How Big is China?

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by

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1. Introduction

In the research leading up to the publication of *World Economic Outlook*, in April 2011, the International Monetary Fund (IMF) predicted that China's economy would exceed the size of the United States by 2016. The IMF projected that the Chinese economy will expand its real GDP from $11.3 trillion in 2011 to $18.7 trillion in 2016, while the U.S. economy will grow from $15.0 trillion to $18.3 trillion in the same period.[1] Based on those forecasts, China would be producing more than 18% of global economic output in 2016, while the U.S. would be producing just 17.7%.[2] This finding received widespread media coverage, with titles like: "IMF Predicts Chinese Economy to Surpass U.S. in 2016,"[3] and "IMF bombshell: Age of America near end."[4] But in fact, the IMF has probably *underestimated* the size of the Chinese economy, which will more likely surpass the United States in economic size in just two years, by 2013 rather than 2016.[5]

In my lecture today, I was to discuss in detail how forecasts like these are made, which require that GDP for China or any other country are converted into dollars. While much of the discussion will focus on 2005, I will also provide my own estimates for Chinese GDP today and in future years. To explain why it is difficult to convert Chinese GDP in dollars, let us start with GDP divided by the total population, or GDP per-capita, which was approximately RMB 13,768 per person in China in 2005. This value cannot be compared directly to the per-capita GDP of another country, like $41,674 per person in the United States in 2005, because the two values are in different currencies, of course. If we divide RMB 13,768 by the official exchange rate

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1 These figures are available in the *World Economic Outlook* database, available at: http://www.imf.org/external/pubs/ft/weo/2011/02/weodata/index.aspx (accessed October 3, 2011).

2 As reported in: http://www.babypips.com/blogs/piponomics/china-to-overtake-us-by-2016-imf.html

3 http://www.foxnews.com/politics/2011/04/25/imf-predicts-chinese-economy-surpass-2016/

4 http://www.marketwatch.com/story/imf-bombshell-age-of-america-about-to-end-2011-04-25

5 In his blog, Arvind Subramanian argues that China's real GDP may exceed that of the United States even in 2010: see http://www.piie.com/realtime/?p=1935 .

between the Chinese RMB and U.S. dollar, which was about 8 RMB per dollar in 2005, then we could convert the Chinese per-capita GDP that year to $1,721. On this basis, we might conclude that the average citizen in China had only 4% (=1,721/41,674) of the income and standard of living as the average citizen in the U.S. But such a conclusion would be wrong.

The reason for this incorrect conclusion is that the average citizen in China faces much lower prices than suggested by the official exchange rate of 8 RMB per U.S. dollar. A Chinese citizen with average income can afford to purchase many more goods in China than if he or she had $1,721 to spend in the United States. This illustrates the fallacy of using official exchange rates to convert GDP from one currency to another. In order to make any meaningful study of the relative wealth or poverty of citizens across different countries, or of the factors contributing to such differences, we need a meaningful way to compute and compare their GDPs in a common currency like the US dollar, which is what we mean by "real GDP". This is done by the World Bank in their World Development Indicators, but is also done independently by the Penn World Table, which I will describe next.

2. The Penn World Table

The Penn World Table, or PWT (Summers and Heston, 1991), is possibly the most widely used dataset in economics, receiving thousands of downloads each month from students and professional economists. The University of Pennsylvania website (http://pwt.econ.upenn.edu/) received unique visitors and page downloads of 150,000 and 1.26 million in 2010, respectively, and these numbers will be the same or higher based on half of 2011.

Johnson, Larson, Papageorgiou and Subramanian (2009) examined many of the academic research papers in the economic growth and development literature, and write: "Roughly 2/3 of all cross country empirical work is based on PWT. Second place is held by the World Bank's World

Development Indicators, which were originally based on PWT but subsequently diverged. The IMF's World Economic Outlook dataset places a distant third." (p.1, footnote). They go on to say that much research by IMF and Bank staff uses PWT. So surprisingly, even staff at the World Bank and IMF use the PWT data rather than these agencies' own datasets. The goal of PWT is to provide a consistent comparison of real per-capita GDP across most of the countries in the world, expressed in dollars. As discussed above, that comparison cannot be made by simply converting national-currency GDP into dollars using market exchange rates, because market fluctuations and government controls render those exchange rates entirely unsuitable for such a task.

Instead, a major international project known as the International Comparisons Program (ICP), with participation by the United Nations, the World Bank and other international agencies, collects prices on comparable goods across many countries in benchmark years. For example, by taking the average of the RMB price of these goods in China relative to their dollar prices in the United States, PWT constructs a "purchasing power parity" (PPP) RMB per dollar exchange rate that reflects the actual prices faced by consumers. That PPP exchange rate is then used to convert the RMB GDP of China to its dollar GDP, which can be compared to the United States to obtain a meaningful measure of relative standard of living in the two countries.

When this calculation is made for China in 2005, the PPP exchange rate is closer to 2.5 RMB per dollar rather than the official exchange rate of 8 RMB per dollar. That means that China's real GDP per capita in 2005 is closer to $5,500 (= RMB 13,768 / 2.5) per person rather than $1,721 as computed above. It can be seen from this example that the average Chinese citizen is in fact much better off (due to the low prices they face) than would be expected from using official exchange rates to convert GDP into dollars. The ICP price comparisons needed to make the proper conversion are undertaken only for benchmark years. In the past the ICP began with 10 countries in 1970 but by 2005 there were 146 (see World Bank 2007), with 180 planned for the 2011 round. Thus, the ICP is getting closer to the PWT goal of providing real GDP comparisons for nearly all countries of the world. In addition, the international agencies associated with ICP now make their own calculations of real GDP. Nevertheless, there are important reasons why the real GDP calculations of the World Bank, reported in the World Economic Indicators, differ from those reported in PWT.

