THE UNIVERSITY OF WESTERN AUSTRALIA

ECONOMICS

SIMPLIFYING THE BIG MAC INDEX

by

Kenneth W. Clements

and

Jiawei Si

Business School
University of Western Australia

DISCUSSION PAPER 16.10

April 2016

SIMPLIFYING THE BIG MAC INDEX*

by

Kenneth W. Clements and Jiawei Si
Business School
The University of Western Australia

DISCUSSION PAPER 16.10

Abstract

The Economist magazine recently introduced a major innovation to its famous Big Mac Index of currency values by adjusting for differences in incomes of countries. A recent paper (O'Brien and Ruiz de Vargas, forthcoming, OR) explains clearly the workings of the new index, something overlooked by The Economist. The current paper draws on OR to suggest an alternative formulation that is attractive in its simplicity.

* For helpful comments, we thank Isabela Banea and Haiyan Liu. This research was supported in part by BHP Billiton and the ARC. All errors are our own.

1. Introduction

The Big Mac Index (BMI), published semi-annually by The Economist for more than quarter of a century, compares Big Mac prices across countries to determine a currency's over/undervaluation. Recently, the magazine introduced the "adjusted BMI", which accounts for prices being cheaper in poorer countries than richer ones. This is done by expressing Big Mac prices as a function of GDP per capita and using the difference between the actual and predicted prices to compute the misvaluation. However, details of these calculations are at best scarce, which has led to a lack of understanding and perhaps even confusion regarding the interpretation of the new index. In a recent paper, O'Brien and Ruiz de Vargas (forthcoming, hereafter referred to as OR) have carried out a very valuable service by clarifying this matter. The authors clearly show that the methodology described by The Economist is the overall misvaluation of a currency against a "basket" of currencies, whilst confusingly, the reported adjusted BMI is a bilateral misvaluation relative to the base currency, the $US. After an additional adjustment involving the $US misvaluation, OR show how to convert the overall misvaluation to the required bilateral counterpart.

The objective of this paper is to use the multilateral/bilateral distinction of OR to show how the adjusted BMI can be reformulated and simplified. This involves a change in the functional form of the pricing equation from linear to logarithmic, which leads to a simplification of the misvaluation calculation and its interpretation. It should be clear that the simplified index is based on the adjusted BMI, as clarified by OR. Thus, while the misvaluations from the two approaches are not identical, they are broadly similar in most cases.

In what follows, we first briefly describe ORs' interpretation of the adjusted BMI and illustrate its workings with the valuation of the euro in terms of the dollar. Then, in Section 3, we introduce our alternative formulation, again illustrated with the euro, as well as for a number of other currencies. Section 4 deals with a comparison of three indexes of currency misvaluation -- the original BMI, the adjusted and simplified versions. Concluding comments are given in Section 5.

2. Overall vs Bilateral Misvaluation

This section summarises the contribution of OR in understanding the adjusted BMI, specifically the distinction between a currency's overall and bilateral misvaluation.

Let p_c be the price of a Big Mac in country c and y_c its GDP per capita, both expressed in the base currency. The Economist (online) describes the relationship between these variables as a "line of best fit" according to

(1) $\quad p_c = \lambda + \phi y_c + \mu_c,$

where λ and ϕ are parameters and μ_c is the disturbance term for country c, which represents the deviation of the actual Big Mac price p_c from the predicted price $\hat{p}_c$, predicted on the basis of (1). Currency c is overvalued if the actual price exceeds predicted, that is, if $p_c > \hat{p}_c$. The proportionate overvaluation (the over valuation, $p_c - \hat{p}_c$, as a proportion on the predicted price, $\hat{p}_c$) is then

(2) $\quad m_c = \dfrac{p_c}{\hat{p}_c} - 1 = \dfrac{\mu_c}{\hat{p}_c} > 0.$

OR point out that this methodology is incomplete as equation (2) expresses c's overvaluation relative to the line of best fit, equation (1), or relative to a synthetic "basket" of all currencies underlying the regression. OR calls this the overall misvaluation. By contrast, The Economist's adjusted BMI is the bilateral misvaluation, which is calculated with the additional step below.

Denote the Big Mac price and GDP per capita in the base country by p^* and y^*, respectively. Suppose pricing equation (1) also applies to this base country. Thus, the overall misvaluation of the base currency is $m^* = p^*/\hat{p}^* - 1$. The adjusted BMI gives the value of the currency in terms of the US dollar (the base), rather than a basket of currencies. To eliminate the role of the basket, the overall misvaluation of currency c is "crossed" with that of the base currency:

(3) $\quad \dfrac{1+m_c}{1+m^*} - 1 = \dfrac{p_c/\hat{p}_c}{p^*/\hat{p}^*} - 1.$

This is the bilateral misvaluation of country c's currency relative to the base country, the adjusted BMI.

To illustrate this distinction, we use the 49 countries in the July 2015 BMI data from The Economist (online) to estimate by ordinary least squares equation (1) with the US dollar as the base and GDP per capita, y_c, measured in terms of US$'000.[1] The estimated intercept and slope coefficients are $\hat{\lambda} = 2.522$ and $\hat{\phi} = 0.035,$ as given in row 3 and column 3 of Table

[1] See Appendix A1 for details of the data.

