	18.8	–4.4	9.6
Jul-15	16.4	–4.9	6.8
Jan-16	23.7	–0.7	7.9

YUAN			
DATE	$m_{Raw}^{EQ/¥}$ (%)	$m_{Raw}^{GDPp/¥}$ (%)	$m_{Raw}^{GDPt/¥}$ (%)
Jul-11	–42.3	–54.8	–44.1
Jan-12	–33.4	–46.4	–37.8
Jul-12	–32.6	–45.5	–37.0
Jan-13	–33.6	–46.7	–36.8
Jul-13	–30.4	–43.9	–34.0
Jan-14	–27.1	–42.2	–31.9
Jul-14	–30.3	–43.8	–35.0
Jan-15	–22.8	–37.9	–28.8
Jul-15	–21.4	–35.8	–27.9
Jan-16	–17.0	–33.4	–27.6

Table 2 shows misvaluation estimates for the raw Big Mac method for the US dollar, the euro, and the yuan versus equally-weighted, GDPp-weighted, and GDPt-weighted EER baskets of 37 currencies. Data sources: *The Economist's* downloadable data spreadsheet and International Monetary Fund (IMF).

The Adjusted Big Mac Method

The Economist's adjusted Big Mac method involves estimating a cross-sectional "line of best fit" between Big Mac prices and per capita GDP estimates, measured in a reference currency:[6]

$$\hat{P} = \alpha + \beta \cdot GDPp \tag{3}$$

where $\hat{P}$ is the predicted Big Mac price, expressed in the reference currency, α is the intercept, and β is the slope coefficient of the regression line.

The adjusted Big Mac method is an offshoot (without logarithms) of the "Penn effect", which refers to the positive cross-sectional empirical association between traditional PPP deviations and per capita GDPs.[7] This empirical approach has been frequently used in FX valuation by research economists like Rogoff (1996), Frankel (2006), Xu (2009), and Cheung and Fujii (2014). As a model of FX valuation, the Penn effect assumes that an individual currency may deviate from the estimated relationship, perhaps due to speculation by FX traders, and this deviation is a misvaluation; however, currencies are on average correctly valued per the estimated line. Note that the estimated line tends to vary from one period to the next, because of changes in PPP deviations and GDP estimates.

The most prominent theoretical explanation (and often used as a synonym) for the Penn effect is the Balassa-Samuelson effect (Balassa, 1964; Samuelson, 1964). The Balassa-Samuelson effect is based on the tendency for a high income economy to have higher nontraded goods prices,

[6] We use the term "line of best fit" to be consistent with *The Economist's* language; for all purposes it refers to a simple OLS regression.

[7] The name "Penn effect" is credited to Samuelson (1994) and refers to the research home of pioneering empirical studies of price level and GDP, the University of Pennsylvania. See Kravis and Lipsey (1983, 1987), Kravis, Heston, and Summers (1978), and Summers and Heston (1991).

relative to traded goods prices, than a low income economy. Therefore, even if FX rates align with traded goods prices according to the international law of one price, the traditional PPP condition does not hold using composite price indexes that include both traded and nontraded goods. The currency of a high (low) income economy tends to be overvalued (undervalued), relative to traditional PPP intrinsic FX value. Unfortunately, economists have been unable to derive a theoretical relationship between PPP deviations and GDP (Asea and Corden, 1994; Asea and Mendoza, 1994), so the empirical Penn effect serves as the model of FX valuation.

The Economist estimates a "line of best fit" with data for 49 economies, including 12 individual Eurozone countries and the Eurozone aggregate. However, for consistency with the EER basket construction, we exclude the individual Eurozone countries in our adjusted Big Mac analysis, and thus use only 37 economies/currencies to estimate a "line-of-best-fit". The results are only slightly different from those reported by *The Economist*. (The r-squared with 37 economies is 0.627 versus 0.622 with 49 economies.)

