Estimating Real Production *and* Expenditures Across Nations: A Proposal for Improving the Penn World Tables[*]

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Abstract

We propose a new approach to the international comparison of real GDP, as measured from the output-side. The traditional Gary-Khamis system, which measures real GDP from the expenditure-side, is modified to include differences in the terms of trade between countries. It is shown that this system has a strictly positive solution under mild assumptions. On the basis of a sample of 151 countries in 1996, it is shown that differences between real GDP measured from the expenditure-side and output-side can be substantial, especially for small open economies. We also obtain cross-country measures of "real openness" and the terms of trade.

JEL-code: F41, O47

1. Introduction

From its inception, the Penn World Tables (PWT), building on the International Comparisons Program (ICP) of the United Nations, has sought to compare the *standard of living* of individuals in different countries. That is, the term "real GDP per capita" as reported in the PWT is intended to represent the ability to purchase goods and services by a representative agent in the economy. The same is true of benchmark comparisons as published by the United Nations, Eurostat or OECD. As such, real GDP is a measure of the wealth of nations, which indicates the amount of goods and services that are available for consumption and investment. However, this expenditure-side interpretation of real GDP is quite different from the uses to which benchmark ICP and PWT data are often applied, where "real GDP" is intended to reflect the output-side of the economy. For example, in the "technology gap" models such as Acemoglu, Aghion and Zilibotti (2006), the value of adopting technologies depends on each country's distance to the world technology frontier. When these models are applied to country-level data, as in Vandenbussche, Aghion and Meghir (2006), then real GDP on the output-side (relative to the factor inputs) should be used to measure the technology frontier, and not real-GDP on the expenditure-side, which is influenced by a country's terms of trade.[1]

A simple example can illustrate the difference between these two concepts of real GDP. In a two-good open economy, suppose that the price of the country's export good rises relative to the price of its imports, but outputs do not respond. Since the representative consumer is better off, we will argue that real GDP measured on the expenditure side has increased. But since outputs have not changed, then there is also no change in real GDP on the output-side. Studies that are interested in the wealth of countries would want to use the former concept of real GDP, whereas studies that are interested in country productivity would want to use the latter concept.

We will give more specific examples from the literature in section 5.

The goal of this paper is to carefully distinguish the output-side measure of real GDP, denoted *real GDP*^{o}, from the expenditure-side measure, denoted *real GDP*^{e}. The reason these concepts were not distinguished in the ICP and PWT is that these projects treat the net foreign balance in an unsatisfactory way. While there may have been some data justifications for that treatment in benchmark studies of the 1970s, this is no longer the case. In this paper we will introduce new series of both real GDP^{o} and real GDP^{e} which complement the PWT. The treatment of exports and imports proposed here will not only remove the ambiguity presently surrounding real GDP in the ICP and PWT, but provides a rich new international measure, namely the difference between them. Essentially, these two concepts differ by the *terms of trade* in the economy, i.e. the prices at which goods are exported and imported. We provide a new cross-country series on the terms of trade, which is used to construct a new measure of openness, called *real* openness, that should prove useful in studies of trade and income.

In section 2, the distinction between real GDP on the output-side and expenditure-side is set out conceptually, followed by a discussion of how they are separately measured in time series data. In order to incorporate these concepts into the PWT, however, we need to have a cross-country measure of their difference. To achieve this, we propose a measure of the purchasing power parity for outputs (PPP^{o}) rather than expenditures (PPP^{e}). Currently the cornerstone of the ICP and PWT is the PPP for final expenditures (PPP^{e}), used to deflate nominal national income to obtain real GDP^{e}. Expenditure PPPs are constructed from the prices of final goods, whether they are produced domestically or imported. If instead we want to deflate nominal GDP to obtain *real GDP*^{o}, then we need to use PPP^{o}, which incorporates prices for exports, and nets out the prices of imports.

In section 3 we show how PPP^o can be computed using the Geary (1958)-Khamis (1970,1972) (GK) system, and how it is built up from separate PPP's for final expenditures, exports and imports. It should be emphasized that by working at the level of entire economies, rather than sectors, some of the difficulties with measuring real GDP from the output side are avoided. In particular, we find that while the *international* prices of intermediate inputs are used, the corresponding *domestic* prices of intermediates are not needed at all. In this sense, our use of trade data provides a *short cut* to obtain output-based deflators for the entire economy.[2]

In section 4, we provide an empirical application of our techniques. The data used for this illustration are from the 1996 ICP-PWT benchmark comparison, using 4-digit SITC export and import unit-values for 151 countries. With the normalization that world real GDP^e equals world real GDP^o, we find that one-third of the countries have real GDP^e exceeding real GDP^o, which means that they are less productive than indicated by the PWT and instead benefit from high terms of trade. Included in this group are Austria, New Zealand, Japan, North America and most countries in Europe, but also a set of developing countries that happen to benefit from high unit-values on selected export products. The remaining two-thirds of countries have real GDP^e below real GDP^o, which means that they are more productive than indicated by the PWT but have low terms of trade. That group has lower GDP per capita on average than the former group, but still includes some wealthy countries such as Australia, Hong Kong and Norway.

When we split our sample between oil and non-oil exporters, we find that the relationship between GDP per capita and the terms of trade differs for the two sets of countries. Generally, there is a positive relationship for non-oil exporters: countries with higher per-capita GDP also have higher terms of trade. This terms of trade effect is driven mainly by an increase in export price levels, as import price levels are relatively stable. In contrast, we find no significant relationship between GDP per capita and the terms of trade for our set of 25 oil exporters. This appears to be due to the fact that export prices in these countries are driven by movements in the global oil market that are common to all.