1.[2] Thus, in a country where GDP is \$10,000 higher, the Big Mac is predicted to cost $0.035 \times 10 = 35$ cents more than in the base country, which seems reasonable. Using Europe as "country" c, with the euro as its currency, and the US the base, the Big Mac prices are $p_c = \$4.05$ and $p^* = \$4.79,$ respectively (row 5 of Table 1). Applying equations (2) and (3), we obtain:

Misvaluation	Euro	US
Overall [eq.(2)]	3.55%	8.32%
Bilateral [eq.(3)]	-4.40%	0%

The Euro and US dollar are 3.55% and 8.32% overvalued against the "basket" of currencies. After applying the adjustment in equation (3), the bilateral misvaluation of the euro is –4.40%, that is, the currency is undervalued relative to the US dollar. Since the euro is less overvalued than the US dollar relative to the "basket" of currencies, against the dollar itself the currency is undervalued. Comparatively, the raw Big Mac Index is $\left[\left(4.05/4.79\right)-1\right]\times 100 = -15.37\%$, a 15.37% undervaluation of the euro against the US dollar (column 2, Table 1). Compared to the US, Big Macs are cheaper in Europe. In the adjusted BMI, this price difference is partially offset by Europeans being about 25% poorer than Americans. This is why the euro is less undervalued according to the adjusted index.

3. An Alternative Formulation

A country's exchange rate is the domestic-currency cost of a unit of foreign exchange; it is the relative price of two assets – foreign and domestic moneys. As this involves a ratio of comparison, a logarithmic formulation seems useful. Thus, the raw BMI could be reformulated as

(4) $$\log\left(\frac{p_c}{p^*}\right).$$

When $p_c/p^* > 1,\ \log\left(p_c/p^*\right) > 0,$ Big Macs are relatively expensive in country c and that country's currency is overvalued.[3]

Equation (1) is a linear relation between prices and GDP. Let that relation now be logarithmic for country c and the base country:

(5) $$\log p_c = \alpha + \beta \log y_c + \varepsilon_c, \quad \log p^* = \alpha + \beta \log y^* + \varepsilon^*,$$

[2] These estimates are identical to those of OR.
[3] Here and below, log denotes the natural logarithm.

where ε_c and ε^* are disturbances in country c and the base, respectively. Subtracting the second equation from the first gives the following expression for equation (4):

$$\begin{aligned} \log\left(\frac{p_c}{p^*}\right) &= \alpha + \beta \log y_c + \varepsilon_c - \left[\alpha + \beta \log y^* + \varepsilon^*\right] \\ &= \gamma + \beta \log\left(\frac{y_c}{y^*}\right) + \varepsilon_c, \end{aligned} \tag{6}$$

where $\gamma = -\varepsilon^*$. The overall proportionate misvaluation of the US dollar is $\exp(\varepsilon^*) - 1 = \exp(-\gamma) - 1 \approx -\gamma$, while $\exp(\varepsilon_c) - 1 \approx \varepsilon_c$ is that for the currency of country c, where the approximations hold if mispricing is not "too large". The bilateral proportionate misvaluation of currency c relative to the dollar is just $\exp(\varepsilon_c - \varepsilon^*) - 1 = \exp(\varepsilon_c + \gamma) - 1 \approx \varepsilon_c + \gamma$. From (6), $\varepsilon_c + \gamma = \log(p_c/p^*) - \beta \log(y_c/y^*)$, so proportionate bilateral mispricing can be expressed as

$$\left(\frac{p_c}{p^*}\right)\left(\frac{y^*}{y_c}\right)^{\beta} - 1 = e^{\varepsilon_c + \gamma} - 1 \approx \varepsilon_c + \gamma, \tag{7}$$

The percentage mispricing is thus $\left(e^{\varepsilon_c + \gamma} - 1\right) \times 100$.[4] We obtain the original BMI, $p_c/p^* - 1$, if $y_c = y^*$ (incomes are the same) or $\beta = 0$ (incomes do not affect prices).

Equation (7) is the reformulation of the adjusted BMI. This would seem to be somewhat simpler than the approach of the previous section. Equation (6) expresses the price difference directly in terms of the income differences. The slope coefficient β in that equation has a familiar interpretation as the elasticity of the price with respect to income, while the intercept γ is (approximately) the misvaluation of the base currency. There are two other convenient properties of this approach: (i) Misvaluation is symmetric in currencies. It follows from (6) and (7) that if c is mispriced relative to the dollar by $\left(e^{\varepsilon_c + \gamma} - 1\right) \times 100$ percent, then

[4] Note that equation (7) involves the departure of the observed currency value from the regression line, ε_c, the disturbance term in equation (6), and not its expected value. What if we were to use the expected value instead? If ε_c follows a normal distribution with a zero mean and variance σ^2, then e^{ε_c} is log-normal with mean $0.5\sigma^2$ and the expected value of equation (7) is

$$E\left[\left(\frac{p_c}{p^*}\right)\left(\frac{y^*}{y_c}\right)^{\beta}\right] - 1 = e^{\frac{1}{2}\sigma^2 + \gamma} - 1 \approx \frac{1}{2}\sigma^2 + \gamma.$$

As the right-hand side does on involve a country subscript, the misvaluation is now the same for each currency (and could be interpreted as reflecting the value of the base currency).

the dollar is mispriced relative to c by $\left(e^{-(\varepsilon_c+\gamma)}-1\right)\times 100$ percent. (ii) Changing the base country is straightforward. If relative to a common base, currencies c and d are misvalued by $\left(e^{\varepsilon_c+\gamma}-1\right)\times 100$ and $\left(e^{\varepsilon_d+\gamma}-1\right)\times 100,$ respectively, then c is misvalued in terms of d by $\left(e^{\varepsilon_c-\varepsilon_d}-1\right)\times 100.$[5]