A major constraint imposed built into the ICP, and inherited by the World Development Indicators of the World Bank which use the ICP data, is the issue of “regional fixity.” This constraint means that regional calculations of real GDP that are done by the international agencies participating in the ICP (e.g. Eurostat’s calculations for Europe, the United Nations Economic and Social Commission for Asia and the Pacific, or ESCAP etc.) remained “fixed” in subsequent calculations for the world. Specifically, the World Development Indicators must accept the relative levels of real GDP within Europe, Asia, Africa, etc. that arise from the ICP calculations in any benchmark year, and cannot diverge from these calculations even if it believed that the underlying data might be inaccurate. This constraint can sometimes lead to calculations that are plainly at odds with our view of the world.

For example, due to new price information collected in the 2005 ICP, the World Bank recently revised its estimate of real GDP per capita in China for the year 2005 ***downwards by fully 40%*****!** As Deaton and Heston (2010, p. 3) report:

> …the 2007 version of the World Development Indicators (WDI), World Bank (2007), lists 2005 per capita GDP for China as $6,757 and for India as $3,452, both in current international dollars. The 2008 version, World Bank (2008a,b), which includes the new[2005] ICP data, gives, for the same year, and the same concept $4,088 for China and $2,222 for India. For comparison, GDP per capita at market exchange rates is $1,721 for China and $797 for India.

This remarkable revision to the official numbers from the World Bank is but one recent example that convinces academics that independent estimates of real GDP – that are not constrained by "regional fixity" or other considerations imposed on international agencies – are needed. Such calculations have been made since the 1980s by Alan Heston, Irving Kravis, and Roberts Summers at the University of Pennsylvania (hence the name "PWT"). Their advantage in constructing a dataset like PWT was their knowledge of how ICP was put together and their understanding of how it needed to be modified to produce better international comparability. For example, PWT does not adhere to "regional fixity," but uses the raw price data from the ICP to make entirely new calculations of real GDP for all countries of the world simultaneously. In cases where the raw price data are judged to be unreliable, PWT is free to adjust it (e.g. it adjusts the 2005 ICP prices for China, as discussed below). While PWT can certainly compare its results to those obtained by the World Bank or other agencies, it is not constrained by those other calculations, and can use its own judgment as to the best data and methodology to employ.

In this lecture, I will explain how the real GDP calculations of PWT reported in PWT differ from those of the World Bank, particularly for China. In addition, I will discuss new calculations for China's real GDP that will be made by the "next generation" of scholars taking over this project. I have been meeting with Alan Heston for close to a decade to learn about the methodology used in PWT, while a similar line of research has been undertaken for many years at the University of Groningen, inspired by the work of Angus Maddison and now directed by Marcel Timmer (see Inklaar and Timmer, 2009; and O'Mahony and Timmer, 2009). Heston, Timmer and myself have met with others at annual workshops since 2004 to discuss this research. These meetings have included scholars such as Bert Balk (2008), Erwin Diewert (2010a,b), Angus Deaton (2010) and Peter Neary (2004). At the meeting in 2010 at the University of Oxford, it was decided that the work of PWT would transition to the University of California, Davis and the University of Groningen, effective with PWT version 8, planned for release in 2013. In this lecture, I will draw on the work of Feenstra, Inklaar and Timmer (2012) and present some of the preliminary estimates for real GDP in China coming from this "next generation" of PWT. I will focus on 2005, since that is the latest year for which there is an ICP benchmark.[6]

3. The 2005 ICP data

For its estimates of real GDP reported in the World Development Indicators, the World Bank takes as given the price data reported by the ICP. China was included in the ICP for the first time in 2005, and it is believed that the prices collected were more representative of urban rather and higher than found in rural areas. Evidence for this comes from the Asian Development Bank (2007), which reports that the prices collected in China were restricted to 11 capital cities and the rural areas surrounding these 11 cities. The ADB constructed a national average price using a method of extrapolation also described in ADB (2007). However, the extrapolation method did not make any explicit allowance for spatial price differences across different regions and across rural and urban regions of China. As a result the general consensus is that national average prices have a tendency to overstate the actual prices.

The estimate of real GDP in China of $4,088 per-capita in 2005, coming from the World Bank (2008a), is made using the prices collected under the ICP: as discussed above, the World Bank must maintain "regional fixity" and is not permitted to change these prices when calculating real GDP. But PWT is not constrained in the same way and is able to revise the ICP data if it believes that should occur. In PWT version 7.0, available online since June 3, 2011,[7] there are two estimates for China, labeled as "China version 1" and "China version 2." The first

[6] The price data from the 2011 ICP will not be available until 2013.
[7] See: http://pwt.econ.upenn.edu/

uses the ICP price data as collected for China, and give per-capita real GDP of $4,736 in 2005, while the second version makes an adjustment to the prices of final consumer goods in China to correct for the urban bias, and gives per-capita real GDP of $5,218 in 2005. Notice that both these estimates are well above the World Bank estimate of $4,088. The difference between them is for an adjustment to the ICP prices for China: "version 2" lowers the prices for Chinese consumer goods collected by the 2005 ICP by 20% before being used to compute real GDP in that country. That adjustment is justified based on the gap between rural and urban prices for China, and results in a 10% increase in real GDP, from $4,736 to $5,218.

