WORKING PAPER SERIES

Currency Conversion and Energy Projections: Some Questions and Answers

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November 2015

Independent Statistics & Analysis

www.eia.gov

U.S. Energy Information Administration

Washington, DC 20585

Summary

International economic models—particularly those with an energy component—need to work in a common currency when using concepts such as GDP. Such conversions can be done using market exchange rates (MER)—those you hear about on the news every night—or purchasing power parity (PPP) exchange rates, which you learned about a long time ago and never wanted to see again. While both have strengths and weaknesses, PPP exchange rates are appropriate when generating energy projections. I discuss why in this paper, covering common questions about each type of exchange rate—from how they are calculated or determined to their appropriate use.

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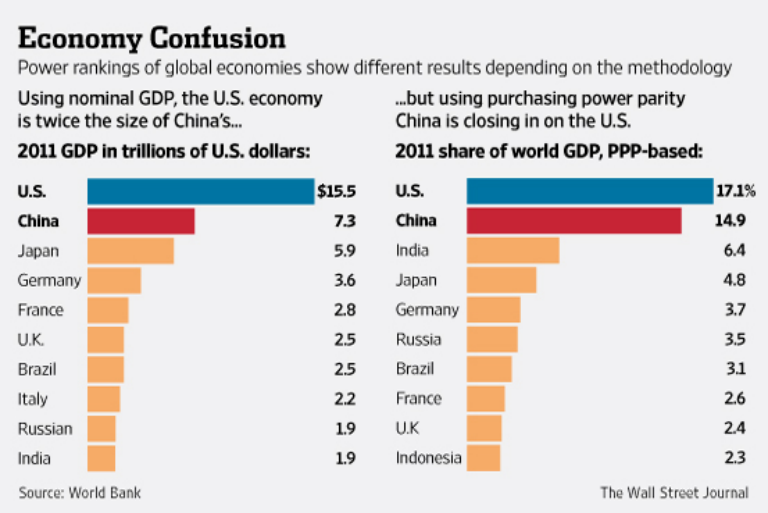
Introduction

While Duke Ellington and Louis Armstrong inaugurated the jazz age in America, Sun Yat-Sen plotted his return to power in Southern China, and Kemal Ataturk became the first president of the Turkish republic, Weimar Germany was in economic crisis. The culprit was soaring prices—the same loaf of bread that a corner bakery in Berlin sold for a mark in 1919 cost above 200 billion marks by the end of 1923. And nominal output—the current value of production throughout the German economy—grew at a remarkable pace, albeit slower than prices in general.

Yet most of us know this was a mirage: the German people were hurting, there was little business investment, and hiring was tepid—actual production increased at a much slower rate than its value, even falling between 1922 and 1923. This is a textbook example of how comparing output values without adjusting for inflation can be misleading. Most of us are unaware, however, that similar concerns bedevil the comparison of output across countries. The logic across space is exactly the same as over time: both prices and production levels determine output, and there is no way to separate out production without controlling for price.

In fact, price differences across countries can have a large impact on comparisons of output in a given year (Figure 1).

Figure 1: Different comparisons of GDP in 2011



Source: WSJ.[1]

The chart on the left values GDP in the U.S. at over $15 trillion in 2011—more than double the Chinese total of $7.3 trillion. All of the GDP estimates in the left chart are converted from local currency units to U.S. dollars using market exchange rates (MER)—your run-of-the-mill quotes provided by Yahoo! Finance.

The chart on the right presents a much different picture. The U.S. still has the world's largest economy in 2011, with a share around 17%. But China is almost as large—Chinese GDP accounts for nearly 15% of

[1] http://blogs.wsj.com/economics/2014/04/30/chinas-economy-surpassing-u-s-well-yes-and-no/.

global output in 2011. The values on the right are converted using a different exchange rate, one based on the theory of purchasing power parity (PPP). PPP exchange rates adjust for price differences across countries, just as price indices adjust for inflation across time.

If they account for prices differences, shouldn't PPP exchange rates always be used when converting between different currencies? Not necessarily. Both methods have their strengths and weaknesses, proper uses and misuses. The remainder of this paper covers common questions about MER and PPP exchange rates and their application. The topics range from why exchange rates are used and how they are calculated, to which rate is preferable for use in generating energy projections.

Why convert the value of output or expenditure from one currency to another?

The most popular reason is to make GDP comparisons across countries (Figure 1), which allows for ranking the relative sizes of different economies—either in total or per person. Such cross-country comparisons imply that the values being compared represent volumes of production or expenditures, not differences in price. Estimating such volumes can be tricky because so many goods are produced throughout modern economies, and these must be aggregated into a single number such as GDP.