Figure 1 is a scatter plot corresponding to equation (6) for the same 49 countries in July 2015 used in the previous section. As can be seen, the estimated income elasticity of prices is almost 0.2, implying that a 20% increase in income leads to prices being 4% higher, which is reasonable. The estimated intercept is $\hat{\gamma}=-0.1474,$ which is equal to $-\hat{\varepsilon}^{*}$. This means that the dollar is overvalued against all other currencies by about 15%. Column 4 of Table 1 refers to the simplified index and applies it to the euro. Using equation (7), the bilateral misvaluation of the euro relative to the dollar is -10.34%, which lies between the values for the raw and adjusted indexes (columns 2 and 3 of Table 1). As $\hat{\varepsilon}_c=0.0382$ and $\hat{\gamma}=-0.1474$, $\hat{\gamma}+\hat{\varepsilon}_c=-0.1092,$ or -10.92%, which is close to the misvaluation of -10.34% in the previous sentence; evidently, the approximation in (7) holds reasonably closely.

4. Comparing the Three Indexes

Table 2 contains the values of the three indexes for each country and Table 3 gives the correlations. The simplified BMI is more closely correlated with raw BMI than is the adjusted index; and the simplified and adjusted are highly correlated. The estimates of dollar misvaluation are given in Table 4 and Figure 2.[6] While there are some differences here, in broad outline the adjusted and simplified indexes are reasonably close and in each period, the simplified version is bracketed by the other two. The simplified index also comes with a standard error, so we can test for misvaluation of the dollar. As can be seen from Figure 2, the error band covers zero for several years, but not at the beginning and end of the period. Thus, we can reject the hypothesis that the dollar was correctly valued in 2015, but not in the three previous years.

[5] See Appendix A2 for an analysis of the role and determinants of the income elasticity β.

[6] The US dollar misvaluation is approximated by $1/(1+\bar{m})-1,$ where $\bar{m}$ is the average bilateral misvaluation. This follows equation (6) of OR; however, that equation contains a typographical error as the right-hand side is written as $1/(1-\bar{m})-1,$ which is < 0 (> 0) when $\bar{m}<0$ (>0). If the other currencies are undervalued (overvalued) against the dollar on average, so that $\bar{m}<0$ (> 0), the dollar is overvalued (undervalued) against all others; thus, the expression should be $1/(1+\bar{m})-1>0$ (< 0) when $\bar{m}<0$ (> 0). However, this is not a substantive error and has no effect on the results of OR, which we reproduced.

As undervalued currencies should subsequently appreciate and overvalued ones depreciate, the three BMIs can be evaluated by comparing them to subsequent changes in the actual rate. Following OR, we consider a two-year forecasting horizon. Columns 2-4 of Table 5 show that on an average-absolute-error basis, over the five years to July 2015 the performance of the adjusted and simplified indexes is considerably better than that of the raw index. While there is not a great deal of differences between adjusted and simplified, over the whole period the adjusted index performs slightly better than the simplified version (average absolute error = 22.5% vs 23.2%). Columns 5-7 of the table give pairwise comparisons by recording the proportion of cases in which one index is closer to the actual change than the other. The adjusted and simplified both perform better than the raw index (columns 5 and 6). For the whole period, the last entry of column 7 reveals that the simplified index does worse than the adjusted version as it is closer to actual in about 42% of cases. The difference in the performance of these two indexes is not large, however.

5. Concluding Comments

Casual observation shows that prices of apparently identical goods diverge across countries, with differences tending to grow the greater the income differences. In a useful effort to account for this effect, the Big Mac Index (BMI) of currency misvaluation has recently been adjusted for cross-country income differences by The Economist. The exact steps involved in this adjustment are not available from The Economist, which has possibly limited the use and acceptance of this new measure. But the full details have now been discovered by O'Brien and Ruiz de Vargas (forthcoming, OR). Drawing on their work, this paper has proposed an alternative approach that is arguable simpler in its interpretation. Thus, there are now three versions of the BMI: (i) The original one (the "raw") index; (ii) the adjusted one, proposed by The Economist, the details of which are set out by OR; and (iii) our "simplified" version. The choice between versions (ii) and (iii) on the basis of their forecasting performance is not clear-cut. We found that versions (ii) and (iii) outperform the raw index in forecasting future currency values, and that the adjusted index is somewhat better than the simplified one, but the differences are not large.

References

O'Brien, T. J., and S. Ruiz de Vargas (forthcoming). "The Adjusted Big Mac Methodology: A Clarification." Journal of International Financial Management and Accounting.

The Economist (online). "The Big Mac Index." Available at: http://www.economist.com/content/big-mac-index [Accessed March 2016].

International Monetary Fund (online). World Economic Outlook, October 2015. Available at: https://www.imf.org/external/pubs/ft/weo/2015/02/weodata/index.aspx [Accessed March 2016].

APPENDIX

A1. The Data

The data are from a downloadable spreadsheet from The Economist (online) which contains Big Mac prices for 58 countries as of July 2015. The adjusted Big Mac index calculated by The Economist is based on 49 of these countries, which include the Euro area as well as 12 of its member countries. Sensitivity tests excluding the 12 Euro area countries yielded almost identical values of the adjusted BMI; this finding accords with OR. To be consistent with The Economist's results, we use all 49 countries.

GDP per capita is not included in the The Economist spreadsheet but instead available at The Economist (online) by examining their "line of best"; however, the source of these data is not mentioned. We have identified the source to be GDP per capita at current prices from the IMF (online). In order to calculate GDP per capita of the Euro area, we use the GDPs of the member countries and then divide by total population.

