The Use of Purchasing-Power-Parity Exchange Rates in Economic Modeling: An Expository Note

Lawrence J. Lau
Department of Economics
Stanford University
Stanford, CA 94305-6072
U.S.A.

1. Comparisons of the Standards of Living across Economies

Consider two hypothetical economies, C and U. Let there be two goods in each of the two economies, X_{1i} and X_{2i}, i = C, U, respectively. Let the prices of the two goods in each of the two economies be given by P_{1i} and P_{2i}, i = C, U, in their domestic currencies, Yuan and Dollar, respectively. Let s be the "market" exchange rate between the two currencies, in terms of Yuan per Dollar.

In period 0, if we were to try to compare the standard of living between the two economies, given the data on the prices and quantities, the following comparisons can be made directly, without appealing to the use of the exchange rate:

(1) The values of the total expenditures in C and U, evaluated in Dollars, is given by $EX_{i,U}=P_{1U}X_{1i} + P_{2U}X_{2i}$, i = C, U. Depending on which of $EX_{U,U}$ and $EX_{C,U}$ is greater, and by how much, we can make a statement on the relative standard of living in C and U.

(2) Similarly, we can also compute $EX_{i,C}=P_{1C}X_{1i} + P_{2C}X_{2i}$, i = C, U, which provides an alternative comparison of the relative standard of living in C and U.

Unfortunately, as is well known as the index number problem, (1) and (2) can yield inconsistent results in both the direction and the magnitude. We illustrate this point with the following numerical example.

	C	**U**
P1	**1**	**10**
P2	**5**	**5**
X1	**1,000**	**10**
X2	**1**	**1,000**
EXU	**10,005**	**5,100**
EXC	**1,005**	**5,010**

We note that in this admittedly artificial example, the value of C's total expenditure, in Dollars, is almost twice that of U's; but in Yuan, the value of C's total expenditure is only a fifth of that of U's. It is thus impossible to say unequivocally whether C or U has a higher standard of living. It depends on which set of prices are used to value the goods produced or consumed in the two economies respectively. Our numerical example illustrates clearly the difficulty of making international comparisons of the standards of living under conditions of vastly different relative prices and preferences (tastes). Averaging the two sets of prices (and calling them "international prices") does not really solve the problem. Only under conditions of similar relative prices or similar preferences does the problem of inconsistency disappear. But in the case of similar relative prices, it makes no difference which set of prices are used—they will give the same ranking of the total expenditures. And in the case of similar consumption patterns, a consistent ranking can be obtained from the relative quantity of any one good alone. In the general case of neither similar prices nor similar consumption patterns, the possibility of inconsistency is always

present, regardless of the set of prices used (or any arbitrary set of prices, including a weighted average of the two sets of prices).

Thus far we have not said anything about exchange rates. Suppose s is the "market" exchange rate between the two currencies, then another possible indicator of the relative standard of living is given by a comparison of:

(3) $EX_{U,U}$ ($=P_{1U}X_{1U} + P_{2U}X_{2U}$) and $EX_{C,C}/s$ ($=(P_{1C}X_{1C} + P_{2C}X_{2C})/s$). There is of course no a priori reason to expect that this comparison will yield the same answer as either (1) or (2) above.

In our numerical example, s is not yet specified. It is reasonable to assume that s should lie somewhere between the price ratios of the two goods across economies, that is, in this case, between 0.1 (the price ratio of good 1 across the two economies) and 1 (the price ratio of good 2 across the two economies) Yuan per Dollar. If we assume s = 0.1, then C will have a much higher standard of living than U (10,050 compared to 5,100). If we assume s= 1, then C will have a much lower standard of living than U (1,005 compared to 5,010). If we take X_2 to be the tradable good, then the fact that P_2 is the same in both economies suggests that the exchange rate should be closer to 1 than to 0.1, because price equalization across economies is much more likely for tradable goods.

2. Purchasing-Power-Parity (PPP) Exchange Rates

Thus far we have not used the concept of a purchasing-power-parity (PPP) exchange rate. A purchasing-power-parity exchange rate is an exchange rate estimated on the assumption that the same set of (international) prices prevail for the same goods, quality adjusted, in both economies. In other words, the PPP exchange rate of C is the ratio of the value of its total expenditure, in Yuan, to the value of its total expenditure, measured in international prices, in "international" Dollars. Thus, for example, $s_{PPP,U}$, in terms of Yuan per Dollar at international prices, can be estimated as:

(1) $s_{PPP,U} = EX_{C,C}/EX_{C,U}$. At this exchange rate, C will be able to purchase the same bundle of goods it did at domestic prices but now at international prices (taken to be the prices prevailing in U in Dollars).