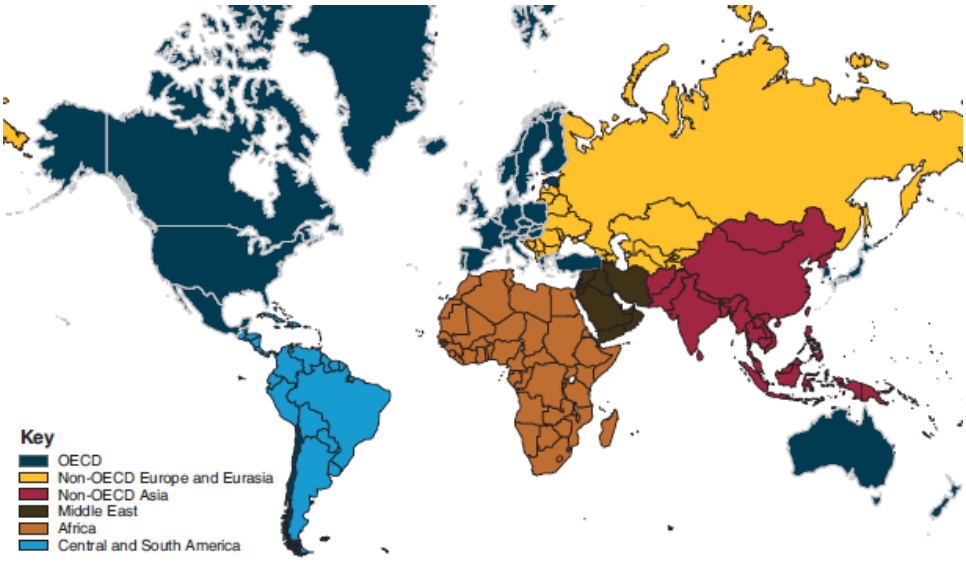
Conversions are also used to understand how countries differ in terms of the components of expenditures—consumption, investment, government spending, exports, and imports; or even in comparing the different production levels of specific industries across countries.[2] There is no way to make such comparisons if these concepts are expressed in local currencies.

Aggregation—especially when modeling—is another reason to convert concepts such as GDP or investment to a common currency. For example, the U.S. Energy Information Administration (EIA) publishes global projections of energy consumption every year in the International Energy Outlook (IEO) for 16 countries and regions: eight individual countries and eight aggregate regions (all of these countries fall within six basic country groupings, Figure 2).[3]

[2] See Tim Callen, "PPP Versus the Market: Which Weight Matters?" *Finance and Development*, Volume 44, Number 1, March 2007. URL: http://www.imf.org/external/pubs/ft/fandd/2007/03/basics.htm.

[3] The countries in the IEO are Brazil, Canada, China, India, Japan, Russia, South Korea, and the United States. The regions include: Africa, Australia/New Zealand, Mexico/Chile, the Middle East, OECD Europe, Other Central and South America, Other Non-OECD Asia, and Other Non-OECD Europe and Eurasia.

Figure 2: Map of six basic IEO country groupings



Source: EIA.[4]

Most energy models in the IEO use GDP as an input, which means that generating energy projections for the eight aggregate regions requires either: (i) aggregating GDP from the country-level to the IEO region-level, then projecting energy consumption; or (ii) building individual energy models for each country, generating country-level energy projections, and then aggregating to the IEO region-level.

The IEO first aggregates GDP (and other economic concepts) to the regional level and then projects energy consumption at this aggregate level. Why? Data availability and resource constraints.

In terms of data availability, consider the IEO's Africa region: there are over 50 African countries of varying size and age, with many different currencies. It is not plausible to build energy and economic models for each country because quality data for many are unavailable. But even a region such as OECD Europe, with close to 30 countries, where reliable data are available presents a problem: the effort required to build and maintain individual country-level models is prohibitive. These limitations make aggregating key economic concepts a necessary compromise when generating projections of energy consumption in the IEO.

How is the value of output converted from one currency to another?

There are two common methods for converting output between currencies: using exchange rates determined by national authorities or in legally-sanctioned markets where currencies are traded (market exchange rates), or using purchasing power parities, sometimes called PPP exchange rates.

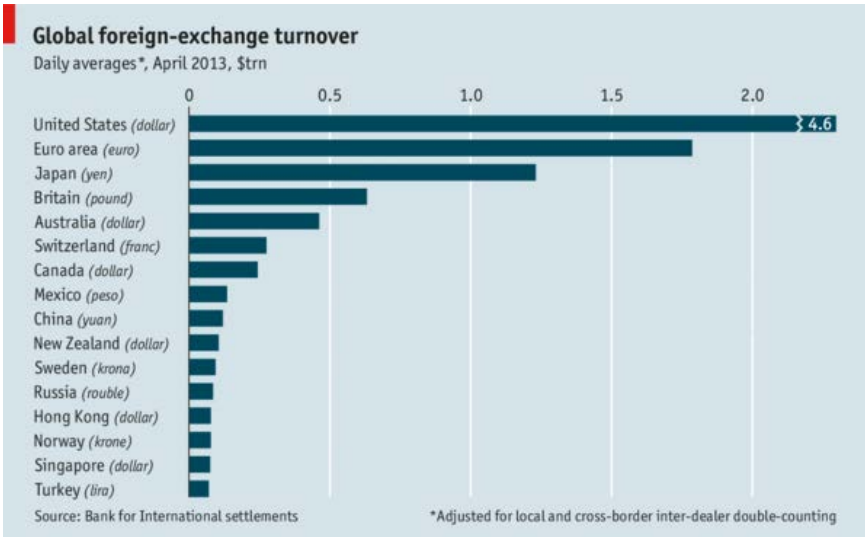
Market exchange rates are those which prevail in foreign exchange markets. These enormous global markets are open 24 hours a day, with daily trade exceeding $5 trillion (Figure 3).[5] Foreign exchange

[4] See Appendix M in http://www.eia.gov/forecasts/ieo/pdf/0484(2013).pdf.

[5] See Simon Potter, "Trends in Foreign Exchange Markets and the Challenges Ahead," Remarks at the 2015 FX Week Conference, New York City, July 14, 2015. URL: http://www.ny.frb.org/newsevents/speeches/2015/pot150714.html.

markets span a variety of trading centers—London, New York, and Tokyo are the largest—and consist of many interconnected marketplaces that are made up of different exchanges and trading systems. There are also many types of foreign exchange contracts and instruments—spots, forwards, futures, swaps, and options, to name a few. The U.S. dollar, Euro, and Japanese Yen are the world's most traded currencies, with the dollar/euro and dollar/yen the most-traded currency pairs.[6]

Figure 3: Daily foreign exchange trading



Source: The Economist magazine.[7]

Spot exchange rates are often quoted in the popular press: they are trades of one currency for another conducted "on the spot", and comprise nearly 40% of daily foreign exchange trading. Averages of daily spot exchange rates (weekly, monthly, and annual) are often used to convert between currencies.