We have extended the benchmark calculations for real GDP^e and real GDP^o backwards and forwards in time, creating "constant price" real GDP series that are alternatives to the constant-price series reported in PWT. This is reported in the Appendix to this paper. [3] In section 5 we show how the new series for real GDP^e, real GDP^o, and real openness can be used in practice, by re-estimating some studies using these series. Conclusions and directions for further research are discussed in section 6.

2. Concepts of Real GDP

The distinction between real GDP on the output and expenditure-side can be illustrated by a simple diagram in a two-good economy, shown in Figure 1. We suppose that the production possibilities frontier shifts out due to technological change. At unchanged prices, production would increase from point A to point B. Suppose, however, that the relative price of good 1 falls due to its increased supply, so that the new prices are shown by the slope of the line P_3P_3. Production now occurs at B' rather than B. We have drawn the case where the budget lines P_1P_1 and P_3P_3 are both tangent to an indifference curve U, at points C and D, indicating that the utility of the representative consumer is unchanged. In the case we have illustrated, the production points A and B' lie on the same ray from the origin so that the *relative outputs* of the two goods are unchanged. This means that any index of real output would be identical, and would simply equal 0B'/0A > 1, which is the proportional increase in both outputs. This is the increase in real GDP^o as measured on the output-side and reflects an increase in productive capacity.

Now suppose we pose a different question, and ask what has happened to the welfare of the representative consumer, with indifference curve shown by U in Figure 1. An exact measure of consumer welfare, or real GDP^e measured on the expenditure-side, would be *unchanged* since the consumer has the same utility at the two sets of prices. This occurs because there has been a fall in the price of the exportable good 1. The change in real GDP^e could be measured by the change in nominal expenditure deflated by an *exact consumer price index*, constructed with the same prices as real GDP^o but using *consumption quantities* rather than *production quantities* in the index. The difference between these is exports and imports, of course, but for production quantities we also need to include the imports and exports of all *intermediate inputs,* as well as their prices. These data are not currently used by the ICP, which restricts attention to final goods.

This distinction between real GDP on the expenditure and output-side is recognized by the United Nations 1993 System of National Accounts (SNA). The former is called real Gross Domestic Income (GDI), while the latter is real GDP. One definition[4] of real GDI is:

$$\text{Real GDI} = (\text{Nominal GDP})/(\text{Domestic absorption price index}), \qquad (1)$$

as compared to:

$$\text{Real GDP} = (\text{Nominal GDP})/(\text{GDP price index}). \qquad (2)$$

Nominal GDP, of course, is domestic absorption (C+I+G) adjusted for the trade balance (X–M). The "domestic absorption price index" in (1) is constructed over the components of (C+I+G). By *excluding* export and import prices from this price index, changes in the terms of trade (which affect nominal GDP) are then reflected in real GDI, as demonstrated by Diewert and Morrison (1986). An improvement in the terms of trade would cause real GDI to grow faster than real GDP. Kohli (2004, 2006) has shown that this pattern holds for Switzerland and Canada, for example, due to their terms of trade improvements. Kehoe and Ruhl (2006) also show how the terms of trade affect real income, but should not have a first-order effect on real GDP. We shall avoid the term “real GDI,” because it is suggestive of the income-approach to measuring GDP (i.e. adding up the earnings of factors) which we do not use. Instead, we use real GDP^e to reflect the expenditure-side concept like (1), and real GDP^o to reflect the output-side concept like (2).

Now we come to the key question motivating this paper: which concept does the PWT use as “real GDP” – the output-side measure real GDP^o, or the expenditure-side measure real GDP^e? It turns out that the answer is unclear: the ICP constructs real GDP^e in *benchmark years*, but then to interpolate between these years, the PWT must reconcile these changes in real GDP^e with the national accounts data reports on countries real GDP growth. Since national accounts real GDP growth is closer to real GDP^o, which is being compared to benchmark estimates of real GDP^e, the distinction between these becomes lost in the reconciliation, as we shall discuss further in section 5 and in the Appendix. The fact that the distinction between real GDP^e and GDP^o is not clearly made is a limitation of previous versions of the PWT that this paper and future revisions intend to improve upon.

3. Measurement of Real GDP

Suppose there are i =1,…,M final goods, such as the categories of goods currently collected by the ICP, of which the first M_0 are non-traded. These final goods may also be used as intermediate inputs, and there are another i =M+1,…,M+N goods that are exclusively intermediate inputs; for convenience we treat these all as traded internationally. To treat domestic demand, trade and production in a consistent framework, an input-output analysis must be used. In this framework the fundamental equality is between total demand and total supply of each good. For each country j = 1,…,C, denote final demand[5] by q_{ij}, intermediate demand by z_{ij}, output by y_{ij}, exports by x_{ij} and imports by m_{ij}, for i = 1,…,M+N. We assume that all of these quantities are *nonnegative,* but many can be zero: in particular, the intermediate inputs i = M+1,…,M+N have $q_{ij} = 0$, and the non-traded goods = 1,…,M_0 have $x_{ij} = m_{ij} = 0$. Total demand in country j is given by $q_{ij} + x_{ij} + z_{ij}$, and total supply by $y_{ij} + m_{ij}$. Hence the equality between demand and supply is:

$$q_{ij} + x_{ij} + z_{ij} = y_{ij} + m_{ij}, \quad i = 1,\ldots,M+N. \qquad (3)$$

Re-arranging terms, we obtain:

$$q_{ij} + x_{ij} - m_{ij} = y_{ij} - z_{ij}, \quad i = 1,\ldots,M+N. \qquad (4)$$

where we refer to $y_{ij} - z_{ij}$ as "net output" of each good, i.e. gross output minus intermediate demand.