A2. Analysis of the Income Elasticity

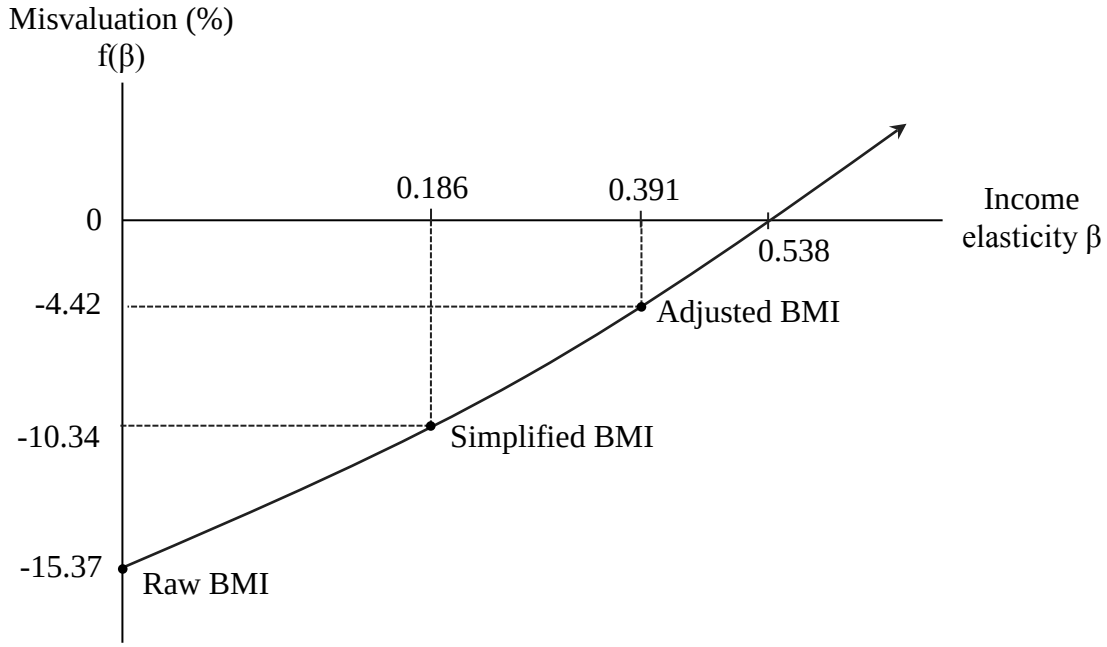
Prices in low-income countries are frequently low, not because their currency is undervalued, but because of other economic circumstances such as low wages and other costs. These features are measured in the pricing equations (1) and (5) by the income term y_c. Thus, in the context of equation (7) that measures misvaluation, the low price of a Big Mac in a low-income country relative to the (richer) base country, $p_c / p^* < 1$, is "inflated" by

the relative income term $\left(y^*/y_c\right)^{\beta}$, which always exceeds unity for $y^*/y_c > 1$ and $\beta > 0$. In view of the importance of the income elasticity β in the measurement of misvaluation, an analysis of its implications and determinants is appropriate.

Equation (7) gives the bilateral misvaluation of c, which in percentage terms is

(A2.1) $$\left[\left(\frac{p_c}{p^*}\right)\left(\frac{y^*}{y_c}\right)^{\beta} - 1\right] \times 100 = f(\beta).$$

Using the euro-dollar case in July 2015 again, below is a plot of this misvaluation against β:



This relationship is slightly nonlinear and shows mispricing is moderately sensitive to the value of β: When $\beta = 0$, $f(\beta) = -15.37\%$, the raw BMI case, and the currency becomes steadily less undervalued and then more overvalued as β increases. In other words, as β increases, the income differences become more important in partially offsetting the price differences that drive currency valuation.[7]

To analyse the determinants of β, write the price of a Big Mac as the sum of the cost of traded and nontraded inputs (C_T, C_N):

(A2.2) $$p = C_T + C_N.$$

[7] It follows from equation (A2.1) that $df/d\beta = 100 \cdot \left(p_c/p^*\right)\left(y^*/y_c\right)^{\beta} \log\left(y^*/y_c\right)$, which is positive for $y^*/y_c > 1$.

Traded inputs include wheat, beef and parts of energy costs; the prices of these items are determined predominantly in world markets independent of domestic economic conditions. On the other hand, the nontraded inputs are rent, local taxes and changes, wages and so on, which are dependent on domestic conditions as measured by income at home:

(A2.3) $$C_N = q_N p_N = q_N \cdot \sigma \cdot y^{\eta},$$

where q_N is the volume of nontraded inputs, p_N is an index of their price, σ is a positive constant and $\eta > 0$ is the elasticity of nontraded costs with respect to income.

It follows from equations (A2.2) and (A2.3) that the income elasticity $\partial \log p / \partial \log y = (C_N / p)\eta,$ or writing $s = C_N / p$ for the share of nontraded inputs in the price (or total cost),

$$\beta = s \cdot \eta.$$

In words, the income elasticity of the price is the product of the cost share of nontraded goods and the income elasticity of the price of those goods. If, for example, the share and the elasticity η are both equal to one-half, then $\beta = 0.25.$ Then, if a country is 20% poorer than the base country, its price of a Big Mac is predicted to be $0.25 \times 20 = 5\%$ lower than that in the base. Note that the larger the nontraded share, the larger is the elasticity, so domestic income has a more pronounced effect on the price. Or to put it another way, as the "tradability" of the product increases, the smaller is the cost share s and the smaller the role of the domestic economy in pricing.