Feenstra, Ma, Neary, and Rao (2011) have explored an alternative correction to the prices of Chinese consumption goods collected in the 2005 ICP. They predict the Chinese prices from a simple linear regression model of price levels based on data for the other Asian countries. Of the 12 categories of consumption goods, they adjust five prices downwards (for food and non-alcoholic beverages; clothing and footwear; education; restaurants; and other goods and services), four prices upwards (for gross rent, fuel, power; medical and health services; transport; and recreation), and leave three prices unchanged due to lack of data to adjust them.

Focusing on *real consumption*, Feenstra, Ma, Neary, and Rao (2011) find that these corrections to the prices reported by China lead to an increase in Chinese real consumption of between 9% and 21% in 2005, depending on the measure of real consumption that is used. All of the real consumption measures only use the prices and quantities of goods purchased by consumers, and do not consider the role of investment by firms and government expenditure, or export and imports. So in order to compare this adjustment to PWT version 7.0, I need to extend the calculation of real consumption to encompass total GDP, by include investment, government expenditures, and trade, as will be done next.

4. Concepts of Real GDP

When assessing the real GDP of China – or any other country –a distinction should made between the *relative income* of nations and their *productive capacity*. Through engaging in international trade and benefitting from high prices for exports relative to imports, a country can increase the goods available from its income without necessarily improving its productive capacity. Thus, two concepts of real GDP – “real GDP on the expenditure side” and “real GDP on the output side” – should be distinguished to allow a sharper study of the factors leading to a country’s prosperity.

This distinction is made formally by Feenstra, Heston, et al (2009). Let me summarize their theoretical results, and then show how this distinction makes a difference for China.

4.1 Real GDP on the Expenditure-side

PWT uses the so-called Geary-Khamis (GK) system to compute real GDP. To understand this, start with the data for i =1,…,M goods for consumption, investment or government, such as collected by the ICP in each benchmark year, with prices p_{ij} and quantities q_{ij} across countries j = 1,…,C. The reference prices (denoted by “e” for expenditure) π_i^e and the purchasing power parities PPP_j^e are defined as the solution to the simultaneous system:

$$\pi_i^e = \sum_{j=1}^{C} (p_{ij} / PPP_j^e) q_{ij} \Big/ \sum_{j=1}^{C} q_{ij} \;, \qquad i = 1,\ldots,M. \tag{1}$$

$$PPP_j^e = \sum_{i=1}^{M} p_{ij} q_{ij} \Big/ \sum_{i=1}^{M} \pi_i^e q_{ij} \;, \qquad j = 1,\ldots,C. \tag{2}$$

subject to a normalization. The PPP in (2) is used to adjust expenditure in national currency to obtain that in reference prices, or real expenditure:

$$\sum_{i=1}^{M} \pi_i^e q_{ij} = \sum_{i=1}^{M} p_{ij} q_{ij} \;/\; PPP_j^e , \qquad j = 1,\ldots,\mathrm{C}. \tag{3}$$

PWT defines real GDP by using the purchasing-power-parity exchange rate in (2) to convert nominal GDP, in national currency, to real GDP measured in dollars across countries:

$$\begin{aligned} RGDP_j^e &\equiv (\text{Nominal } GDP_j)/PPP_j^e \\ &= \textstyle\sum_{i=1}^{M} \pi_i^e q_{ij} + (X_j - M_j)/PPP_j^e \end{aligned} \tag{4}$$

where the equality follows from nominal $GDP_j = \sum_{i=1}^{M} p_{ij} q_{ij} + (X_j - M_j)$, where X_j and M_j are the nominal values of export and imports. Note that PPP_j^e is defined in (2) and (3) is computed over all final goods, i.e. for consumption, investment and government expenditures, but in (4) we use that purchasing-power-parity exchange rate to *also* convert nominal export and imports into real terms. We use the superscript *e* on real GDP^e to stress that this is an expenditure-based measure, since the price used to compute PPP_j^e are those for final goods only. As discussed by Feenstra, Heston *et al* (2009), this measure of real GDP is intended to reflect the *living standards* or *consumption possibilities* of an economy.

In Feenstra, Inklaar and Timmer (2012), calculations of real GDP^e are made for all the countries included in the 2005 ICP benchmark, and in Table 1 we report preliminary results for just a handful of countries. Iceland, listed first in the table, has the highest nominal GDP per-capita when it is converted to dollars using market exchange rates, as shown in column (1). But in real terms, $RGDP^e$ is the highest for the United States, at $41,553 per-capita. We adopt the normalization that $RGDP^e$ for the United States equals its nominal GDP per-capita in 2005, and that normalization fixes the calculation of $RGDP^e$ for all countries from the GK system. Iceland has $RGDP^e$ of $38,592, for example, and the other countries shown in Table 1 are lower than that. China has *RGDP*^{e} of $5,097, which is about 25% higher than the World Bank's calculation of $4,088.

The impact of making these adjustments to the prices of Chinese consumption goods are reported in the final row of Table 1. After making the adjustments recommended by Feenstra, Ma, Neary and Prasada Rao (2011), as described in the previous section, real GDP^e for China rises to $5,543, which is 35% higher than the World Bank's estimate. The increase from $5,097 to $5,543 is a 9% rise, which is roughly the same magnitude as the rise from "version 1" to version 2" of the estimate reported by PWT. In other words, even though PWT uses a *uniform* 20% reduction in the price of all consumer goods in China, whereas Feenstra, Ma, Neary, and Rao (2011) use an adjustment whose size differs across goods, we still find that the impact of these adjustment are about the same in both cases. That gives me confidence in the specific adjustments to the consumer prices that made by Feenstra, Ma, Neary, and Rao (2011). Even though the "next generation" estimates are not that different from PWT, however, both sets of estimates *are higher than those* made by the World Bank (2008a). I believe that the "regional linking" which is done by the World Bank must account for that remaining difference.