A currency's residual is the actual Big Mac price minus the predicted Big Mac price (in the reference currency), $P - \hat{P}$, and the relative residual is the residual divided by the predicted Big Mac price, $(P - \hat{P})/\hat{P}$. For example, the euro's relative residual is given by equation (4):

$$m_{Adj}^{RR/€} = (P_E - \hat{P}_E)/\hat{P}_E = P_E/\hat{P}_E - 1 \qquad (4)$$

In the adjusted Big Mac method, a currency's relative residual measures the currency's percentage misvaluation relative to the "line of best fit" and thus to an EER basket with weights implicitly determined by the regression. Unfortunately, *The Economist* does not report these effective misvaluation estimates.

For the US dollar reference currency, the estimated 37-currency "line of best fit" for July 2015 had an intercept of 2.493 and a slope coefficient of 0.0359, where *GDPp* is in 000s of US dollars. The relative residual estimates of effective misvaluation versus the 37-currency "line-of-best-fit" basket for July 2015 are shown in the first data column of Table 3. For example, the Eurozone's estimated GDPp (in US dollars) was $40,028, so the predicted Eurozone Big Mac price (in US dollars), $\hat{P}_E$, was $3.93. Given the price of a Eurozone Big Mac in US dollars in July 2015, $4.054, the euro's relative residual was $4.054/$3.93 – 1 = 0.032, or a 3.2% effective overvaluation versus the regression line basket, as highlighted in Table 3.

The adjusted Big Mac method also finds a residual for the reference currency. For example, the US dollar's relative residual is $m_{Adj}^{RR/\$} = (P_U - \hat{P}_U)/\hat{P}_U = P_U/\hat{P}_U - 1$, where $\hat{P}_U$ is found using equation (3) and the US GDP. Given the US dollar as the reference currency, the actual US Big Mac price of $4.79, and the predicted US Big Mac price of $4.45 (determined by equation (3) using the US GDPp), the US dollar's adjusted Big Mac relative residual in July 2015 was $4.79/$4.45 – 1 = 0.076, or a 7.6% effective overvaluation versus the regression line basket, as highlighted in Table 3.[8]

The adjusted Big Mac method calculates the estimated bilateral misvaluation between two currencies using the relative residual estimates of both currencies. For example, the adjusted Big Mac estimate of the euro's misvaluation versus the US dollar, $m_{Adj}^{\$/€}$, uses the relative residual estimates for the euro and the US dollar, and equation (5):

$$m_{Adj}^{\$/€} = (1 + m_{Adj}^{RR/€})/(1 + m_{Adj}^{RR/\$}) - 1 = (P_E/\hat{P}_E)/(P_U/\hat{P}_U) - 1 \qquad (5)$$

[8] Note that a currency's residual misvaluation estimate in the adjusted Big Mac method is the same from the perspective of any reference currency, including itself.

In July 2015, the adjusted Big Mac estimate of the euro's bilateral misvaluation versus the US dollar was 1.032/1.076 – 1 = –0.041, or –4.1% (as highlighted in Table 3), which is substantially different from the raw Big Mac estimate of –15.4%.

The logic for equation (5) is as follows: Given the euro's estimated overvaluation by 3.2% versus the regression basket, and the US dollar's estimated overvaluation by 7.6% versus the regression basket, it follows that the euro's estimated bilateral misvaluation versus the US dollar is –4.1%.[9] This logic is the same as the consistency condition noted above, and an analogous version of equation (5) holds for each of the other EER basket types of this study, for either the adjusted or raw Big Mac methods.

In addition to the relative residual estimates of effective misvaluation in the first data column, Table 3 shows the percentage bilateral misvaluation estimates versus the US dollar, the euro, and the yuan (including a zero misvaluation for each currency versus itself). The last rows of Table 3 show the misvaluation estimates of the other three EER baskets versus each of the three featured currencies.

[9] This logic may be easier to see if we substitute the British pound for the basket. That is, if the euro were overvalued by 3.2% versus the British pound, and the US dollar were overvalued by 7.6% versus the British pound, it is intuitive (and easy to show) that the euro would be undervalued versus the US dollar by 4.1%.