Table 1 Three Approaches to Currency Mispricing

Description	Big Mac Index		
	Raw	Adjusted	Simplified
(1)	(2)	(3)	(4)
1. Pricing model	$p_c = p^*$	$p_c = \lambda + \phi y_c + \mu_c$	$\log \frac{p_c}{p^*} = \gamma + \beta \log \frac{y_c}{y^*} + \varepsilon_c$
2. Parameters	–	$\lambda =$ intercept $\phi =$ slope, dp_c/dy_c $\mu_c =$ disturbance for country c	$\gamma =$ intercept, dollar mispricing $= -\varepsilon^*$ $\beta =$ slope, income elasticity of mispricing, $d\left[\log\left(p_c/p^*\right)\right]/d\left[\log\left(y_c/y^*\right)\right]$ $\varepsilon_c =$ disturbance for country c
3. Estimated parameters	–	$\hat{\lambda} = 2.5223,\ \hat{\phi} = 0.0348$	$\hat{\gamma} = -0.1474,\ \hat{\beta} = 0.1858$
4. Mispricing (proportional)	Bilateral: $\frac{p_c}{p^*} - 1$	Country c / Base country Overall: $\left(p_c/\hat{p}_c\right) - 1$; $\left(p^*/\hat{p}^*\right) - 1$ Bilateral: $\left(\frac{p_c/\hat{p}_c}{p^*/\hat{p}^*}\right) - 1$; $\left(\frac{p^*/\hat{p}^*}{p^*/\hat{p}^*}\right) - 1$	Bilateral: $\left(\frac{p_c}{p^*}\right)\left(\frac{y^*}{y_c}\right)^{\beta} - 1$
5. Application to c = Europe, Base = US, July 2015 Euro / US Price $p_c = 4.054$ $p^* = 4.790$ Income $y_c = 40.028$ $y^* = 54.598$	$\frac{4.054}{4.790} - 1 = -15.37\%$	$\hat{p}_c = 2.5223 + 0.0348 \times 40.028 \approx \$3.915$ $\hat{p}^* = 2.5223 + 0.0348 \times 54.598 \approx \$4.422$ Euro / US Overall: $(4.054/3.915) - 1 \approx 3.55\%$; $(4.790/4.422) - 1 \approx 8.32\%$ Bilateral: $\left(\frac{4.054/3.915}{4.790/4.422}\right) - 1 \approx -4.40\%$; $\left(\frac{4.790/4.422}{4.790/4.422}\right) - 1 = 0\%$	$\left(\frac{4.054}{4.790}\right)\left(\frac{54.598}{40.028}\right)^{0.1858} - 1 = -10.34\%$

Note: Prices $\left(p_c, p^*\right)$ are in dollars. GDPs per capita $\left(y_c, y^*\right)$ are in thousands of dollars. To aid understanding the row 5 calculations, the misvaluations use rounded values. These are close approximations of the results in Table 2 that are not based on rounding.

Table 2 Three Indexes of Misvaluation,
49 Currencies, July 2015
(Percentage misvaluation relative to dollar)

Country	Raw BMI	Adjusted BMI	Simplified BMI
(1)	(2)	(3)	(4)
1. Argentina	-36.01	-4.76	-16.31
2. Australia	-18.12	-22.17	-19.84
3. Brazil	-10.59	35.07	19.21
4. Britain	-5.79	1.33	-2.61
5. Canada	-5.30	-2.07	-3.89
6. Chile	-31.76	-0.30	-12.67
7. China	-42.84	-9.32	-17.53
8. Colombia	-39.12	-3.99	-13.16
9. Czech Republic	-40.84	-18.34	-28.41
10. Denmark	6.02	1.27	4.00
11. Egypt	-54.86	-24.34	-23.99
12. Euro area	-15.37	-4.42	-10.34
13. Hong Kong	-48.28	-41.51	-45.17
14. Hungary	-33.58	-2.29	-14.33
15. India	-61.74	-34.42	-26.51
16. Indonesia	-52.28	-20.26	-20.65
17. Israel	-3.31	12.23	3.95
18. Japan	-37.67	-27.22	-32.77
19. Malaysia	-58.04	-36.00	-43.31
20. Mexico	-35.01	-0.76	-12.05
21. New Zealand	-18.38	-10.83	-14.98
22. Norway	17.94	-11.56	5.99
23. Pakistan	-28.15	23.62	43.01
24. Peru	-34.42	5.53	-2.50
25. Philippines	-24.73	26.89	30.14
26. Poland	-46.89	-22.32	-31.95
27. Russia	-60.68	-41.52	-48.62
28. Saudi Arabia	-33.20	-12.45	-22.45
29. Singapore	-28.19	-29.15	-28.60
30. South Africa	-56.28	-29.66	-35.04
31. South Korea	-21.50	-0.83	-11.18
32. Sweden	7.05	3.86	5.68
33. Switzerland	42.42	13.16	30.48
34. Taiwan	-46.83	-28.95	-37.36
35. Thailand	-33.86	7.82	1.51
36. Turkey	-19.12	23.85	9.90
37. United States	0.00	0.00	0.00
Mean	-27.28	-7.70	-11.41

Notes:
1. A negative value means the country's currency is overvalued relative to the dollar; a positive value means undervalued.
2. The adjusted BMI of column 3 here is identical to OR, Table 2; these were reproduced by us.

Table 3 BMI Correlations, July 2015

Index	Raw BMI	Adjusted BMI	Simplified BMI
Raw	1.00	0.59	0.70
Adjusted		1.00	0.92
Simplified			1.00

Note: Based on estimates in Table 2.