Multiplying by prices and summing over goods i = 1,…,M+N, nominal GDP can be measured either from the expenditure side (left-hand side of (4)) or from the production side (right-hand side), where the units are the national currency. We presume that for a particular product, the prices of exports and imports can differ from domestic output and consumption. Such price differences always occur in practice, which is why we incorporate them here, without considering why the price differences arise. We distinguish the prices $p_{ij} > 0$ for domestic output and consumption, used to multiply q_{ij}, i = 1,…,M+N, from those for exports and imports, $p_{ij}^{x} > 0$ and $p_{ij}^{m} > 0$ respectively.[6] Consistent with the System of National Accounts (SNA), the export prices are measured *net of tariffs and freight, including any subsidy to the buyer but not to the seller*, i.e. as the f.o.b. (free on board) price in the exporting country.[7] Likewise, the import prices are measured *net of tariffs.*[8]

With these conventions for p_{ij}^m and p_{ij}^x, let $X_j = \sum_{i=M_0+1}^{M+N} p_{ij}^x x_{ij}$ and $M_j = \sum_{i=M_0+1}^{M+N} p_{ij}^m m_{ij}$ denote the value of exports and imports at tariff-free prices, so that nominal GDP measured on the expenditure side is:

$$\text{Nominal GDP}_j^e \equiv \sum_{i=1}^{M} p_{ij} q_{ij} + (X_j - M_j) . \tag{5}$$

Using (4), we can re-write (5) as:

$$\begin{aligned} \sum_{i=1}^{M} p_{ij} q_{ij} + (X_j - M_j) &= \sum_{i=1}^{M+N} p_{ij}[(y_{ij} - z_{ij}) - (x_{ij} - m_{ij})] + \sum_{i=M_0+1}^{M+N} (p_{ij}^x x_{ij} - p_{ij}^m m_{ij}) \\ &= \sum_{i=1}^{M+N} p_{ij}(y_{ij} - z_{ij}) + \sum_{i=M_0+1}^{M+N} [(p_{ij} - p_{ij}^m) m_{ij} - (p_{ij} - p_{ij}^x) x_{ij}] \quad , \end{aligned} \tag{6}$$

where the first line is obtained by using $q_{ij} = (y_{ij} - z_{ij}) - (x_{ij} - m_{ij})$ for the final goods i=1,…,M, whereas the intermediates have $q_{ij} = 0$, so that $[(y_{ij} - z_{ij}) - (x_{ij} - m_{ij})] = 0$ for i=M+1,…,M+N. Then the second line follows because $x_{ij} = m_{ij} = 0$ for the non-traded goods i=1,…,M_0. We can interpret $(p_{ij} - p_{ij}^m)$ as import tariffs (subsidies if negative), and $(p_{ij} - p_{ij}^x)$ as exports subsidies (taxes if negative). So the final summation on the second line is interpreted as import revenue less export subsidies. Adding this to the value of net output $\sum_{i=1}^{M+N} p_{ij}(y_{ij} - z_{ij})$ as in (6) gives us nominal GDP measured on the production or output side:

$$\text{Nominal GDP}_j^o = \sum_{i=1}^{M+N} p_{ij}(y_{ij} - z_{ij}) + \sum_{i=M_0+1}^{M+N} [(p_{ij} - p_{ij}^m) m_{ij} - (p_{ij} - p_{ij}^x) x_{ij}] , \tag{7}$$

which clearly equals nominal GDP measured on the expenditure side, from (6).

The real counterpart to GDP measured on the expenditure-side in the PWT is obtained by using data for many countries, and computing average “reference prices” for goods according to the Geary-Khamis (GK) system. The reference prices π_i^e for final goods and the purchasing power parities PPP_j^e for each country are obtained from the simultaneous equations:

$$\pi_i^e = \sum_{j=1}^{C} (p_{ij} / PPP_j^e) q_{ij} \Big/ \sum_{j=1}^{C} q_{ij} \;, \qquad i = 1,\ldots,M, \tag{8}$$

and,

$$PPP_j^e = \sum_{i=1}^{M} p_{ij} q_{ij} / \sum_{i=1}^{M} \pi_i^e q_{ij} \;, \qquad j = 1,\ldots,C. \tag{9}$$

In (8), the nominal prices p_{ij} of final goods are deflated by the PPP's, and then averaged across countries. The PPP's are obtained from (9), as the ratio of nominal to real final expenditure, where real expenditure is evaluated using the reference prices. The fact that $q_{ij} \geq 0$ in (8)-(9), along with $\sum_{j=1}^{N} q_{ij} > 0$, ensures a positive solution for π_i^e and PPP_j^e (Prasada Rao, 1971, Diewert, 1999). Then a normalization can be used to obtain a unique solution.