Table 3: Regression Residuals and Bilateral Misvaluation Estimates versus the US Dollar, Euro, and Yuan: Adjusted Big Mac Method (July 2015)

ECONOMY	$m_{Adj}^{RR/C}$ (%)	$m_{Adj}^{\$/C}$ (%)	$m_{Adj}^{€/C}$ (%)	$m_{Adj}^{¥/C}$ (%)	GDP ($)
Argentina	3.8	–3.6	0.5	4.8	12,873
Australia	–16.3	–22.3	–18.9	–15.5	61,219
Brazil	47.2	36.8	42.7	48.7	11,604
Britain	9.3	1.5	5.9	10.4	45,653
Canada	5.5	–2.0	2.2	6.5	50,398
Chile	8.5	0.8	5.2	9.6	14,477
China	–1.0	–8.0	–4.1	0.0	7,589
Colombia	4.8	–2.6	1.6	5.9	8,076
Czech Republic	–11.3	–17.6	–14.0	–10.4	19,563
Denmark	8.9	1.2	5.5	10.0	60,564
Egypt	–17.2	–23.1	–19.8	–16.4	3,304
Eurozone	3.2	–4.1	0.0	4.2	40,028
Hong Kong	–36.8	–41.3	–38.8	–36.2	39,871
Hungary	6.4	–1.2	3.1	7.4	13,881
India	–28.2	–33.3	–30.4	–27.5	1,627
Indonesia	–12.7	–18.9	–15.5	–11.9	3,534
Israel	21.3	12.7	17.5	22.5	36,991
Japan	–21.3	–26.9	–23.8	–20.6	36,332
Malaysia	–30.2	–35.2	–32.4	–29.5	10,804
Mexico	8.2	0.5	4.9	9.3	10,715
New Zealand	–3.8	–10.6	–6.8	–2.9	43,837
Norway	–5.4	–12.1	–8.3	–4.5	97,013
Pakistan	35.5	25.8	31.2	36.8	1,343
Peru	15.3	7.1	11.7	16.4	6,458
Philippines	38.9	29.1	34.6	40.3	2,865
Poland	–15.4	–21.4	–18.1	–14.6	14,379
Russia	–36.3	–40.8	–38.3	–35.7	12,926
Saudi Arabia	–5.0	–11.8	–8.0	–4.1	24,454
Singapore	–23.8	–29.2	–26.1	–23.0	56,319
South Africa	–23.2	-28.6	–25.5	–22.4	6,483
Korea	7.4	–0.2	4.1	8.5	28,101
Sweden	11.7	3.8	8.2	12.8	58,491
Switzerland	21.2	12.6	17.4	22.4	87,475
Taiwan	–22.9	–28.4	–25.3	–22.1	22,598
Thailand	17.9	9.5	14.2	19.0	5,445
Turkey	35.1	25.5	30.9	36.4	10,482
United States	7.6	0.0	4.3	8.7	54,597
Equally-Weighted AVG		**–6.9**	**–2.9**	**1.2**	
GDPp-Weighted AVG		**–7.5**	**–3.6**	**0.5**	
GDPt-Weighted AVG		**–5.8**	**–1.7**	**2.4**	

Table 3 shows the regression residual misvaluation percentages and the estimated bilateral misvaluation percentages for 37 currencies versus the US dollar, the euro, and the Chinese yuan, given the adjusted Big Mac approach. $m_{Adj}^{RR/C}$ = currency C's regression residual misvaluation percentage; $m_{Adj}^{\$/C}$ = currency C's percentage misvaluation versus the US dollar; $m_{Adj}^{€/C}$ = currency C's percentage misvaluation versus the euro; $m_{Adj}^{¥/C}$ = currency C's percentage misvaluation versus the yuan; GDPp ($) = estimated per capita GDP in US dollars.