Table 4 US Dollar Overall Misvaluation

(Percentage misvaluation)

Date	Misvaluation according to		
	Raw BMI	Adjusted BMI	Simplified BMI
(1)	(2)	(3)	(4)
Jul-11	3.27	-23.35	-19.00 (4.83)
Jan-12	14.65	-12.15	-4.20 (4.34)
Jul-12	19.08	-6.82	1.24 (4.64)
Jan-13	12.83	-9.63	-8.21 (4.61)
Jul-13	21.60	-2.73	-0.45 (4.46)
Jan-14	22.82	-3.39	-2.87 (4.47)
Jul-14	22.67	-3.87	-0.44 (4.44)
Jan-15	33.50	4.24	10.87 (4.78)
Jul-15	37.51	8.34	14.84 (4.22)

Notes:

1. A negative value means the dollar is undervalued vis-à-vis all other currencies; a positive value means overvalued.
2. The overall misvaluation of the dollar according to the raw and adjusted BMI is $1/(1+\bar{m})-1$, where $\bar{m}$ is the average bilateral misvaluation of all currencies in terms of the dollar. For example, the adjusted BMI in July 2015, $\bar{m}=-7.70\%$ (Table 2), which gives a dollar misvaluation of $1/(1-0.0770)-1=8.34\%$.
3. The US dollar misvaluation for the simplified BMI is approximated by the estimate of $-\gamma$ from equation (6). This equation is re-estimated for each period using the previous calendar year's GDP per capita. Standard errors are in parentheses.
4. Columns 2 and 3 are identical to those of OR, Table 3; these were reproduced by us.

Table 5 Forecasting Performance of Three BMIs,

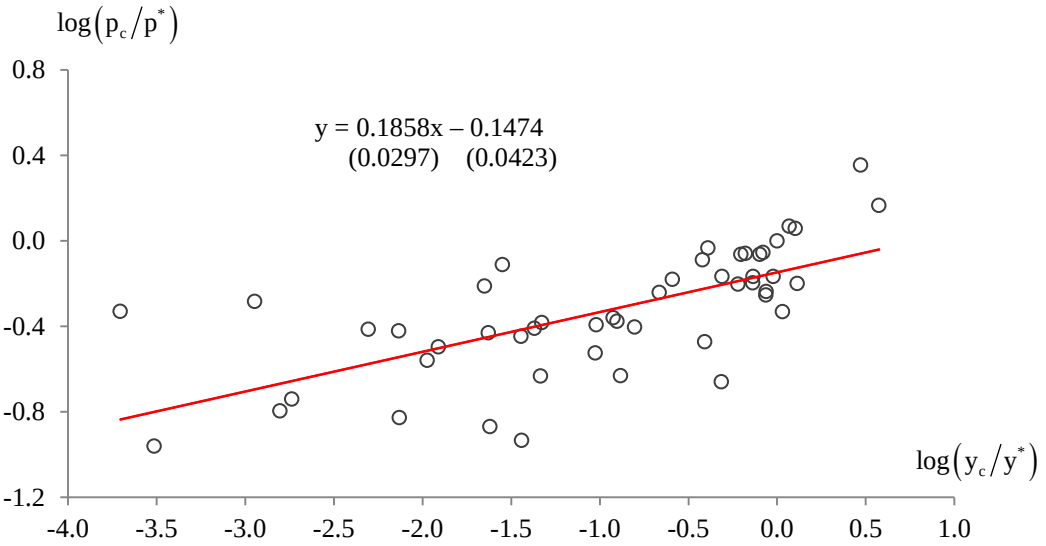
36 Currencies against the Dollar

Reference date	Average absolute deviation from actual exchange-rate change (%)			Proportion closer to actual change (%)		
	Raw BMI	Adjusted BMI	Simplified BMI	Adjusted vs raw	Simplified vs raw	Simplified vs adjusted
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Jul-11	34.1	27.9	26.5	66.7	66.7	50.0
Jan-12	31.8	22.7	21.2	69.4	75.0	52.8
Jul-12	31.1	21.1	22.0	71.4	74.3	42.9
Jan-13	35.8	20.6	23.2	77.8	80.6	33.3
Jul-13	38.3	20.3	22.9	83.3	80.6	30.6
Overall	34.2	22.5	23.2	73.7	75.4	41.9

Notes:

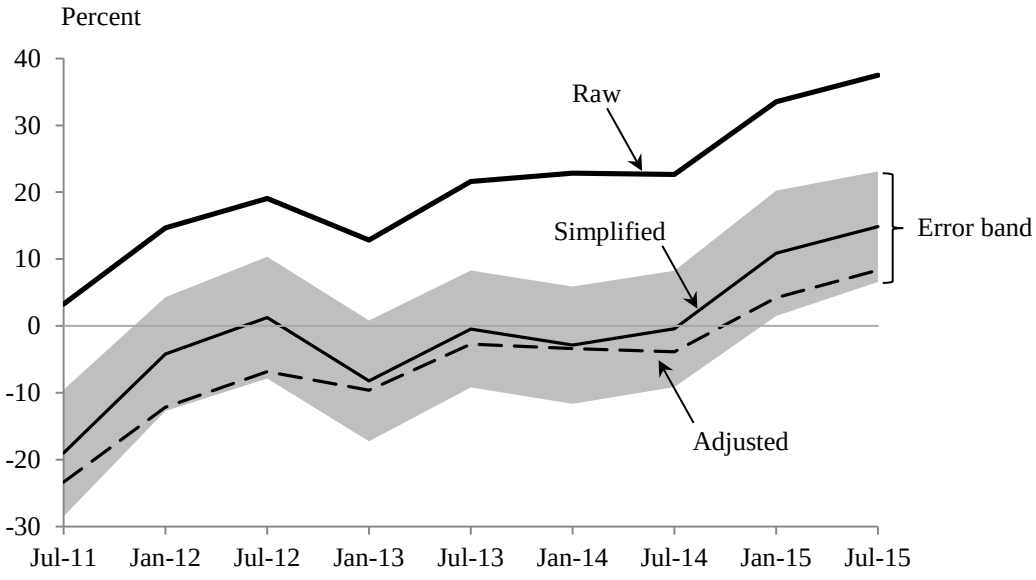
1. The reference date in column 1 is when the forecast is made. For each currency, each index is compared to the actual change in the exchange rate over the subsequent two years.
2. The raw and adjusted BMIs, as well as market exchange rates, are taken from The Economist's spreadsheet; the simplified BMIs are our own. To ensure consistency with The Economist's approach, all 49 countries (including the 12 euro area countries) are used to estimate equation (6).
3. Following OR, the 12 countries that make up the Euro area are omitted for the forecast evaluation in order to avoid double counting, as well as the US (the base currency). There are thus 49-12-1 = 36 currencies in the evaluation.
4. The results in columns 2, 3 and 5 are identical to those of OR, Table 4; these were reproduced by us.