Subtracting from real expenditure the trade balance deflated by the expenditure PPP, we obtain what is called real GDP in the PWT, and what we shall call real GDP_j^e:

$$\text{Real } GDP_j^e \equiv \sum_{i=1}^{M} \pi_i^e q_{ij} + (X_j - M_j) / PPP_j^e \,. \tag{10}$$

Notice that the trade balance $(X_j - M_j)$ is deflated by the PPP for final goods, to evaluate real GDP_j^e on the expenditure side. In contrast to (10), suppose that we have reference prices for final goods, π_i^o, i=1,…,M as well as for the traded exports and imports, π_i^x and π_i^m, for i=M_0+1,…,M+N. Then consider the following definition of real GDP_j^o on the output side:

$$\begin{aligned} \text{Real } GDP_j^o &= \sum_{i=1}^{M+N} \pi_i^o (y_{ij} - z_{ij}) + \sum_{i=M_0+1}^{M+N} [(\pi_i^o - \pi_i^m) m_{ij} - (\pi_i^o - \pi_i^x) x_{ij}] \\ &= \sum_{i=1}^{M} \pi_i^o q_{ij} + \sum_{i=M_0+1}^{M+N} (\pi_i^x x_{ij} - \pi_i^m m_{ij}) \;, \end{aligned} \tag{11}$$

where the second line follows from (4) using $(y_{ij} - z_{ij}) = q_{ij}$ for non-traded final goods $i=1,\dots,M_0$, while the intermediate inputs have $q_{ij} = 0$ so that $(y_{ij} - z_{ij}) = (x_{ij} - m_{ij})$, $i=M+1,\dots,M+N$.

The first line of (11) is similar to nominal GDP measured on the production side in (6), but using reference prices in (11) rather than nominal prices. In principle, the first line of (11) relies on domestic reference prices for intermediate inputs (that is, π_i^o for $i=M_0+1,\dots,M+N$). But the second line of (11), where we re-write real GDP_j^o using the trade balance evaluated with reference prices, shows that the domestic reference prices for intermediate inputs are not needed after all! Essentially, the use of the international reference prices π_i^x and π_i^m gives us a short-cut method for evaluating real GDP_j^o on the output side.

To evaluate the reference prices used in (11), consider the augmented-GK system:

$$\pi_i^o = \sum_{j=1}^{C} (p_{ij} / \text{PPP}_j^o) q_{ij} \Big/ \sum_{j=1}^{C} q_{ij}, \qquad i=1,\dots,M, \tag{12}$$

$$\pi_i^x = \sum_{j=1}^{C} (p_{ij}^x / \text{PPP}_j^o) x_{ij} \Big/ \sum_{j=1}^{C} x_{ij}, \qquad i=M_0+1,\dots,M+N, \tag{13}$$

$$\pi_i^m = \sum_{j=1}^{C} (p_{ij}^m / \text{PPP}_j^o) m_{ij} \Big/ \sum_{j=1}^{C} m_{ij}, \qquad i=M_0+1,\dots,M+N, \tag{14}$$

and,

$$\text{PPP}_j^o = \frac{\text{Nominal GDP}_j^o}{\sum_{i=1}^{M} \pi_i^o q_{ij} + \sum_{i=M_0+1}^{M+N} (\pi_i^x x_{ij} - \pi_i^m m_{ij})}, \quad j=1,\dots,C. \tag{15}$$

In (12) we construct domestic reference prices for the final goods, and in (13) and (14) we construct reference prices for exports and imports. These are used to construct purchasing-power-parity PPP_j^o in (15), which is the ratio of nominal GDP and real GDP_j^o. In order for these definitions to make sense, we assume:

Assumption 1

Quantities are non-negative, $q_{ij}, x_{ij}, m_{ij} \geq 0$, with $\sum_{i=1}^{M} q_{ij} > 0$, $\sum_{i=M_0+1}^{M+N} x_{ij} > 0$, $\sum_{i=M_0+1}^{M+N} m_{ij} > 0$.

Summing up, we have shown that the augmented-GK system (12)- (15) can be used to obtain a cross-country measure of the GDP price deflator on the output-side, which is PPP_j^o. We have therefore achieved our goal of demonstrating that final goods data, in conjunction with export or import data, can be used to construct real GDP_j^o on the output side. However, it remains to be shown that this system has a solution. This task is complicated by the fact that real GDP_j^o, appearing in (11) and the denominator of (15), is not guaranteed to be positive for all possible reference prices. This can be ruled out by some additional assumptions, as follows.

First, define the *budget shares* for each final, export and import goods as:

$$\theta_{ij}^v \equiv p_{ij}^v v_{ij} / \text{Nominal GDP}_j \geq 0, \qquad v = q, x, m, \tag{16}$$

where i=1,…,M for v = q; i= M_0+1,…,M+N for v = x, m; and j=1,…,C. Notice that these budget shares are measured relative to nominal GDP. In addition, define the *market shares* for each good as:

$$\mu_{ij}^v \equiv v_{ij} / \sum_{k=1}^{C} v_{ik} \geq 0, \qquad v = q, x, m, \tag{17}$$

where i=1,…,M for v = q; and i=M_0+1,…,M+N for v = x, m. The market shares are measured relative to the world quantity of final demand, exports or imports for each good. Denote the column vectors of budget and market shares by θ_j^v and μ_j^v for v = q, x, m and country j. Then our second assumption is:

Assumption 2

For all countries j, k = 1,…,C, we have: $w_{jk} \equiv \theta_j^{q\prime}\mu_k^q + \theta_j^{x\prime}\mu_k^x - \theta_j^{m\prime}\mu_k^m > 0$.