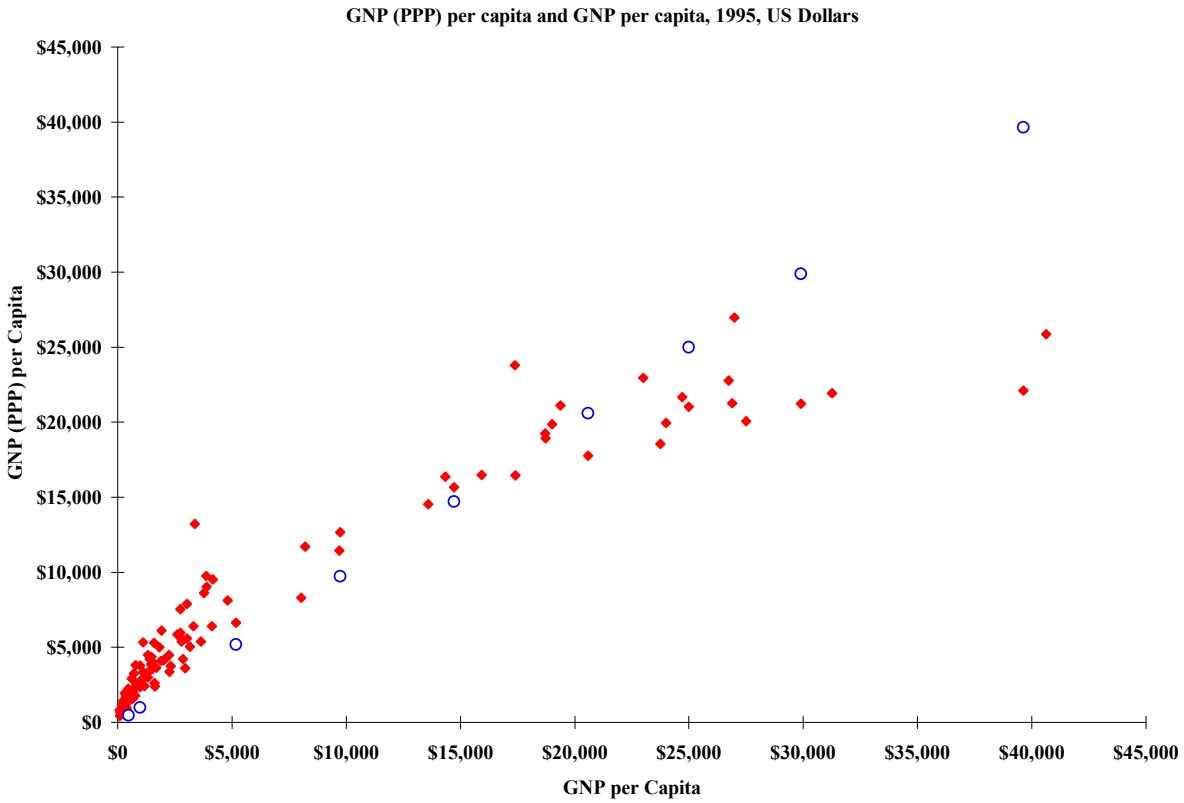
Similarly, one can define an alternative PPP exchange rate as:

(2) $s_{PPP,C} = EX_{U,C}/EX_{U,U}$. At this exchange rate, U will be able to purchase the same bundle of goods it did at domestic prices but now at the prices prevailing in C in Yuan.

In terms of our numerical example, $s_{PPP,U} = EX_{C,C}/EX_{C,U} = 1{,}005/10{,}005 = 0.10$; $s_{PPP,C} = EX_{U,C}/EX_{U,U} = 5{,}010/5{,}100 = 0.98$. So clearly the PPP exchange rate is sensitive to the particular set of prices adopted as the set of "international" prices. Of course, an entirely different set of prices other than those prevailing in either C or U can also be used. Theoretically, there is no compelling reason to choose between one set and another. In practice, the use of market prices prevailing in the developed economies is probably quite acceptable on the grounds that (1) these prices are more likely to reflect the underlying scarcities than prices prevailing in the developing economies, with all the market imperfections and restrictions; and (2) the consumption patterns in the developed economies (most of them Western) are in fact quite similar and more stable than those in the developing economies. However, one must remain sensitive to the effects of the existence of persistent differences in relative prices and/or preferences across economies. What this example shows is that theoretically there is nothing sacred about PPP exchange rates, and certainly not the PPP exchange rate based on a particular choice of "international" prices.