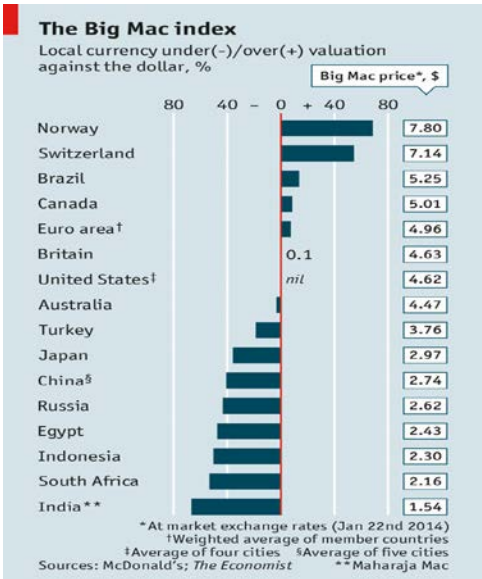
PPP exchange rates come from purchasing power parity theory: the idea that prices and exchange rates adjust in the long run so that the purchasing power of currencies is comparable across countries. Its logic is easiest to explain with one good. If the price of that good—call it oil—differs in two locations, then there are opportunities to buy it in the cheaper country and sell it in the more expensive one for a profit (arbitrage). So if oil costs $100 per barrel in Chicago and €130 per barrel in Barcelona, and the market exchange rate is 1.15 $/€, one could buy in Chicago for $100 and sell in Barcelona at the equivalent of about $150 per barrel—a guaranteed profit of roughly $50.

Many people will then attempt to buy in Chicago and sell in Barcelona—simultaneously raising the price in Chicago and lowering it in Barcelona. Such arbitrage will continue until the prices are the same in a common currency; until the price of oil in Barcelona times the $/€ exchange rate is equal to the price of oil in Chicago. A common interpretation is that the $/€ exchange rate is proportional to the ratio of oil prices in both locations. This is the so-called law of one price.

[6] See BIS, *Triennial Bank Survey*, September 2013. URL: http://www.bis.org/publ/rpfx13fx.pdf.
[7] http://www.economist.com/news/economic-and-financial-indicators/21586351-global-foreign-exchange-turnover.

The Economist magazine's Big Mac index is an example of how the law of one price can be used (Figure 4). The magazine gathers the average price of a Big Mac sandwich in a number of countries (valued in local currency). Each of these are then converted to dollars at MER and compared with the average U.S. price, providing the hypothetical under or over valuation against the U.S. dollar shown in the figure. This is the same as calculating a parity based on the price of the Big Mac in a country relative to the U.S., and comparing that parity with the corresponding market exchange rate.

Figure 4: An example of the law of one price



Source: The Economist magazine.[8]

Absolute PPP theory takes this logic and extends it to multiple goods and services: the price of a basket of goods and services (represented by a price index) in a common currency should be the same across countries. Put differently: the $/€ exchange rate is proportional to the ratio of price indices across countries.

Notice that PPP theory focuses on price levels and market exchange rates, but also produces the PPP exchange rate, which is the ratio of price levels between the countries. The theory is centered on the idea that arbitrage should move market exchange rates close or equal to this parity value. But the PPP exchange rates that result can also be used to convert between currencies.[9]

Because parities come from PPP theory, they have a different interpretation than market exchange rates. Parities reflect the value of the exchange rate that would need to hold so that a unit of currency could purchase the same basket of goods in one country or another. They allow for conversions that both alter currency units and account for price differences in the same (or similar) goods and services. When used in this capacity PPP exchange rates are not meant to estimate market exchange rates—they are intended to better compare volumes across countries by accounting for price differences.

[8] See http://www.economist.com/content/big-mac-index.

[9] See Robert Lafrance and Lawrence Schembri, "Purchasing-Power Parity: Definition, Measurement, and Interpretation," *Bank of Canada Review*, Autumn 2002, p.27-33. URL: http://www.bankofcanada.ca/wp-content/uploads/2010/06/lafrance_e.pdf.

Absolute PPP has been rejected in many studies, for various countries, over different years. There is little evidence that a basket of goods and services, or even one good, cost the same across countries when converted at market exchange rates.[10] Relative PPP is a slight modification which states that market exchange rates grow at a rate proportional to the ratio of inflation across two countries. Relative PPP has found more support than its absolute cousin, especially recently, but only in the very long-run, and not universally.[11]

The reasons for such deviations appear to be well-understood. Absolute PPP theory and the law of one price assume there are no transactions costs. But the costs of transportation, taxes and tariffs, delays, legal obstacles, and the like are major impediments to the convergence of prices or price indices between countries.

Additionally, arbitrage arguments behind price convergence rely on trade between countries—completely ignoring goods that are not traded across national boundaries. Such non-traded goods can account for a large share of GDP, often about 50%.[12] It should therefore not be a surprise that relative prices between countries do not move proportionately with market exchange rates.

Does the success or failure of PPP theory have any bearing on the validity of using PPP exchange rates for conversion to a common currency?

No. PPP theory is about the determination of market exchange rates, and its confirmation or rejection has nothing to do with using PPP exchange rates to convert between currencies.