Clearly, this assumption limits the size of the import shares θ_{ij}^{m} and μ_{ij}^{m}. It is appropriate to think of w_{jk} as "weights" because $\sum_{k=1}^{C} w_{jk} = 1$. While is it easy to construct examples where Assumption 2 is violated for some countries j and k, it is also true that for many values of the import budget and market shares, Assumption 2 will hold.[9] Then we prove in the Appendix:

Theorem

Under Assumptions 1 and 2, the system (12)- (15) has a strictly positive solution for π_i^o, π_i^x, π_i^m, real GDP_j^o and PPP_j^o.

By rewriting real GDP_j^o, it is possible to give a clear interpretation about the difference between it and real GDP_j^e. Notice that real GDP_j^o in (11) can be decomposed as:

$$\text{Real } GDP_j^o = \left(\frac{\sum_{i=1}^{M} \pi_i^o q_{ij}}{\sum_{i=1}^{M} p_{ij} q_{ij}}\right) \sum_{i=1}^{M} p_{ij} q_{ij} + \left(\frac{\sum_{i=M_0+1}^{M+N} \pi_i^x x_{ij}}{\sum_{i=M_0+1}^{M+N} p_{ij}^x x_{ij}}\right) X_j - \left(\frac{\sum_{i=M_0+1}^{M+N} \pi_i^m m_{ij}}{\sum_{i=M_0+1}^{M+N} p_{ij}^m m_{ij}}\right) M_j . \quad (18)$$

We can define the three ratios appearing in (18) as the inverse of the PPP's for final expenditure, exports and imports:

$$PPP_j^q \equiv \left(\frac{\sum_{i=1}^{M} p_{ij} q_{ij}}{\sum_{i=1}^{M} \pi_i^o q_{ij}}\right), \; PPP_j^x \equiv \left(\frac{\sum_{i=M_0+1}^{M+N} p_{ij}^x x_{ij}}{\sum_{i=M_0+1}^{M+N} \pi_i^x x_{ij}}\right), \; PPP_j^m \equiv \left(\frac{\sum_{i=M_0+1}^{M+N} p_{ij}^m m_{ij}}{\sum_{i=M_0+1}^{M+N} \pi_i^m m_{ij}}\right). \quad (19)$$

Comparing (10) and (18), it is immediate that the difference between real GDP_j^e and real GDP_j^o is due to the deflation of final expenditure, exports and imports:

$$\text{Real GDP}_j^e - \text{Real GDP}_j^o$$

$$= \left(\frac{PPP_j^q}{PPP_j^e} - 1\right)\left(\frac{\sum_{i=1}^{M} p_{ij} q_{ij}}{PPP_j^q}\right) + \left(\frac{PPP_j^x}{PPP_j^e} - 1\right)\left(\frac{X_j}{PPP_j^x}\right) - \left(\frac{PPP_j^m}{PPP_j^e} - 1\right)\left(\frac{M_j}{PPP_j^m}\right). \qquad (20)$$

We will find in practice that PPP_j^e and PPP_j^q are very 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 $PPP_j^x > PPP_j^e$ or $PPP_j^m < PPP_j^e$ is needed to have real GDP_j^e exceed real GDP_j^o, and both inequalities holding is sufficient for this. 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 PPP_j^m and tending to make real GDP_j^e less than real GDP_j^o. We can use the components of real GDP_j^o to construct a new measure of "real openness", defined as:

$$\text{Real Openness} \equiv \frac{(X_j / PPP_j^x) + (M_j / PPP_j^m)}{\text{Real GDP}_j^o}. \qquad (21)$$

As we show in section 5, this variable improves upon the nominal openness variable now included in PWT, which is commonly used in applications.

We conclude this section by noting that for export prices to influence real GDP_j^o, countries need to produce some goods in common. To see this, consider the opposite case where all countries are fully specialized in their own goods. Then the summations used in (13) to obtain reference prices for the export goods would actually be over a *single* country, i.e. the unique country exporting that good. For convenience, suppose that each country exports just one good, and re-order goods so that $x_{ij} = 0$ for $i \neq j$ and $x_{jj} > 0$, so (13) becomes $\pi_j^x = p_{jj}^x / PPP_j^o$. It follows from (19) that $PPP_j^x = PPP_j^o$, so with complete specialization, the PPP for exports is identical to the overall output PPP. This means that export prices will not contribute to any differences between real GDP_j^e and real GDP_j^o; only import prices matter. Countries with high import prices will still have real GDP_j^e less than real GDP_j^o, due to their poor terms of trade.[10]

4. Application to UN Trade Data and Penn World Tables

In this section we apply our formula's to a dataset for expenditure and trade in 1996 for a set of 151 countries. The source for the trade data in the NBER-UN dataset described in Feenstra *et al* (2005), and we use only data for those countries that also appear in the PWT.[11] These trade data contains specific product data classified at the 4-digit SITC level, from which we obtain unit-values for exports and imports. The number of unit-values on the export side ranges from 10 for Chad to 1,020 in the United States, and on the import side from 29 in Israel to 776 in Egypt.