The Adjusted Big Mac Method and Effective Exchange Rates

For the 37-currency adjusted Big Mac analysis for July 2015, the US dollar was overvalued versus all four EER baskets: by 7.6% versus the regression basket; by 7.4% versus the equally-weighted basket; by 8.1% versus the GDPp-weighted basket; and by 6.1% versus the GDPt-weighted basket. The euro was overvalued by 3.2%, 3.0%, 3.7%, and 1.8%, and the yuan was undervalued by 1%, 1.2%, 0.5%, and 2.4%, versus the four baskets respectively. These results are highlighted in Table 4. Other than the relative residuals, the effective misvaluation estimates for the three given currencies were found by converting the basket misvaluation estimates versus the given currencies (shown in the last rows of Table 3), as before.

Table 4 summarizes all four types of effective misvaluation estimates for the semiannual 37-currency adjusted Big Mac analyses from July 2011 to January 2016. For all dates, all three currency's misvaluation estimates are close for (1) the relative regression residual, (2) the equally-weighted basket, and GDPp-weighted basket. Because the adjusted Big Mac analysis adjusts for GDPp in the regression, the GDPp basket weights are "sort of random" and have much the same impact as equal weights. Therefore, a given currency's effective misvaluation estimate versus the GDPp-weighted basket tends to be close to the estimates of the relative regression residual and the equally-weighted basket. The misvaluation estimates for the GDPt-weighted basket deviate a bit from the "grouping" of the other three estimates on some dates, but by no more than around 700 basis points.

Table 4: Effective Misvaluation Estimates for US Dollar, Euro, and Yuan Adjusted Big Mac Method (July 2011 – January 2016)

US DOLLAR				
DATE	$m_{Adj}^{RR/\$}$ (%)	$m_{Adj}^{EQ/\$}$ (%)	$m_{Adj}^{GDPp/\$}$ (%)	$m_{Adj}^{GDPt/\$}$ (%)
Jul-11	–22.6	–22.9	–22.0	–17.2
Jan-12	–11.4	–11.6	–10.8	–8.9
Jul-12	–3.2	–3.5	–2.5	–2.8
Jan-13	–9.3	–9.6	–8.6	–6.9
Jul-13	–3.7	–3.9	–3.2	–1.9
Jan-14	–4.4	–4.6	–3.8	–3.6
Jul-14	–3.9	–4.1	–3.4	–4.1
Jan-15	4.5	4.2	5.1	3.2
Jul-15	7.6	7.4	8.1	6.1
Jan-16	16.9	16.8	17.2	10.5

EURO				
DATE	$m_{Adj}^{RR/€}$ (%)	$m_{Adj}^{EQ/€}$ (%)	$m_{Adj}^{GDPp/€}$ (%)	$m_{Adj}^{GDPt/€}$ (%)
Jul-11	5.7	5.3	6.5	13.2
Jan-12	4.2	3.9	4.8	7.1
Jul-12	5.6	5.3	6.3	6.1
Jan-13	10.3	9.9	11.1	13.1
Jul-13	11.8	11.5	12.4	13.9
Jan-14	17.5	17.2	18.2	18.4
Jul-14	12.7	12.4	13.2	12.4
Jan-15	5.6	5.3	6.2	4.3
Jul-15	3.2	3.0	3.7	1.8
Jan-16	8.4	8.3	8.6	2.5

YUAN				
DATE	$m_{Adj}^{RR/¥}$ (%)	$m_{Adj}^{EQ/¥}$ (%)	$m_{Adj}^{GDPp/¥}$ (%)	$m_{Adj}^{GDPt/¥}$ (%)
Jul-11	–19.8	–20.1	–19.1	–14.1
Jan-12	–11.7	–11.9	–11.2	–9.2
Jul-12	–11.5	–11.8	–10.9	–11.1
Jan-13	–12.7	–13.0	–12.0	–10.4
Jul-13	–9.7	–9.9	–9.2	–8.0
Jan-14	–3.1	–3.3	–2.5	–2.3
Jul-14	–9.9	–10.0	–9.4	–10.1
Jan-15	–0.1	–0.3	0.5	–1.3
Jul-15	–1.0	–1.2	–0.5	–2.4
Jan-16	7.4	7.3	7.6	1.5

Table 4 shows percentage estimates of effective misvaluation for the US dollar, the euro, and the yuan, given the adjusted Big Mac method, versus: (1) the regression residual EER basket ($m_{Adj}^{RR/C}$); (2) the equally-weighted EER basket ($m_{Adj}^{EQ/C}$); (3) the GDPp-weighted EER basket ($m_{Adj}^{GDPp/C}$); and (4) the GDPt-weighted EER basket ($m_{Adj}^{GDPt/C}$). Data sources: *The Economist's* downloadable data spreadsheet and the International Monetary Fund (IMF).