But there is an important distinction to be made between the failure or lack of success of the theory and the use of PPP exchange rates for converting to a common currency. The tests of PPP theory use market exchange rates, and effectively conclude that because of transactions costs and non-traded goods market exchange rates are not proportional to relative price levels across countries, or that growth in market exchange rates is only proportional to the ratio of growth in the price levels in the long-run. However, PPP theory's lack of empirical success has no bearing on the validity of PPP exchange rates for converting values of output to a common currency.

Put another way: PPP theory is not a good guide to the determination of market exchange rates, especially in the short-to-medium term. But the parities themselves reflect the value of the exchange rate that would need to hold so that a unit of currency could purchase the same basket of goods in one country or another. They are not meant to approximate market exchange rates when used for such conversions.

How are MER and PPP exchange rates determined?

There are many explanations and hypotheses for how market exchange rates are determined. They differ in the time frames considered, but usually distinguish between the short and long-run, and

[10] See Kenneth Rogoff, "The Purchasing Power Parity Puzzle," *Journal of Economic Literature*, Volume XXXIV, June 1996, p. 647-668. URL: http://scholar.harvard.edu/rogoff/publications/purchasing-Power-Parity-Puzzle.

[11] See Alan M. Taylor and Mark P. Taylor, "The Purchasing Power Parity Debate," Journal of Economic Perspectives, Volume 18, Number 4, p. 135-158. URL: https://www.aeaweb.org/articles.php?doi=10.1257/0895330042632744.

[12] See Alan Heston, "The Flaw of One Price: Some Implications for MER-PPP Discussions," Presentation to the PPP vs MER Workshop, Stanford University, February 2004. URL: https://pwt.sas.upenn.edu/papers/Stanford4.pdf.

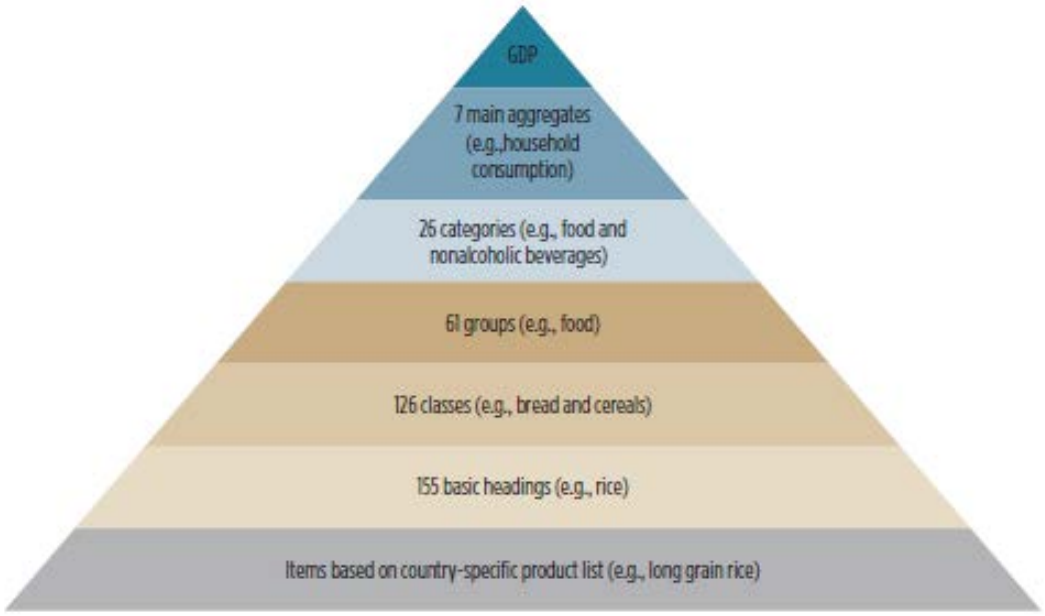
consider various driving factors from interest rates to inflation, monetary policy to trade in goods and services, speculation to government intervention.[13] The actual quoted values are generally averages of spot market transactions from foreign exchange markets (see above).

PPP exchange rates are much different: they are determined by actual price data at the country level, the manner in which these prices are aggregated to form price indices, and then application of the PPP formula to derive an exchange rate value. The International Comparison Program (ICP) and Penn World Tables (PWT) are the two most commonly used sources for PPP exchange rates.

The ICP is coordinated by the World Bank and involves the collection of prices and calculation of PPP exchange rates (at various levels of aggregation) for about 199 countries in a given year.[14] The entire ICP process is called a round, and is conducted every six years. The PWT—originally created and hosted at the University of Pennsylvania—uses ICP prices to calculate PPP exchange rates (and other concepts), but with different methods than the ICP.[15]

The first step for ICP in calculating PPP exchange rates is collecting data at the country-level. ICP does this in each round in conjunction with national statistical agencies—gathering prices and expenditures for the whole range of final goods and services that comprise GDP (Figure 5).

Figure 5: Levels of aggregation in ICP2005



Source: Chapter 1 of the ICP 2011 handbook.[16]

[13] See chapters 13-16 in Robert C. Feenstra and Alan M. Taylor, *International Economics,* 3rd Edition, 2014.
[14] See ICP.
[15] See PWT.
[16] See D.S. Prasada Rao, "The Framework of the International Comparison Program," Chapter 1 in *Measuring the Real Size of the World Economy: The Framework, Methodology, and Results of the International Comparison Program—ICP*, 2013. URL: Handbook.

The prices are annual averages of over 1000 items, and are gathered about four times each year in more than one market—rural and urban, formal and informal—within the country. To ensure products are as similar as possible, ICP issues a detailed description for each, referred to as a Structured Product Description (SPD).