To summarize, the "next generation" of PWT finds an estimate of real GDP per capita for China of $5,097 for 2005, or $5,543 after correcting for the urban price bias. These estimates are 25–35% higher than the figure of $4,088 reported by the World Bank. I believe, however, that the actual size of the Chinese economy is even bigger than this, once we start to distinguish different concepts of GDP. In the next section I will discuss an alternative output-based measure, real GDP^o, that reflects the *production possibilities* of an economy.

4.2 Real GDP on the Output-Side

I will now establish results for real GDP^o on the output-side. The *M* final goods still include those used for consumption, investment and government purchases, all of which are treated as non-traded. In addition, suppose that there are *i* =M+1,…,M+N intermediate inputs that can be both imported and exported (imports and exports are different varieties). For example, a car imported at its wholesale price would show up as an imported intermediate input, and then when the car is sold at a retail price it would be treated a non-traded final good. This convention that all traded goods are by definition intermediate inputs follows the "production approach" to modeling imports and exports of Diewert and Morrison (1986) and Kohli (2004), as will be followed here.

Specifically, let us denote three groups of commodities:

- those for final domestic demand (quantities $q_{ij} \geq 0$ and prices $p_{ij} > 0$, for *i* = 1,…,M);
- those for export (quantities $x_{ij} \geq 0$ and prices $p_{ij}^x > 0$, for *i* = M+1,…,M+N);
- imported intermediate inputs (quantities $m_{ij} \geq 0$ and prices $p_{ij}^m > 0$, *i* = M+1,…,M+N).

The world price vectors for exports and imports are p_j^x and p_j^m in country *j*, and domestic prices are $p_j^x + s_j$ and $p_j^m + t_j$, where s_j is the vector of export subsidies and t_j is the vector of import tariffs.

We will distinguish the reference prices π_i for final goods, *i* =1,…,M, and two sets of reference prices π_i^x, π_i^m for exports and imported intermediate inputs, *i* =M+1,…,M+N. These reference prices are computed as a weighted average of observed prices, from the system:

$$\pi_i^o = \sum_{j=1}^{C} (p_{ij} / PPP_j^o) q_{ij} \Big/ \sum_{j=1}^{C} q_{ij}, \qquad i = 1,\ldots,M, \tag{5}$$

$$\pi_i^x = \sum_{j=1}^{C} (p_{ij}^x / PPP_j^o) x_{ij} \Big/ \sum_{j=1}^{C} x_{ij}, \qquad i = M+1,\ldots,M+N, \tag{6}$$

$$\pi_i^m = \sum_{j=1}^{C} (p_{ij}^m / PPP_j^o) m_{ij} \Big/ \sum_{j=1}^{C} m_{ij} \ , \qquad i = M+1,\ldots,M+N, \qquad (7)$$

and,

$$PPP_j^o = \frac{\text{Nominal GDP}_j}{\sum_{i=1}^{M} \pi_i^o q_{ij} + \sum_{i=M+1}^{M+N} (\pi_i^x x_{ij} - \pi_i^m m_{ij})}, \ j = 1,\ldots,C. \qquad (8)$$

As in the GK system (1)–(2), one normalization is needed in the system (5)–(8). This system *extends* the GK system by adding information on export and import prices and quantities.

The measure of real GDP on the output-side, or real GDP^o, is defined using reference prices for final outputs π_i^o, exports π_i^x and imports π_i^m, as:

$$\begin{aligned} RGDP_j^o &\equiv \sum_{i=1}^{M} \pi_i^o q_{ij} + \sum_{i=M+1}^{M+N} (\pi_i^x x_{ij} - \pi_i^m m_{ij}) \\ &= \sum_{i=1}^{M} \pi_i^o q_{ij} + (X_j / PPP_j^x) - (M_j / PPP_j^m), \end{aligned} \qquad (9)$$

where the equality follows by defining the PPPs of exports and imports, over the traded goods *i = M+1,…,M+N:*

$$PPP_j^x = \sum_{i=M+1}^{M+N} p_{ij}^x x_{ij} \Big/ \sum_{i=M+1}^{M+N} \pi_i^x x_{ij} \ \text{and} \ PPP_j^m = \sum_{i=M+1}^{M+N} p_{ij}^m m_{ij} \Big/ \sum_{i=M+1}^{M+N} \pi_i^m m_{ij} \, . \qquad (10)$$

I follow Feenstra, Heston *et al* (2009) in rewriting $RGDP_j^o$ to give a clear interpretation about the difference between it and $RGDP_j^e$. Notice that $RGDP_j^o$ in (9) can be decomposed as:

$$RGDP_j^o = \left(\frac{\sum_{i=1}^{M} \pi_i^o q_{ij}}{\sum_{i=1}^{M} p_{ij} q_{ij}} \right) \sum_{i=1}^{M} p_{ij} q_{ij} + \left(\frac{\sum_{i=M+1}^{M+N} \pi_i^x x_{ij}}{\sum_{i=M+1}^{M+N} p_{ij}^x x_{ij}} \right) X_j - \left(\frac{\sum_{i=M+1}^{M+N} \pi_i^m m_{ij}}{\sum_{i=M+1}^{M+N} p_{ij}^m m_{ij}} \right) M_j \, . \qquad (11)$$