There is also no a priori reason why the market exchange rates should necessarily converge to the PPP exchange rates even in the long run given the large share of the non-tradable sector in developed (as well as developing) economies. While it is reasonable to assume that with free trade, the prices of tradable goods should have a tendency to converge, the same cannot be said of non-tradable goods and services.

Empirically, using PPP exchange rates instead of market exchange rates typically raise the measured GNP (or GDP) of low-income countries and lower the measured GNP (or GDP) of high-income countries. This is most clearly illustrated in the following chart, in which the PPP GNPs per capita of various economies, as measured by the World Bank are plotted against the respective market exchange rate GNPs per capita. The open circles indicate the line on which the PPP GNPs per capita should lie if they are equal to the market exchange rate GNPs per capita.



3. Aggregating across Economies

Thus, we have seen above that the choice of the set of "international" prices can be quite arbitrary and moreover can lead to potentially vastly different "PPP" exchange rates and therefore different estimates of "PPP" GDPs. Why are PPP exchange rates still being used? They are used because under some circumstances using the "market" exchange rates for the purpose of comparing GDPs or standards of living across economies can lead to even greater distortions both internationally and intertemporally. For example, at market exchange rates, Japanese GDP per capita is much higher than that of the U.S., and has been so for quite some time, but almost no economist in either Japan or the U.S. believes that it is really the case. For another example, Chinese GDP per capita is certainly much lower than that of the U.S., but is the standard of living in China only 3 percent that of the U.S.? Thus, the use of some PPP

exchange rate, however unreliable, may be necessary. Moreover, as noted above, among economies in which prices and preferences are similar, "PPP" exchange rates can be quite robust.

Once it is accepted that the use of market exchange rates can distort the relative magnitudes of GDPs and GDP-per-capita's across economies, an alternative set of exchange rates, such as PPP exchange rates, will have to be used in aggregating GDPs across economies. For example, whether market exchange rates or PPP exchange rates are used in deriving an aggregate GDP in U.S. Dollars for the Organization for Economic Cooperation and Development (OECD) countries will make a significant difference in the resulting value. The problem is even more severe if it is necessary to take into account differential economic growth over time, a subject that will be taken up in the next section.

4. Measurement and Comparison of Economic Growth

Thus far, we have considered only the comparisons of levels of economic activities (e.g., total expenditure) at a given point in time, but not the rates of growth. There can be great discrepancies between a rate of growth of GDP measured in constant local currency and measured in PPP, i.e., international, prices. Thus, an economy with given trajectories of the (physical) quantities of output can wind up with two different real rates of growth, depending on whether constant prices in local currency or constant prices in international Dollars are used. The simplest way to understand why this could happen is to see that if different sectors grow at different real rates, then the relative prices of the outputs of the different sectors in the base period matters. To the extent that the relative domestic prices and the relative international prices are different in the base period, the weights of the different sectors in GDP will differ, depending on whether domestic or international prices are used, resulting in different measured real rates of growth for the aggregate economy. Moreover, at different stages of economic development, the relative weights of the different sectors also evolve differently. The constant-price local currency weights are unlikely to be the same as the constant-price PPP weights.

We illustrate this point with the following numerical example. We now introduce period 1 (which we take to be ten years from period 0). Between period 0 and period 1, economies C and U have both grown. However, the two sectors in C do not grow at identical rates. The changes in prices in both economies are minimal. There are no changes in the prices in U, and only the price of good 1 in C has gone up by 20 percent over ten years. We introduce the new notation of EXtit', where t is the period, i is the country whose prices are being used and t' is the base year of the constant prices. Thus, EX0U0 is the value of the expenditure in period zero measured in terms of the prices in U in period 0.