It is well-known that trade unit-values are measured with error, and so we applied a regression-based procedure to omit outliers. The procedure was to predict import and export unit values based on tariff rates, distance to trading partners and exporter wages. Unit values which were greater than five or less than one-fifth times the predicted unit value were identified and omitted. By this method, 11% of the 50,115 observations for export unit values were excluded and 8% of the import unit values. The resulting cleaned data set had on average about 294 export and 432 import price observations per country.[12]

For measuring the expenditure price level, we used the PPP's for three categories of final goods (private consumption, government consumption and investment) provided by the version 6.1 of the PWT, so M = 3. Denoting these aggregate prices from PWT by PPP_{ij}, we compute the "expenditure price levels" for each country, defined as:

$$PL_j^e \equiv PPP_j^e / E_j = \sum_{i=1}^{3} (PPP_{ij} / E_j) q_{ij} / \sum_{i=1}^{3} \pi_i^e q_{ij} \ ,$$

where E_j denotes the local currency price of US$ in each country j. Unlike the PPP's, the price levels are unit free, and indicate how the US$ prices in each country compare to the reference prices, also in dollars. In column (1) of Tables 1 and 2, we report the expenditure price levels.

We next combine the three categories of final goods with i = 4,…,N+3 categories of export and import unit-values, and compute the extended-GK system in (12)-(15). In column (2) we report the relative output price level PL^o_j, computed as PPP^o_j / E_j. The normalization used in column (2) is identical to that in column (1), i.e. the value of real GDP^e_j or real GDP^o_j summed over all 151 countries equals the summed nominal value of GDP in US$. The output price levels PPP^o_j and expenditure price levels PPP^e_j, and hence real GDP measured either from the output or the expenditure side, varies a great deal across countries, as shown in column (9). In Table 1 we report the 51 countries with real $GDP^e_j >$ real GDP^o_j, and in Table 2 the 100 countries with real $GDP^e_j <$ real GDP^o_j.

Output price levels are decomposed into price levels for final goods, exports and imports:

$$PL^q_j \equiv PPP^q_j / E_j = \sum_{i=1}^{3} (PPP_{ij} / E_j) q_{ij} / \sum_{i=1}^{3} \pi^o_i q_{ij} ,$$

$$PL^x_j \equiv PPP^x_j / E_j = \sum_{i=4}^{N+3} (p^x_{ij} / E_j) x_{ij} / \sum_{i=4}^{N+3} \pi^x_i x_{ij} ,$$

$$PL^m_j \equiv PPP^m_j / E_j = \sum_{i=4}^{N+3} (p^m_{ij} / E_j) m_{ij} / \sum_{i=4}^{N+3} \pi^m_i m_{ij} .$$

These price levels are reported in columns (3), (5) and (6) in Table 1. The ratio of PL^x_j / PL^m_j is reported as the terms of trade for each country in column (4):

$$TOT_j \equiv PL^x_j / PL^m_j , \quad j = 1,\dots,C.$$

A number of observations can be made. First, the output price levels for final goods in column (3) are very close to the expenditure price levels in column (1), which is encouraging. It indicates that the use of a different set of reference prices for final goods does not influence the estimation of a PPP for final goods: PPP_j^q is almost equal to PPP_j^e.

Second, export price levels differ greatly across countries (see column 5). The highest export price levels are found for Switzerland, Ireland, Sweden and Bermuda, while low levels are found for countries such as Bangladesh, Cambodia, Guinea Bissau, Lao and Nepal. Several factors play an important role in explaining differences in export prices. It is well known that under imperfect competition, exporters can and do charge different prices in various destination markets. Such market segmentation can arise in response to changes in nominal exchange rates, or trade policies of the importer. In addition, it is becoming recognized that countries differ systematically in their qualities and bundles of export goods (Lipsey, 1994, Schott, 2004). This would also create differences in the relative unit-value of their exports.

To give one specific example, Bermuda has the highest terms of trade, which is explained by a high price level for exports as compared to imports. Ships and boats (SITC 7932) is by far the most important export product, with exports of $145 million in 1996, and an export unit-value of $2,680 per metric ton. This is higher than its reference price of $1,910 per ton. So Bermuda's exports of ships and boats are priced higher than the world average, and this product is primarily responsible for Bermuda's high price level for exports. To the extent that the boats exported from Bermuda are of higher quality than other countries (which seems quite plausible to us), then the high price level of exports and high terms of trade is being driven by quality rather than a pure price difference with other countries. As we discuss in the conclusions, correcting the unit-values for quality is the most important direction for further research.

The third observation is that import price levels of countries, shown in column (6) of Table 1, are much closer together than export prices – the standard deviation of import price levels are less than two-thirds for exports, and less than half that for final goods. This might be related to the fact that import baskets are much more similar across countries than export baskets. High import prices are found for countries like Japan, Korea, Switzerland and Scandinavian countries, whereas Benin, Gambia, Mexico, Niger and Sierra Leone are prominent examples of countries in which import price levels are low.

Dividing the export and import price level, we obtain the terms of trade for each country. These are especially low for countries like Cambodia, Guinea Bissau, India, Lao, Mongolia and Nepal. In these countries terms-of trade were lower than 60, indicating that their export PPPs are much lower than their import PPPs. In contrast, countries like Bermuda, Democratic Republic of Congo, Equatorial Guinea, Ireland, Malta, Niger and Switzerland benefit from high terms of trade (140 or higher). Those countries with high terms of trade also tend to have real GDP^e above real GDP^o, but that is not guaranteed, as shown by (20).