The three ratios appearing in (11) are defined as the inverse of the PPP's for final expenditure, exports and imports:

$$PPP_j^q \equiv \left(\frac{\sum_{i=1}^{M} p_{ij} q_{ij}}{\sum_{i=1}^{M} \pi_i^o q_{ij}} \right), \; PPP_j^x \equiv \left(\frac{\sum_{i=M+1}^{M+N} p_{ij}^x x_{ij}}{\sum_{i=M+1}^{M+N} \pi_i^x x_{ij}} \right), \; PPP_j^m \equiv \left(\frac{\sum_{i=M+1}^{M+N} p_{ij}^m m_{ij}}{\sum_{i=M+1}^{M+N} \pi_i^m m_{ij}} \right).$$

It will be convenient to work instead with the associated *price levels* for final goods, exports and imports, obtain by dividing the PPP's by the nominal exchange rate E_j:

$$PL_j^e \equiv \frac{PPP_j^e}{E_j}, \quad PL_j^q \equiv \frac{PPP_j^q}{E_j}, \quad PL_j^x \equiv \frac{PPP_j^x}{E_j}, \quad PL_j^m \equiv \frac{PPP_j^m}{E_j}.$$

Comparing (4) and (11), it is immediate that the difference between $RGDP_j^e$ and $RGDP_j^o$ is:

$$\frac{RGDP_j^e - RGDP_j^o}{RGDP_j^e}$$

$$= \left(1 - \frac{PL_j^e}{PL_j^q}\right)\left(\frac{\sum_{i=1}^{M} p_{ij} q_{ij}}{GDP_j}\right) + \left(1 - \frac{PL_j^e}{PL_j^x}\right)\left(\frac{X_j}{GDP_j}\right) - \left(1 - \frac{PL_j^e}{PL_j^m}\right)\left(\frac{M_j}{GDP_j}\right). \tag{12}$$

In practice, PL_j^e and PL_j^q are often quite similar, since they are both computed from final expenditures, but with different reference prices. If these two deflators for final expenditure are equal, then either $PL_j^x > PL_j^e$ or $PL_j^m < PL_j^e$ is needed to have real GDP_j^e exceed real GDP_j^o, and both inequalities holding is sufficient for this. To interpret these conditions, having export prices above their reference level and import prices below their reference level will contribute towards $RGDP_j^e$ exceeding $RGDP_j^o$. For example, proximity to markets that allow for higher export prices would work in this direction, but being distant from markets leading to high import prices would work in the opposite direction, raising PL_j^m and tending to make $RGDP_j^e$ less than $RGDP_j^o$.

Empirical implementation of the GK method from the output-side described in equations (5)-(8) was done for the 1996 ICP benchmark in Feenstra, Heston, et al (2009), but China was not included in that benchmark. Results for the 2005 benchmark are currently being undertaken as a part of the "next generation" PWT methodology described in Feenstra, Inklaar and Timmer (2012). They use the normalization that $RGDP_j^e$ equals $RGDP_j^o$ when summed across for the 2005 sample of countries. Complete results for all countries are reported in Feenstra, Inklaar and Timmer (2012), and preliminary results for a handful of countries are shown in Table 1.

It can be seen from Table 1 that per-capita $RGDP_j^o$ for China exceeds $RGDP_j^e$, so China is even bigger when viewed from its ability to produce goods. To see where this calculation comes from, equation (12) is computed for China as:

$$\frac{RGDP_j^e - RGDP_j^o}{RGDP_j^e} = \left[\quad 0 \quad\right]0.95 + \left[1 - \left(\frac{0.32}{0.45}\right)\right].36 - \left[1 - \left(\frac{0.32}{0.68}\right)\right]0.31 \approx -0.06.$$

The first term appearing on the right of (12) is zero, because the price levels PL_j^e and PL_j^q, both computed over just final goods, are equal at 0.32. The price level for exports in China is about 0.45, or slightly less than one-half of the reference prices for exports, while the price level of imports is about 0.68. That means the *terms of trade* for China is 0.45/0.68 < 1, which make $RGDP_j^e$ less than $RGDP_j^o$. This finding occurs even though nominal exports are larger than nominal imports, which would tend to make $RGDP_j^e$ exceed $RGDP_j^o$ (i.e. as would occur if the price levels for exports and equal were equal but above that for final goods). So we see that real GDP on the output side for China is higher than that on the expenditure side, by about 6%. This means that $RGDP_j^o$ exceeds the World Bank estimate of real GDP by more than 40%.

The finding that $RGDP_j^o$ exceeds $RGDP_j^e$ holds for the other developing countries and newly-industrialized countries in Table 1, with the reverse comparison holding for the developed countries. This illustrates the tendency for the developed countries to have strong terms of trade which tend to make (28) positive. There are many exceptions to this tendency, however. Norway, for example (not shown in Table 1) has the highest value of per-capita $RGDP_j^o$, at $58,842, which is more than 25% above its per-capita $RGDP_j^e$, at $46,242. This result comes from a low terms of trade for Norway, which can be traced to unusually high import prices. Conversely, Chad (also not shown in Table 1) has per-capita $RGDP_j^o$ at $4,030, which is 25% below its per-capita $RGDP_j^e$, at $5,373. That result, in turn, can be traced to a strong terms of trade. So the terms of trade faced by countries are positively but only weakly correlated with the real GDP on the expenditure side.