The country-level price data must then be aggregated to form parities for 155 larger categories called basic headings.[17] For example, ICP collects prices for long, medium, and short grain rice, and these prices are then aggregated into a parity in each country for the rice basic heading. Because parities are ratios of price indices, the country-level prices must be expressed relative to a reference price before aggregation to the basic heading level.

The reference prices come from reference countries: ICP divides the world up into 8 regions, and selects a country to serve as the reference for that region.[18] The country-level price ratios are constructed by dividing every price in a particular country by the price of the same good in the reference country for that region. Once these regional price ratios for each item are available, they can be aggregated to parities at the basic heading level using some type of unweighted average.[19] The result is 155 parities for each country, relative to the regional reference country.

The next step is to calculate parities above the basic heading level for each country, up to the level of GDP, as shown in Figure 5. The difference between these aggregations and the ones below the basic heading level is weights. Weighting basic heading prices ensures that their relative importance in expenditures (their respective expenditure shares) is reflected in higher-level parities. The expenditure shares are taken from the national accounts of each country.[20]

At this point a full complement of parities is available for each country, but only relative to the reference country in each of the eight regions (left column in Figure 6). The next step is to move from regional parities to global ones using some type of conversion factor, and these factors come from a parallel process in the ICP (Figure 6).

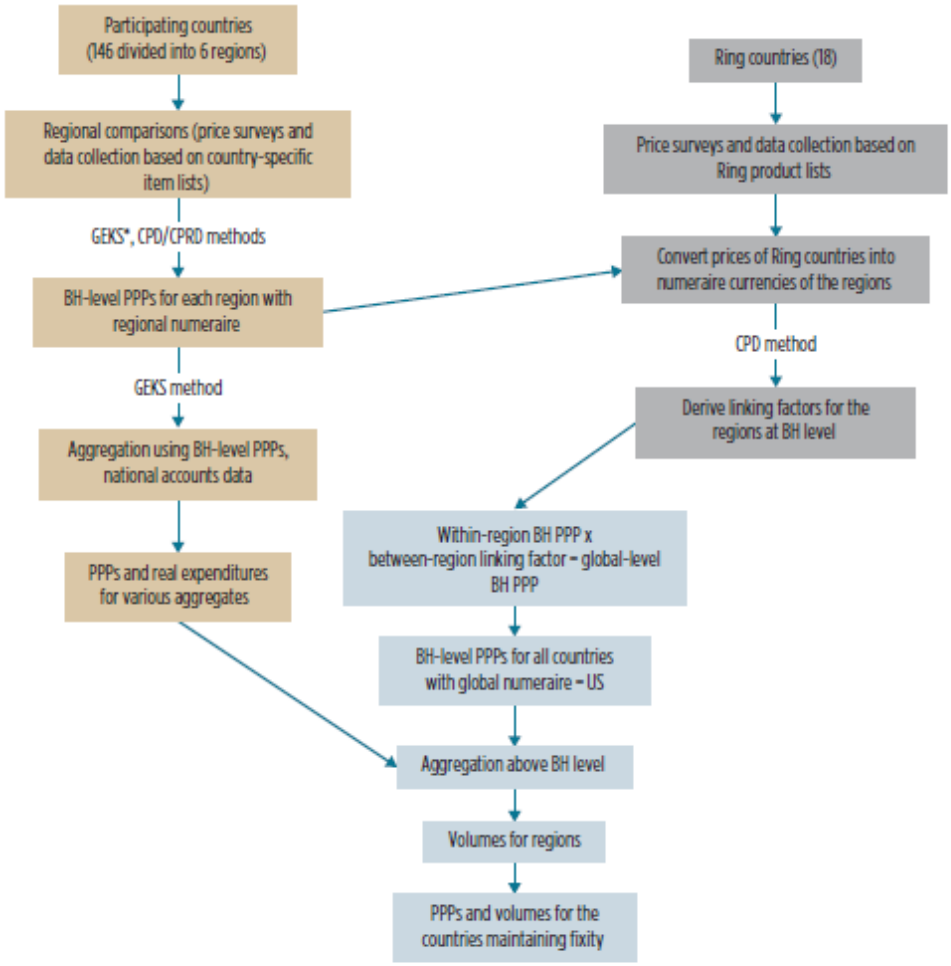
[17] Basic headings are the lowest levels of detail for which most countries have data in their national accounts.

[18] The regions in ICP2011 were Africa, Asia and the Pacific, the Commonwealth of Independent States, Latin America and the Caribbean, OECD – Eurostat, Pacific Islands, Singleton Countries, and Western Asia.

[19] Choosing how to aggregate from the individual prices ratios to basic heading parities is not a simple task, and some of the differences between ICP and PWT stem from the fact that they employ different methods. The issue is that whatever method is chosen needs to ensure transitivity in parities between countries—that the parity of country A relative to B is the same as deriving this parity from the relationship between country C relative to B, and A relative to C (i.e. A/B = C/B * A/C). This is only an issue because some countries are missing data. See p. 15 of Angus Deaton and Alan Heston, "Understanding PPPs and PPP-based National Accounts," *American Economic Journal: Macroeconomics*, Volume 2, Number 4, 2010, p. 1-35. URL: https://www.aeaweb.org/articles.php?doi=10.1257/mac.2.4.1.

[20] The same concerns with aggregating parities as described in the previous footnote arise here, but are complicated somewhat by the presence of weights. In this case the different aggregation methods do not give the same results even in theory, and each method has its own strengths and weaknesses. See p. 6-13 of Angus Deaton and Alan Heston, "Understanding PPPs and PPP-based National Accounts," *American Economic Journal: Macroeconomics*, Volume 2, Number 4, 2010, p. 1-35. URL: https://www.aeaweb.org/articles.php?doi=10.1257/mac.2.4.1.