Overall, we find that one-third of the countries (51) have real GDP^e exceeding real GDP^o, which means that they are less productive than indicated by the PWT and instead benefit from high terms of trade.[13] Included in this group are Austria, New Zealand, Japan, North America and most countries in Europe, but also a set of developing countries that happen to benefit from high unit-values on selected export products. The most extreme case in this group is Bermuda, which has real GDP_j^e twice as high as real GDP_j^o, which is explained by its high export unit-value for ships and boats. The remaining two-thirds of countries (100) have real GDP^e below real GDP^o, which means that they are more productive than indicated by the PWT and have low terms of trade. That group has lower GDP per capita on average than the former group, but still includes some wealthy countries such as Hong Kong, for which real GDP_j^e is two-thirds that of real GDP^o, due to low export prices from Hong Kong.[14]

An alternative way to split our sample is by oil and non-oil exporters, since we expect the relationships for the two sets of countries may be different. In Figure 2 we plot the terms-of-trade and GDP per capita levels for the set of 126 non-oil exporting countries, together with the regression line. Generally, there is a positive relationship: countries with higher per-capita GDP also have higher terms of trade. The slope coefficient on GDP per capita is significantly positive (at the 5% level). This terms-of-trade increase is driven mainly by an increase in export price levels, as import price levels are relatively stable. However, GDP per capita explains only 5% of the variation in the term of trade. In contrast, we find no significant relationship for our set of 25 oil exporters (see Figure 3). This appears to be due to the fact that export prices in these countries are driven by movements in the global oil market that are common to all.

The pattern shown in Figure 2, whereby countries with higher per-capita GDP have higher terms of trade, carries over to the comparison of real GDP^e and real GDP^o. In column (9) of Table 1 the difference between the two is given as a percentage over real GDP^o. The magnitude of this difference depends on the openness of a country and its terms-of-trade. For example, although India had a particularly low terms-of-trade in 1996, the difference between real GDP^e and real GDP^o is only 4%, due to its low share of exports and imports in GDP. Alternatively, big differences can be found for small open economies such as Bermuda, Ireland, Israel, Malta and Singapore in which real GDP^e was at least 30% higher than real GDP^o due to advantageous terms-of-trade. Countries such as the Bahamas, Hong Kong, Moldova, Macao, Mongolia and Norway are prominent examples of the opposite, with real GDP^e at least 19% lower than real GDP^o due to disadvantageous terms-of-trade.

5. Applications

We believe that there are several areas of inquiry where our new series on real GDP and openness will be useful. First, as mentioned in the introduction, country-level studies of "technology gap" models should use output-based GDP^o, and not expenditure-based GDP^e, to construct country productivity levels. The reason is that countries terms of trade are incorporated into real GDP^e, whereas the technology gap models are focusing on pure productivity differences across countries. Indeed, the industry-level studies in this area, such as Griffith, Redding and Van Reenen (2004) and Cameron, Proudman and Redding (2005), use industry productivity measures that are analogous to what we construct as real GDP^o for countries, in the sense that such series exclude the terms of trade.

Second, we can consider the models of trade and growth, such as Frankel and Romer (1999). The empirical work on these models often rely on a cross-section of country GDP, representing the *income* of countries, and relate income to their openness. In this case we feel that real GDP^e is (arguably) the correct concept of real GDP. As shown above, in a benchmark year measures of GDP in PWT reflect GDP^e, so no adjustment is needed to the cross-country PWT measure of real GDP in those years.[15]

But these papers could benefit from an improved measure of *openness*. Currently, PWT has two measures of openness: at "current prices," which equals nominal exports plus imports relative to nominal GDP; and at "constant prices," which equals exports plus imports converted by the domestic absorption PPP relative to real GDP from PWT. We propose in (21) a measure of *real openness* that equals real exports plus imports computed with *specific PPPs for exports and imports separately*, relative to real GDP^o. Recently, Alcala and Ciccone (2004) have proposed an alternative, hybrid measure of openness that equals nominal exports plus imports converted by the official exchange rate divided by real GDP at PPP: this measure mixes nominal and real units in the numerator and denominator, and as such will be highly sensitive to changes in nominal exchange rates. We believe that our real openness measure achieves greater consistency of measurement, and will make a difference to empirical studies.

For example, in the Appendix we have replicated the results of Rigobon and Rodrik (2005), who found that nominal openness has a negative and significant impact on real income. When we use "real openness" instead we find that the impact becomes positive, and significant in one case. Furthermore, the "real openness" has a stronger positive impact on the rule of law, which therefore leads to a positive *indirect* impact on income. We also report the results for the terms of trade, which result in positive and significant coefficients on real income.

Notice that the above areas rely on the cross-country measurement of real GDP. Many studies also require time-series measures of real GDP growth. In the Appendix, we show how the growth in real GDP^e and real GDP^o differ from each other, and how the *existing* growth of real GDP in the PWT differs from both of these. In practice, however, the existing measure of real GDP growth in the PWT is much closer to the growth of real GDP^o than to the growth of real GDP^e. The correlation of growth rates of real GDP from PWT with growth in real GDP^e is 0.647, while it is 0.867 with GDP^o. So even though real GDP for a benchmark year in the PWT should be interpreted as an expenditure-based measure, its *growth rate* is closer to an output-based measure.