Finally, when computing real GDP on the output-side for the United States in Table 1, it can be seen that its value falls from real GDP on the expenditure-side, from $41,553 to $39,550 per-capita. Thus, taking the ratio of real GDP on the output-side for China relative to the U.S., we obtain $5,862/$39,550 or 15%, using the adjusted Chinese prices. That is fully one and one-half times the ratio of 2005 per-capita real GDP for China and the U.S. from the World Bank, which is $4,088/$41,674 or 9.8%. On this basis, we conclude that real GDP in China relative to the United States is quite plausibly *50% higher* than estimated by the World Bank (2008a).

5. Growth of Real GDP

At the beginning of this lecture I described the press reports that accompanied the publication of the April 2011, *World Economic Outlook*, from the International Monetary Fund, which predicted that China's economy would exceed the size of the United States by 2016. That estimate from the IMF relies on the figures for real GDP published by the World Bank in its World Development Indicators. As I have indicated in this lecture, I believe that the World Development

Indicators understates the size of China, which means that we should expect China to overtake the United States in size *sooner* than the 2016 date predicted by the IMF.

To obtain my own estimate of when China will overtake the United States, I can multiply the estimates in Table 1 by the population of each country to compute total real GDP^e in China and the United States. Given that there are two different estimates for real GDP^e in China, depending on whether we adjust the Chinese prices or not, I take a conservative approach and start with a simple average of those two estimates, which is $5,320 per-capita. Multiplying that by the Chinese population of 1.29 billion in 2005, and similarly for the U.S., I obtain:

- Total real GDP in the U.S., 2005: $ 12,364 billion
- Total real GDP in China, 2005: $ 6,863 billion

Feenstra, Inklaar and Timmer (2012) have made preliminary estimates for 2008, which are as follows:

- Total real GDP in the U.S., 2008 (2005 prices): $ 12,716 billion
- Total real GDP in China, 2008 (2005 prices): $ 8,916 billion

Using the same growth rate in each country from 2005 to 2008, and applying this forward, I obtain the following 2011 estimates:

- Total real GDP in the U.S., 2011 (2005 prices): $ 13,078 billion
- Total real GDP in China, 2011 (2005 prices): $ 11,583 billion

Projecting forward one more year to 2012, I obtain:

- Total real GDP in the U.S., 2012 (2005 prices): $ 13,201 billion
- Total real GDP in China, 2012 (2005 prices): $ 12,639 billion

And finally, projecting forward to 2013, I obtain:

- Total real GDP in the U.S., 2013 (2005 prices): $ 13,325 billion

- Total real GDP in China, 2013 (2005 prices): $ 13,791 billion

Thus, according to these estimates of real GDP^e, China will exceed the United States in size in 2013, if it continues to grow in real terms at the same rate as between 2005 and 2008. Of course, if growth slows in China or speeds up in the United States, then it could take longer for China to overtake the U.S. But more likely, I believe this event could even sooner, because I started this calculation with quite a conservative estimate of 2005 per-capita real GDP^e in China: the simple average of the estimates in Table 1, column (2), which is $5,320. Instead, if I started with the highest estimate of real GDP in China for 2005, which is real GDP^o of $5,862 shown at the bottom of column (3), then all of the above estimates of total GDP for China in future years would be 10% higher than shown, which would mean that China would exceed the United States in size by 2012, or not long after this lecture is published!

While the *future* size of China is a question that is often reported in the press, the *past* size is equally important. Angus Maddison (2007), for example, argues that the downward revision for China made by the World Bank is implausible, because extrapolating backwards it would imply per capita income below subsistence levels in early years. He prefers an estimate in 2005 that is 18.5% of U.S. real GDP (Maddison, 2007, Table 5). I have no basis on which to support a current estimate of real GDP that is that large. But we can still ask what is the appropriate growth rate to apply to real GDP?

PWT has always applied the growth rates from *national accounts data* to real GDP, or more precisely, the growth rates of the national accounts prices of C, I and G to deflate the nominal growth each of these components, with the average of these prices used to deflate the trade balance. This procedure used by PWT was intended to be simple: the goal was to make the growth rate of real GDP in PWT essentially the same as the growth rate of real GDP in the national accounts. Unfortunately, it did not achieve that goal. As explained in Feenstra, Heston *et al* (2009, Appendix) and Johnson *et al* (2009), the growth rates for past years reported in PWT differ each time the prices from a new ICP benchmark was used. The reason for this change is that while the growth rates of real C, I, G and (X – M) were fixed by national accounts data, the growth rate of real GDP is a weighted average of these, and the weights (which are shares of real GDP) depend on the benchmark year. Thus, growth rates of real GDP were not invariant to the benchmark year of ICP data being used. Furthermore, all information from *earlier* benchmark years was ignored each time a new benchmark was used.

In the "next generation" of PWT, as reported in Feenstra, Inklaar and Timmer (2012), both of these deficiencies will be addressed. It is relatively easy to address the first issue, by simply fixing the weights (i.e. shares of real GDP) to be the average obtained from two benchmark years before and after the dates for which growth is calculated. For example, growth rates between 1996 and 2005 could be computed using an average of the shares of real GDP in those years, and these weights remain *unchanged* even when the next benchmark year of ICP data – 2011 – is ready for use. But the second deficiency – the fact that earlier benchmarks are not used to compute the growth of components of real GDP – requires more careful work. Feenstra, Inklaar and Timmer (2012) propose a method that interpolates between the ICP benchmarks using the national accounts prices information, so we obtain a hybrid set of prices that combine the successive ICP rounds with national accounts information in the intervening years. The advantage of that method is that all the ICP rounds, from 1970, 1975, 1980, 1985, 1996 and 2005, remain important in establishing the relative GDP across countries.