Figure 6: Overview of ICP2005 methods



Note: GEKS = Gini-Éltető-Köves-Szulc; CPD = Country Product Dummy; CPRD = Country Product Representative Dummy.

Source: Chapter 1 of the ICP 2011 handbook.[21]

In the other process ICP collects price data in the capital cities of 18 so-called "ring countries", which are assumed to represent regions as a whole (there are two or more in each region). The prices collected for ring countries are based on a different list than for all countries, but also contain over 1000 items. Ring country prices are aggregated to the basic heading level, and then converted to the currency of the regional reference country using basic heading parities calculated earlier (represented by the first blue line from the left column in Figure 6 to the right).

From here the country-level basic heading parities are combined to get linking factors, providing a way to convert parities at the regional level—expressed relative to the regional reference country—to the global level, where they are expressed relative to the U.S. The final step at the basic heading level is to

[21] See D.S. Prasada Rao, "The Framework of the International Comparison Program," Chapter 1 in *Measuring the Real Size of the World Economy: The Framework, Methodology, and Results of the International Comparison Program—ICP*, 2013. URL: Handbook.

convert the country-level parities to global ones by multiplying by the linking factors, shown in the top box of the middle column of Figure 6. These global-level basic heading parities are then aggregated to higher aggregation levels.

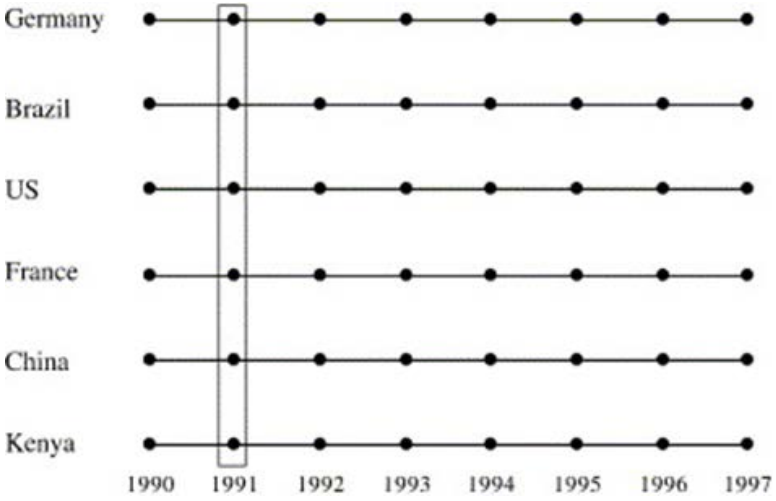
How are PPP exchange rates or values of output obtained in non-benchmark years?

Because country-level price surveys are infrequent, various techniques are employed to extrapolate both PPP exchange rates and concepts such as GDP (converted using PPP exchange rates) in non-benchmark years.[22]

The macro method takes parities in the benchmark year and grows them at a rate proportional to corresponding price indices (the country-of-interest and the reference country, usually the U.S.). For example, at the level of GDP, the ICP PPP exchange rate for India can be moved from 2011 (the benchmark) to 2012 by growing it at the same rate as that of the GDP deflator in India relative to the GDP deflator in the U.S. A similar approach works for the components of GDP as well—the consumption parity can be changed proportional to the rate of growth in the CPIs of both countries, the investment parity by relative growth in an investment deflator, and so on.

Eurostat follows a related procedure at the level of basic headings for many European countries. Their so-called rolling benchmark approach consists of obtaining prices for only a fraction of basic headings each year, extrapolating the remaining basic headings using heading-specific price indices, and then aggregating to parities at higher levels.

Figure 7: Illustration of the constant PPP method



Source: Figure 3 from Nordhaus (2007).[23]

[22] For an overview of these methods see Paul McCarthy, "Extrapolating PPPs and Comparing ICP Benchmark Results," Chapter 18 in *Measuring the Real Size of the World Economy: The Framework, Methodology, and Results of the International Comparison Program—ICP*, 2013. URL: Handbook.

[23] See Figure 3 of William Nordhaus, "Alternative Measures of Output in Global Economic-Environmental Models: Purchasing Power Parity or Market Exchange Rates," *Energy Economics*, Volume 29, 2007, p. 349-372. URL: http://www.sciencedirect.com/science/article/pii/S0140988306000144.

This technique can also be applied to the (already-converted) output values in the base year. The basic idea is shown in Figure 7, where the rectangular box indicates the year actual parities are available. Here, the output value (usually real GDP) is grown by the rate observed in the corresponding concept from the national accounts. So the 1991 value of Brazilian GDP from ICP, for example, is moved forward to 1992 and beyond by growing it at the same rate as that of GDP in the national accounts. This constant PPP method is widely applied, and has been used by the World Bank and the OECD.