	C	U
Period 0		
P10	**1.00**	**10.00**
P20	**5.00**	**5.00**
X10	**1000.00**	**10.00**
X20	**1.00**	**1000.00**
EX0U0	**10005.00**	**5100.00**
EX0C0	**1005.00**	**5010.00**
Period 1		
P11	**1.20**	**10.00**
P21	**5.00**	**5.00**
X11	**1343.92**	**13.44**
X21	**57.67**	**1343.92**
EX1U1	**13727.49**	**6853.97**
EX1C1	**1901.02**	**6735.71**
EX1U0	**13727.49**	**6853.97**
EX1C0	**1632.24**	**6733.02**
Real Growth Rates (Constant Local Currency)	**4.97%**	**3.00%**
Real Growth Rates (Constant International Prices)	**3.21%**	**3.00%**

By comparing EX0C0 and EX1C0 for C, we can derive an average annual real rate of growth of 4.97% for C over the ten years in terms of constant prices of C. By comparing EX0U0 and EX1U0 for C, we can derive an average annual rate of growth of 3.21% for C over the ten years in terms of constant prices of U (or "international" prices). This is a huge difference in the real rates of growth. Over a century, the difference in the two alternative measures of the real GDPs of C will be enormous. But we know that the growth of the physical quantities are actually the same by construction. All that we have done is to use a different set of prices in the base period. Which is the right real GDP to use?

There is, of course, no right or wrong GDP. It all depends on the purpose for which we want the measured GDP. Suppose we wish to project the long term demand for X_1 and X_2 in C, conditional on the growth of real GDP in C, then the income (GDP) elasticities of demand will clearly have to differ depending whether we use real GDP in constant local currency or real GDP in international prices. We note that X_1 has grown 3% per annum and X_2 has grown 50% per annum in C. The expenditure elasticities may therefore be estimated as 0.60 and 10.06 respectively if expenditure is measured in constant local currency; they may be estimated as 0.93 and 15.6 respectively if expenditure is measured in international prices. We cannot mix and match, because at the end of the day whatever we decide to use we have to be able to replicate the growth of X_1 from 1,000 to 1,343.92 over the ten-year period.

That is why, for example, we cannot simultaneously say that in terms of international prices, Chinese GDP is, say, twice what it is measured at the market exchange rate and that it will grow in real terms at 8 percent per annum over the next decade or two. The real rate of growth of 8 percent per annum is based on constant prices in local currency. The real rate of growth will be lower if measured in terms of constant international prices. And depending on whether constant local currency or constant international prices are used, the real income elasticities of demand will have to be adjusted accordingly.

Thus, as long as one is willing and able to keep track of the price basis used in one's modeling work, and maintains its consistency over time, it should not matter whether one uses constant prices in local currency or in international prices. The parameters—the rates of growth, the demand elasticities, etc.—will be different; but there should be a one-to-one correspondence between the parameters of a model written in constant prices in local currency and those of a model written in constant international prices. It is in this sense that it does not matter and should not matter whether one uses PPP or constant local currency prices.

However, to the extent that one needs to model economic behavior, it is probably better done in constant prices in local currency. This is because the economic agents in the economy react to changes in the local currency prices and not to PPP prices, and they have purchasing power only in local currency and not in PPP. For example, by foregoing a haircut, they may supposedly have gained 20 international Dollars, but they cannot trade a haircut for a month worth of food. Moreover, cross-validation of a model denominated in constant local currency is more feasible because there are likely to be more models constructed in constant local currency prices by local researchers than in international prices.

Hence, the conclusion here is that one should model first, in constant local currency, and then aggregate afterwards. Real GDPs can then be aggregated on a PPP basis if one wishes. But the economic variables of interest, such as energy consumption, can be directly aggregated in physical units without reference to the exchange rate, whether market or PPP. This is a far more robust modeling strategy than to aggregate first, and then model. While the physical quantities can still be aggregated appropriately, both the values and the prevailing prices may be subject to large distortions.

5. Concluding Remarks

In constructing an econometric model for an economy, it is better to do so in constant-price local-currency units if at all possible. If aggregation across economies is necessary, it should be done afterwards, not before. For large economies such as the United States, China, India and Japan, the rationale for prior aggregation before modeling is really rather weak—especially since they each follow their own unique, idiosyncratic economic development paths and face different relative prices. When aggregation is inevitable (obviously one is not going to construct one model for each economy in the world, no matter how small), one should only aggregate similar economies, distinguished by their stage of economic development, relative prices and preferences. Use of PPP prices or exchange rates does not help when vastly different economies are being aggregated together in a single econometric model.