Unfortunately, China was not included in an ICP round until the most recent 2005 estimates, so the method proposed by Feenstra, Inklaar and Timmer (2012) cannot be applied to

China. But a neighboring country – India – was included in 1970 and the successive rounds. So by studying how the growth rate of real GDP in India is affected by using the earlier information, I can conjecture how the growth of real GDP in China would also be affected if the ICP price data had been collected in earlier rounds.

Figure 1 shows the series RGDPE_NA for China, which is real GDP^e extended from 2005 using the growth rates of C, I and G from the national accounts. This is essentially the same as the method currently used in PWT, except that a new benchmark appears for China (in 2011), so the weights used to aggregate the components of GDP will not change in years before 2005. Also shown is the series RGDPE_NG for China, which is the "next generation" calculation of real GDP^e, using an alternative formula for the growth rate that in principle depends on past benchmarks. Because there are no previous benchmarks for China, these two series are very close (except in the final year 2008).[8]

Likewise, Figure 2 shows the series RGDPE_NA for India, which is similar to the method currently used in PWT, except correctly the first deficiency: i.e. the weights used to aggregate the components of GDP are fixed between benchmark years. Also shown is the series RGDPE_NG for India, which is the "next generation" calculation of real GDP^e, using an alternative formula for the growth rate that depends on past benchmarks. Because India was included in the 1970 and subsequent benchmarks in the ICP, its real GDP relative to the U.S. is fixed by these benchmarks rather than by national accounts growth rates (which are only used for interpolation in-between the benchmark years). What can be seen is that real GDP^e in India is *much larger* using the ICP data in1970 than obtained by simply applying the growth rates of components of GDP, as PWT has previously done: real GDP^e is estimated at $1,672 using the

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[8] There is a substantial increase in Chinese price from 2007 to 2008, especially for investment goods, which turns out to have a greater impact of reducing growth of the "next generation" (NG) series than that based on the national accounts (NA).

ICP data, but only one-half as much, $876, using the national accounts growth rates. A substantial difference also occurs for 1975 and 1980, while by 1985 the difference between the two series is small. Evidently, the ICP benchmark price data contains information that is not accurately reflected in the national accounts price indexes for consumption, investment and government expenditures.

I would conjecture that if China had been included in early rounds of the ICP, perhaps a similar result would obtain as found for India: rather than having real GDP^e of about $400 in 1970, as shown in Figure 1, perhaps a higher figure would be obtained using actual cross-country price data in that year. If so, then such a result would address the concern expressed by Maddison (2007), that the World Bank estimate of real GDP^e in 2005 is too low to allow for consumption above a subsistence level in earlier periods.

6. Conclusions

In this lecture I have analyzed the revision to real GDP for China made by the World Bank using prices from the 2005 round of the International Comparison Program. Because those prices were higher than expected for China, the corresponding estimate of real GDP in China was lowered: from $6,757 per-capita in World Bank (2007) to $4,088 in World Bank (2008a). Possible reasons for this downward revision have been discussed by Deaton and Heston (2010), and here I provide some alternative estimates of real GDP in China, drawing from the "next generation" of PWT in Feenstra, Inklaar and Timmer (2012).

The empirical results reported here are based on data from the 2005 ICP benchmark comparisons reported in World Bank (2008b). I have drawn upon Feenstra, Ma, Neary and Rao (2011), who provide revised estimates for real consumption in China after making adjustments to prices reported and used in the 2005 ICP comparisons in the Asia-Pacific. Making use of a regression model to explain commodity-specific price levels as a function of real per capita income, and applying the resulting adjustments to price data for China, they measure the revisions to be anywhere between 9% to 21% depending upon the method used to measure real consumption.

Moving from just consumption to total GDP, I have found that the GK estimate of real GDP on the expenditure-side for China is $5,097 in 2005, which is 25% larger than the estimate from the World Bank of $4,088. Also adjusting for the prices of consumption goods, then real GDP^e per capita rises to $5,543, or another 10%. Furthermore, from Feenstra, Inklaar and Timmer (2012), preliminary estimates of real GDP measured on the output-side for China are obtained, which are $5,433 per-capita without the adjustment to consumption prices and $5,862 with this adjustment. The latter estimate is nearly 45% higher than the World Bank figure of $4,088 for real GDP per-capita in China in 2005.

In addition, the same calculation, when switching from expenditure to output, lowers U.S. real per-capita GDP from $41,553 to $39,550. Relative to this, China's real GDP per capita is $5,862/$39,550 or 15%, using the adjusted Chinese prices. That estimate is fully one and one-half times the ratio of real GDP from the World Bank in 2005, which is $4,088/$41,674 or 9.8%. On this basis, we conclude that real GDP in China relative to the United States is quite plausibly *50% higher* than estimated by the World Bank (2008a). An implication of this larger size for China is that it will overtake the U.S. much earlier than predicted by the International Monetary Fund: instead of overtaking in 2016, we expect that China will be larger in 2013 or even 2012. Indeed, on my next opportunity to present a lecture at Peking University, I may very well be visiting a country that is larger than the United States in its economic size!