The PWT use a combination of the macro and constant PPP methods. They extrapolate the components of GDP (consumption, investment, etc.) using growth rates from national accounts. These are then aggregated into an estimate of GDP using weights.[24]

As with the aggregation of parities, each method of extrapolation has strengths and weaknesses. But for modelers interested in extrapolating levels of output at least, there is some evidence that the constant PPP method is preferable to others.[25]

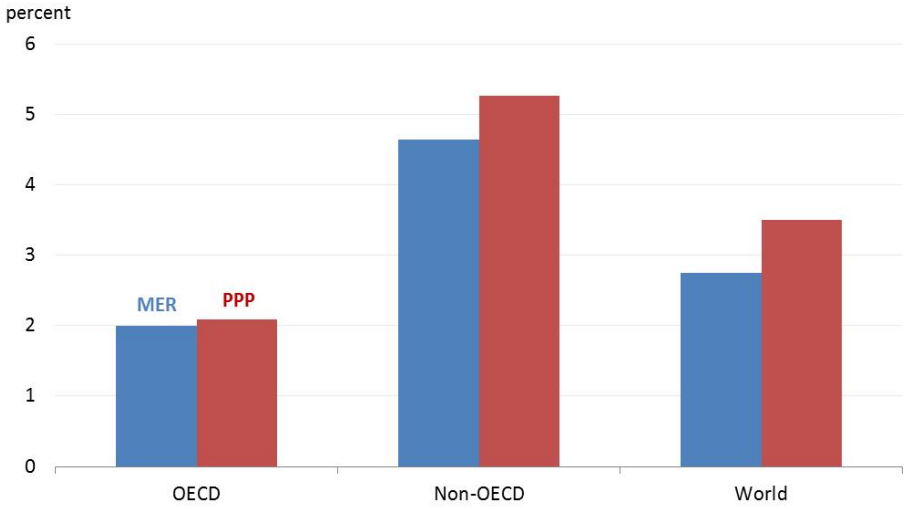
Are there differences in GDP values or growth rates when using MER vs. PPP conversions?

Yes, for both levels and growth rates: differences can be large or small depending upon the country, region, or time-frame under consideration. In terms of levels, MER-based conversions may differ from PPP-based ones by a factor of three in low-income countries.[26] For example, historical GDP data from the IEO value the size of non-OECD countries much lower when converted at MER: 35% of world GDP in 2014 versus 46% for a PPP conversion.

The difference boils down to price levels, more specifically the prices of non-traded goods. Because of higher wages and salaries, goods that are not traded across borders generally cost more in wealthier countries than poorer ones. Market exchange rates ignore such divergences because their values are based on traded goods (among other things, see above). So converting using the level of market exchange rates underestimates the purchasing power of consumers in poorer countries, making their economies look smaller than when such price differences are accounted for (as with PPP exchange rates).[27]

[24] See World Bank, "About the ICPs and PPPs," 2006. URL: World Bank FAQ.
[25] See William Nordhaus, "Alternative Measures of Output in Global Economic-Environmental Models: Purchasing Power Parity or Market Exchange Rates," *Energy Economics*, Volume 29, 2007, p. 349-372. URL: http://www.sciencedirect.com/science/article/pii/S0140988306000144.
[26] See William Nordhaus, "Alternative Measures of Output in Global Economic-Environmental Models: Purchasing Power Parity or Market Exchange Rates," *Energy Economics*, Volume 29, 2007, p. 349-372. URL: http://www.sciencedirect.com/science/article/pii/S0140988306000144.
[27] See ICP.

Figure 8: Comparison of growth in real GDP converted at MER and PPP exchange rates, 1990-2014

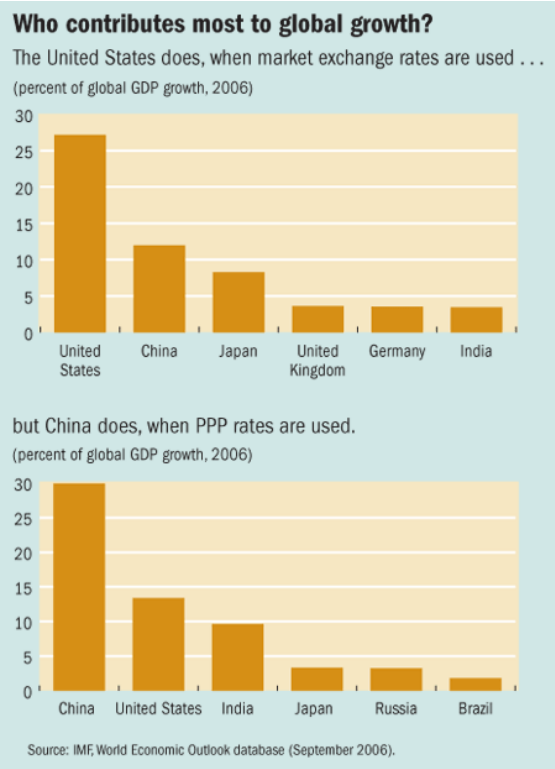


Source: EIA

An implication of the differences in levels is that growth rates can diverge as well depending upon the method of conversion between currencies (Figure 8). IEO historical data show that such dissimilarities are especially pronounced in non-OECD countries since 1990—and this spills over to the world as a whole. Growth rates in OECD countries are relatively similar irrespective of whether currencies are converted using MER or PPP exchange rates.

Finally, MER and PPP-based conversions also differ in terms of identifying which countries account for global GDP growth (Figure 9). IMF estimates for 2006 show the U.S. contributed more than any other country to global GDP growth if MER-based conversions were used. China was next, followed by Japan, and then the U.K. But conversions using PPP exchange rates juggle this order around: China is easily the largest contributor to global GDP growth in 2006, followed by the U.S., then India, and then Japan. The U.K. does not make the top 6.

Figure 9: Comparison of historical PPP and MER exchange rates



Source: IMF.[28]

Do differences in converting output values matter for energy consumption projections?

It depends on the model used to generate projections.[29] The differential growth rates and levels between GDP converted at PPP or MER certainly make a difference in the EIA's World Energy Projection System Plus (WEPS+), the suite of models behind the IEO.

What are the benefits and drawbacks of using MER or PPP conversions for energy consumption projections?