Figure 1 Big Mac Prices and GDPs,
49 Countries in 2015



Note: This is a plot of Big Mac prices in 49 countries against GDP per capita. Prices and GDPs are relative to those in the US and are expressed in US dollars.

Figure 2 US Dollar Overall Misvaluation



Note: A negative value means the dollar is undervalued vis-à-vis all other currencies; a positive value means overvalued. The shaded band is ±1.96 SEs around the simplified BMI. Estimates are from Table 4.

Editor, UWA Economics Discussion Papers:
Sam Hak Kan Tang
University of Western Australia
35 Sterling Hwy
Crawley WA 6009
Australia

Email: ecoadmin@biz.uwa.edu.au

The Economics Discussion Papers are available at:
1980 – 2002: http://ecompapers.biz.uwa.edu.au/paper/PDF%20of%20Discussion%20Papers/
Since 2001: http://ideas.repec.org/s/uwa/wpaper1.html
Since 2004: http://www.business.uwa.edu.au/school/disciplines/economics

ECONOMICS DISCUSSION PAPERS 2015		
DP NUMBER	**AUTHORS**	**TITLE**
15.01	Robertson, P.E. and Robitaille, M.C.	THE GRAVITY OF RESOURCES AND THE TYRANNY OF DISTANCE
15.02	Tyers, R.	FINANCIAL INTEGRATION AND CHINA'S GLOBAL IMPACT
15.03	Clements, K.W. and Si, J.	MORE ON THE PRICE-RESPONSIVENESS OF FOOD CONSUMPTION
15.04	Tang, S.H.K.	PARENTS, MIGRANT DOMESTIC WORKERS, AND CHILDREN'S SPEAKING OF A SECOND LANGUAGE: EVIDENCE FROM HONG KONG
15.05	Tyers, R.	CHINA AND GLOBAL MACROECONOMIC INTERDEPENDENCE
15.06	Fan, J., Wu, Y., Guo, X., Zhao, D. and Marinova, D.	REGIONAL DISPARITY OF EMBEDDED CARBON FOOTPRINT AND ITS SOURCES IN CHINA: A CONSUMPTION PERSPECTIVE
15.07	Fan, J., Wang, S., Wu, Y., Li, J. and Zhao, D.	BUFFER EFFECT AND PRICE EFFECT OF A PERSONAL CARBON TRADING SCHEME
15.08	Neill, K.	WESTERN AUSTRALIA'S DOMESTIC GAS RESERVATION POLICY THE ELEMENTAL ECONOMICS
15.09	Collins, J., Baer, B. and Weber, E.J.	THE EVOLUTIONARY FOUNDATIONS OF ECONOMICS
15.10	Siddique, A., Selvanathan, E. A. and Selvanathan, S.	THE IMPACT OF EXTERNAL DEBT ON ECONOMIC GROWTH: EMPIRICAL EVIDENCE FROM HIGHLY INDEBTED POOR COUNTRIES
15.11	Wu, Y.	LOCAL GOVERNMENT DEBT AND ECONOMIC GROWTH IN CHINA
15.12	Tyers, R. and Bain, I.	THE GLOBAL ECONOMIC IMPLICATIONS OF FREER SKILLED MIGRATION
15.13	Chen, A. and Groenewold, N.	AN INCREASE IN THE RETIREMENT AGE IN CHINA: THE REGIONAL ECONOMIC EFFECTS
15.14	Knight, K.	PIGOU, A LOYAL MARSHALLIAN?
15.15	Kristoffersen, I.	THE AGE-HAPPINESS PUZZLE: THE ROLE OF ECONOMIC CIRCUMSTANCES AND FINANCIAL SATISFACTION