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Table 1: Comparisons of Real GDP per Capita, 2005

Countries	GDP per-capita ($)			GDP per-capita, Relative to the U.S.		
	Nominal GDP	$RGDP^e$	$RGDP^o$	Nominal GDP	$RGDP^e$	$RGDP^o$
	(1)	(2)	(3)	(4)	(5)	(6)
Iceland	51,858	38,592	37,640	1.248	0.929	0.952
United States	41,553	41,553	39,550	1.000	1.000	1.000
United Kingdom	37,190	32,401	30,640	0.895	0.780	0.775
Netherlands	31,414	33,626	31,065	0.756	0.809	0.785
Canada	30,375	33,975	32,159	0.731	0.818	0.813
South Korea	12,341	24,044	26,774	0.297	0.579	0.677
Macedonia	3,158	7,374	8,240	0.076	0.177	0.208
China	956	5,097	5,433	0.023	0.123	0.137
India	582	2,423	2,479	0.014	0.058	0.063
With adjusted Chinese prices:						
China		5,543	5,862		0.133	0.148
% Difference from China above		8.8	7.9		8.8	7.9

Source: Preliminary calculations from Feenstra, Inklaar and Timmer (2012)

Notes: Column (1) give GDP per-capita converted using the nominal exchange rate, and columns (2)-(3) present real GDP measures on the expenditure-side and the on the output-side, respectively. Columns (4)-(6) also give the GDP per-capita measures but expressed relative to the United States.

Figure 1: Real GDP per-capita for China

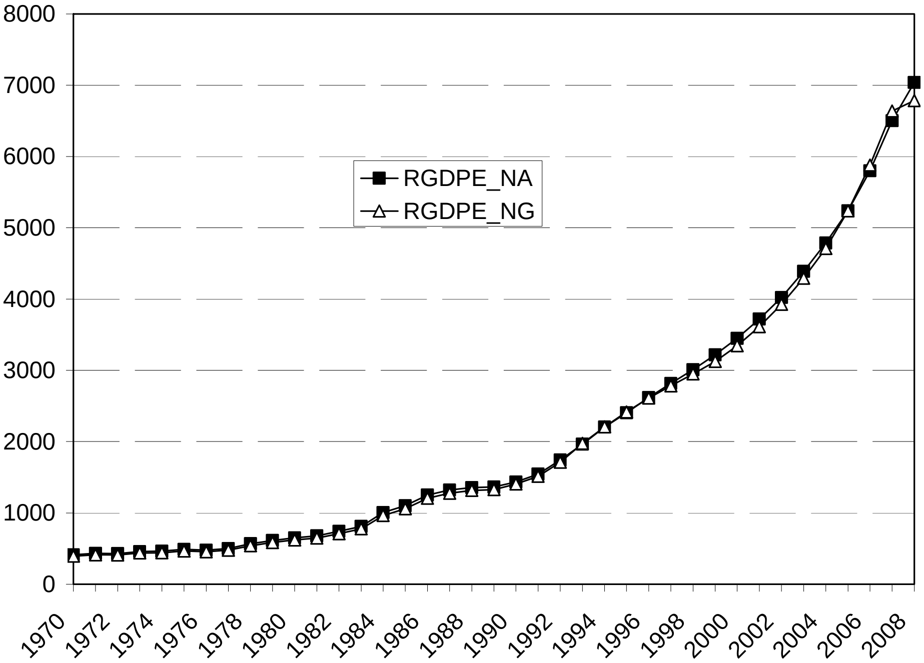
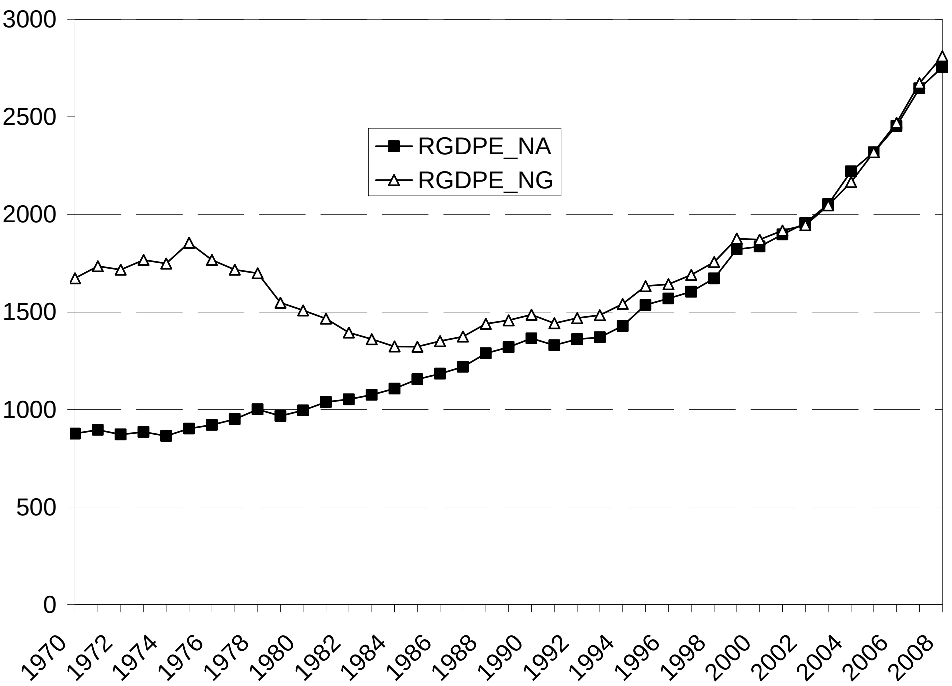


Figure 2: Real GDP per-capita for India



Source: Preliminary calculations from Feenstra, Inklaar and Timmer (2012)