MER exchange rates are widely available and easy to interpret. Most users of economic data understand what such rates are, in general where they come from, and how they are being used.

The drawbacks of market exchange rates are substantial, however. Most important is that they do not provide a good basis for comparing volumes of production across countries (see above). Their values

[28] See Tim Callen, "PPP Versus the Market: Which Weight Matters?" *Finance and Development*, Volume 44, Number 1, March 2007. URL: http://www.imf.org/external/pubs/ft/fandd/2007/03/basics.htm.

[29] See for example Bjart J. Holtsmark and Knut H. Alfsen, "PPP Correction of the IPCC Emission Scenarios – Does it Matter?" *Climatic Change*, Volume 68, Issue 1, p. 11-19, 2005. URL: http://link.springer.com/article/10.1007%2Fs10584-005-1310-2, or Ian Castles and David Henderson, "International Comparison of GDP: Issues of Theory and Practice," *World Economics*, Volume 6, Number 1, p. 55-84. URL: https://press.anu.edu.au/wp-content/uploads/2014/03/16.-International-Comparisons-of-GDP-Issues-of-Theory-and-Practice.pdf.

are unlikely to account for non-tradeable goods and services, which are a large share of output in many countries.

Market exchange rates are also volatile, and especially in the short-run, influenced by factors unrelated to trade in goods and services. These factors—capital flows, government intervention, political events—can move their values away from levels that equate prices across countries.[30]

The primary benefit of using PPP exchange rates is that they allow volume comparisons across countries by accounting as much as possible for price differences. PPP exchange rates also incorporate non-traded goods, and are relatively stable over time, especially when compared with market exchange rates. And they are widely available.

The main drawback of PPP exchange rates is that they are hard to measure—it is very difficult and intensive to collect and tabulate country-level price data on identical goods and services. As a result, collection is not done annually for all countries, but only in benchmark years. This means that PPP exchange rates for most countries in non-benchmark years must be extrapolated from benchmark years. Finally, PPP exchange rates can also be difficult to understand, especially when compared with market exchange rates.

Should MER or PPP be used to convert output for energy consumption projections?

PPP. In projecting energy consumption we are ultimately interested in quantifying the volume of production at the level of industries, broader sectors, and economies as a whole. These volumes can then be used to estimate energy consumption through various methods and models.

The preferred conversion method—MER or PPP—is the one which gives a better approximation of the volume of production across countries. And the discussion above should make clear that PPP exchange rates are better at correcting for price levels across countries/currencies, which makes them better at estimating volumes.

How are values of output converted between currencies in the IEO?

Two different types of output are converted between currencies in the IEO: real GDP and real gross output (GO). Although IEO energy models only use PPP-based values, results from MER conversions are also produced.

The market exchange rates used to convert historical GDP or GO data are annual averages; those used for projections are based on country-level forecasts of annual averages.

Both historical and projected real GDP and GO converted using PPP exchange rates at the country-level apply the constant PPP method (see above). Here, nominal values in the benchmark year are converted

[30] See Box 7.2 of Nicholas Stern, *Stern Review on the Economics of Climate Change*, 2010. URL: http://webarchive.nationalarchives.gov.uk/+/http:/www.hm-treasury.gov.uk/sternreview_index.htm.

to dollars by using the appropriate PPP exchange rate.[31] Both historical and projected values are extrapolated from benchmark years by growing at the rate of the equivalent concept in local currency.

This procedure works for the initial baseline in all 16 IEO regions. But as the IEO models run through different iterations, the GDP and GO values change from baseline. These changes are not a problem for the eight IEO countries, because each is individually modelled within the IEO's macroeconomic model. The eight regions, however, do not have a separate model for every underlying country. In this case both the GDP and GO values are modified from baseline at the regional level, with conversions based on market exchange rates (in so-called behavioral equations). The PPP values are calculated by assuming the baseline ratio of PPP to MER exchange rates in a given year for that region remains the same.

Conclusion

Market and PPP exchange rates are the two common methods for converting output between currencies. Market exchange rates are those which prevail in foreign exchange markets, while PPP rates are based on actual price data at the country level for a given year. The strengths and weaknesses of each approach are summarized in **Table 1**.

Table 1: Benefits and drawbacks of using PPP or MER exchange rates to convert output values

Exchange Rate	Benefits	Drawbacks
MER	Widely available	Do not account for price differences across countries
	Easy to understand and explain	Do not incorporate non-traded goods and services
		Volatile
PPP	Account for price differences across countries	Difficult to measure
	Incorporate non-traded goods and services	Need to extrapolate for non-benchmark years
	Relatively stable over time	Can be difficult to understand
	Widely available	

Source: EIA

While the table makes clear that both have their flaws, PPP exchange rates are appropriate when generating energy projections. Why? PPP exchange rates adjust for price differences across countries, just as price indices adjust for inflation across time—they provide a better estimate of the volume of production in a country for a specific year. And we are ultimately interested in quantifying the volume of production at the level of industries, broader sectors, and economies as a whole for energy projections. These volumes can then be used to estimate energy consumption through various methods and models.

[31] Both GDP and GO are converted using parities at the level of GDP. Applying sectoral-level parities to the GO values is more appropriate, but currently not possible at the level of detail required in the IEO. The reason is that PPP exchange rates are only widely available based on the expenditure side of the national accounts, whereas estimates from the production side are needed for consistency with the GO concept. For more information see Robert Inklaar and Marcel P. Timmer, "Using Expenditure PPPs for Sectoral Output and Productivity Comparisons," Chapter 24 in *Measuring the Real Size of the World Economy: The Framework, Methodology, and Results of the International Comparison Program—ICP*, 2013. URL: Handbook.