Although we featured only three currencies, the effective misvaluation estimates for *all* currencies adhere to the same observed pattern of consistency across the different basket types. We made this point earlier, but equation (5) helps see the reasons more clearly: (1) The bilateral currency misvaluation estimates are the same, regardless of the basket type; and (2) The effective misvaluation estimates for a given basket type are versus the <u>same</u> basket, regardless of currency perspective, so a condition like equation (5) holds for each of the basket types.[10] This logic does not apply if the currency perspective affects the basket weights, such as if trade weights are used.

The relative consistency of the adjusted Big Mac method's effective misvaluation estimates across all four basket types is in contrast to the large differences observed in the effective misvaluation estimates for the raw Big Mac method. This finding supports the superiority of the adjusted Big Mac method over the raw Big Mac method. Moreover, for those who place stock in *The Economist's* adjusted Big Mac approach, the relative consistency across the basket types suggests that one can get a reasonable approximation of a given currency's effective misvaluation by simply averaging the bilateral misvaluation estimates reported by *The Economist* for the adjusted Big Mac method--without using GDP data.

The adjusted Big Mac estimates of effective misvaluation in Table 4 indicate the following FX trends over time: The US dollar was undervalued until January 2015 and was overvalued after that time. Also, the US dollar has been effectively less overvalued recently for the adjusted Big Mac index than for the raw Big Mac index. The euro was effectively overvalued throughout the entire sample period, reaching the maximum overvaluation of around 17.5 percent in January

[10] For example, for July 2015, $m_{Adj}^{\$/€}$ = –4.1%, $m_{Adj}^{RR/\$}$ = 7.6%, and $m_{Adj}^{RR/€}$= 3.2%, as noted earlier and shown in Table 3. Given a condition like equation (5) for the equally-weighted basket, and given $m_{Adj}^{\$/€}$ = –4.1% and $m_{Adj}^{EQ/\$}$ = 7.4%, it follows that $m_{Adj}^{EQ/€}$= (1 – 0.041)(1 + 0.074) – 1 = 0.030, or 3.0%, as shown in Table 4. That is, $m_{Adj}^{EQ/€}$ is close to $m_{Adj}^{RR/\$}$ because $m_{Adj}^{EQ/\$}$ is close to $m_{Adj}^{RR/\$}$.

2014. The yuan has been less effectively undervalued for the adjusted Big Mac index than for the raw Big Mac index, and the undervaluation gradually diminished until becoming a slight overvaluation in January 2016.

Conclusion

This study reports an investigation of currency misvaluation estimates versus effective exchange rate (EER) baskets for *The Economist's* two Big Mac approaches to intrinsic currency value. The original (raw) Big Mac method is based on traditional purchasing power parity, whereas the adjusted Big Mac method uses a regression equation that links Big Mac prices and per capita GDPs. The analysis includes EER baskets where the currency positions are (1) equally-weighted; (2) weighted by per capita GDP; and (3) weighted by total GDP. The adjusted Big Mac method provides a fourth EER basket represented by the regression line.

A given currency's effective misvaluation estimates are relatively consistent across the various EER basket compositions for the adjusted Big Mac method but not for the raw Big Mac method. These contrasting findings support the notion that the adjusted Big Mac method provides an improved model of currency valuation versus the raw Big Mac method.

The general findings pertain for any given currency, but we highlight the effective misvaluation estimates for the US dollar, the euro, and the Chinese yuan. From July 2011 until January 2016, for example, the yuan was effectively less undervalued for the adjusted Big Mac method than for the raw Big Mac method, and the yuan's undervaluation for the adjusted Big Mac method gradually diminished until becoming a slight overvaluation by January 2016.

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