15.16	Azwar, P. and Tyers, R.	INDONESIAN MACRO POLICY THROUGH TWO CRISES
15.17	Asano, A. and Tyers, R.	THIRD ARROW REFORMS AND JAPAN'S ECONOMIC PERFORMANCE
15.18	Arthmar, R. and McLure, M.	ON BRITAIN'S RETURN TO THE GOLD STANDARD: WAS THERE A 'PIGOU-MCKENNA SCHOOL'?
15.19	Fan, J., Li, Y., Wu, Y., Wang, S., and Zhao, D.	ALLOWANCE TRADING AND ENERGY CONSUMPTION UNDER A PERSONAL CARBON TRADING SCHEME: A DYNAMIC PROGRAMMING APPROACH
15.20	Shehabi, M.	AN EXTRAORDINARY RECOVERY: KUWAIT FOLLOWING THE GULF WAR
15.21	Siddique, A., Sen, R., and Srivastava, S.	AUSTRALIA-THAILAND TRADE: AN ANALYSIS OF COMPETITIVENESS AND THE EFFECTS OF THE BILATERAL FTA
15.22	Tyers, R.	SLOWER GROWTH AND VULNERABILITY TO RECESSION: UPDATING CHINA'S GLOBAL IMPACT
15.23	Arthmar, R. and McLure, M.	PIGOU ON WAR FINANCE AND STATE ACTION
15.24	Wu, Y.	CHINA'S CAPITAL STOCK SERIES BY REGION AND SECTOR
15.25	Clements, K. and Si, J.	ENGEL'S LAW, DIET DIVERSITY AND THE QUALITY OF FOOD CONSUMPTION
15.26	Chen, S.	SHIFTS OF DISTORTION AND CORRUPTION OVER LOCAL POLITICAL CYCLES IN CHINA
15.27	Chen, S.	THE EFFECT OF A FISCAL SQUEEZE ON TAX NFORCEMENT: EVIDENCE FROM A NATURAL EXPERIMENT IN CHINA
15.28	Jetter, M.	BLOWING THINGS UP: THE EFFECT OF MEDIA ATTENTION ON TERRORISM
15.29	Tang, S.	MEDIUM-TERM MACROECONOMIC VOLATILITY AND ECONOMIC DEVELOPMENT: A NEW TECHNIQUE
15.30	Alim, A., Hartley, P. and Lan, Y.	ASIAN SPOT PRICES FOR LNG OTHER ENERGY COMMODITIES
15.31	Gannon, B., Harris, D., Harris, M., Magnusson, L., Hollingsworth, B., Inder, B., Maitra, P, and Munford, L.	NEW APPROACHES TO ESTIMATING THE CHILD HEALTH-PARENTAL INCOME RELATIONSHIP
15.32	Czaika, M. and Parsons, C.	THE GRAVITY OF HIGH SKILLED MIGRATION POLICIES
15.33	Parsons, C., Rojon, S., Samanani, F, and Wettach, L.	CONCEPTUALISING INTERNATIONAL HIGH-SKILLED MIGRATION
15.34	Chen, S.	VAT RATE DISPERSION AND TFP LOSS IN CHINA'S MANUFACTURING SECTOR
15.35	Tait, L., Siddique, A. and Chatterjee, I.	FOREIGN AID AND ECONOMIC GROWTH IN SUB-SAHARAN AFRICA

ECONOMICS DISCUSSION PAPERS 2016		
DP NUMBER	**AUTHORS**	**TITLE**
16.01	Xu, R., Wu, Y. and Luan, J.	ANALYSIS OF FARMERS' WILLINGNESS TO ADOPT GENETICALLY MODIFIED INSECT-RESISTANT RICE IN CHINA
16.02	Lia, Y., Fan, J., Zhao, D., Wu, Y. and Li, J.	TIERED GASOLINE PRICING: A PERSONAL CARBON TRADING PERSPECTIVE
16.03	Clements, K.W., Lan, Y. and Si, J.	UNCERTAINTY IN CURRENCY MISPRICING
16.04	Parsons, C. and Vézina, P.L.	MIGRANT NETWORKS AND TRADE:THE VIETNAMESE BOAT PEOPLE AS A NATURAL EXPERIMENT
16.05	Chang, S., Connelly, R. and Ma, P.	WHAT WILL YOU DO IF I SAY 'I DO'?: THE EFFECT OF THE SEX RATIO ON TIME USE WITHIN TAIWANESE MARRIED COUPLES
16.06	Yu, F. and Wu, Y.	BIASES IN PATENT EXAMINATION AND FIRMS' RESPONSES: EVIDENCE FROM THE PHARMACEUTICAL INDUSTRY
16.07	Fan, J., Li, J., Wu, Y., Wang, S. and Zhao, D.	THE EFFECTS OF ALLOWANCE PRICE ON ENERGY DEMAND UNDER A PERSONAL CARBON TRADING SCHEME
16.08	Golley, J., Tyers, R. and Zhou, Y.	CONTRACTIONS IN CHINESE FERTILITY AND SAVINGS: LONG RUN DOMESTIC AND GLOBAL IMPLICATIONS
16.09	McGrath, G. and Neill, K.	FOREIGN AND DOMESTIC OWNERSHIP IN WESTERN AUSTRALIA'S GAS MARKET
16.10	Clements, K.W. and Si, J.	SIMPLIFYING THE BIG MAC INDEX
16.11	Priyati, R.Y. and Tyers, R.	PRICE RELATIONSHIPS IN VEGETABLE OIL AND ENERGY MARKETS
16.12	Wu, J., Wu, Y. and Wang, B.	THE GREENNESS OF CHINESE CITIES: CARBON DIOXIDE EMISSION AND ITS DETERMINANTS
16.13	Arslan, C., Dumont, J.C., Kone, Z., Özden, Ç., Parsons, C. and Xenogiani, T.	INTERNATIONAL MIGRATION TO THE OECD IN THE TWENTY-FIRST CENTURY
16.14	Tomioka, K. and Tyers, R.	HAS FOREIGN GROWTH CONTRIBUTED TO STAGNATION AND INEQUALITY IN JAPAN?
16.15	Donovan, J. and Hartley, P.	RIDING THE IRON ORE CYCLE: ACTIONS OF AUSTRALIA'S MAJOR PRODUCERS