This distinction is important in potential applications of PWT data using growth rates. An example is Acemoglu and Ventura (2002),who study the impact of real GDP growth on the terms of trade. They find a negative relationship between these variables after controlling for other factors that influence real GDP. Since they are using real GDP growth computed from PWT, we need to ask whether this measure incorporates movements in the terms of trade, or not. If it does, that would be problematic since it would contribute to a positive correlation between real GDP growth and the terms of trade. However, as discussed above, we know that the growth of real GDP from the PWT in practice is reasonably close to the growth in real GDP^o, which *excludes* the terms of trade. Indeed, when we replicate the results of Acemoglu and Ventura (2002), and then replace the growth in real GDP from PWT with the growth in real GDP^o, we find that their results are not significantly affected. So for time-series studies, the growth of real GDP from the PWT is the best choice if terms of trade influences are to be excluded.

A final possible application of real GDP data is to the time-series measurement of *living standards* in countries. This is the topic that Kohli (2004, 2006) has studied for Switzerland and Canada, for example. He argues that even though the growth of real GDP from the output side has been poor, the terms of trade have improved for these countries, so that living standards are rising. The measure of real GDP^e that we propose to add to PWT will reflect this improvement in the terms of trade over time. The formulas used to obtain all of the series referred to above – whether in PWT or proposed in this paper – and their extrapolation over time, are described in the Appendix to this paper, and the results given in the data Appendix.

6. Conclusions

We have argued that there is a fundamental difference between real GDP measured from the output side or from the expenditure side in international comparisons. The difference is in the treatment of the terms of trade. Real GDP from the expenditure side represents the ability to purchase goods and services and should incorporate the terms of trade, while real GDP from the output side measures the production possibilities of the economy and should exclude the terms of trade. Available data from the Penn World Tables is based on an expenditure-side measure of real GDP for a benchmark year, with growth rates that mix the two concepts.

In this paper a clear-cut distinction between the two measures is made, with some extrapolations over 1950-2000. We show that in practice, the measure of real GDP growth in the PWT is much closer to the growth of real GDP from the output side than from the expenditure side. Preliminary estimates for real GDP from the output- and expenditure-side are provided in the Appendix, as well as new measures for real openness. These series are experimental and need further development. The main defect of these estimates so far is that they do not correct the unit-values in trade for quality. Recent papers which attempt to tackle this problem include Hallak (2006), Hallak and Schott (2006), Hummels and Klenow (2005), and Timmer and Richter (2006); and we can hope that enough progress will be made on these methods to allow implementation over a wide set of countries, products and years. In our view, that is the key theoretical and empirical issue that must be resolved before applying the techniques described herein to obtain separate measure of real GDP on the output-side, and the expenditure-side, in the Penn World Tables.

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Table 1: Price Levels and Real GDP, 1996 (Countries with GDP^e greater than GDP^o)

Country	Expenditure price level	Output-side price levels					Real GDPe and GDPo per capita		
		Output price level	Final goods	Terms of Trade	Exports	Imports	Real GDPe	Real GDPo	Diff (%)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Austria	163.4	182.0	163.3	122.4	143.4	117.1	17,576	15,776	11.4
Barbados	64.6	76.3	64.7	137.0	120.6	88.1	11,667	9,885	18.0
Belgium	157.2	175.3	157.2	113.0	118.6	104.9	16,903	15,165	11.5
Belize	59.1	61.6	59.1	110.5	73.6	66.6	4,799	4,603	4.3
Bermuda	178.1	370.3	178.2	196.8	157.1	79.9	15,033	7,229	108.0
Bolivia	46.6	47.1	46.7	114.4	73.4	64.2	2,091	2,070	1.0
Brazil	88.1	88.5	88.1	101.0	79.3	78.5	5,448	5,421	0.5
Canada	109.5	117.6	109.4	120.1	115.3	96.0	18,656	17,361	7.5
Congo, Dem.Rp.	30.2	33.0	30.2	151.2	76.4	50.5	245	224	9.3
Cyprus	95.6	97.5	95.6	100.9	79.9	79.2	12,535	12,283	2.0
Denmark	176.8	185.6	176.8	115.1	131.6	114.3	19,682	18,757	4.9
Djibouti	49.1	50.2	49.2	116.7	69.8	59.8	1,613	1,580	2.1
Eq.Guinea	57.0	69.9	57.0	142.5	85.0	59.7	1,105	902	22.5
Finland	156.4	160.4	156.4	110.6	132.4	119.6	15,915	15,511	2.6
France	158.2	167.0	158.2	121.4	133.6	110.0	16,500	15,630	5.6
Gabon	72.5	73.8	72.5	95.7	82.4	86.1	7,092	6,966	1.8
Gambia	41.2	41.6	41.2	102.6	43.4	42.3	830	823	0.9
Germany	168.1	177.3	168.1	118.3	142.4	120.3	17,310	16,411	5.5
Greece	114.3	117.8	114.3	97.8	78.1	79.9	10,388	10,075	3.1
Guyana	37.2	42.0	37.2	129.4	78.5	60.6	2,241	1,989	12.7
Hungary	63.1	64.1	63.1	106.1	88.6	83.5	7,025	6,915	1.6
Ireland	133.0	175.4	133.0	140.0	157.9	112.8	15,166	11,501	31.9
Israel	127.8	182.1	127.7	170.4	134.7	79.1	13,152	9,229	42.5
Italy	128.2	129.8	128.2	107.1	114.9	107.2	16,760	16,550	1.3
Jamaica	71.8	82.8	71.8	123.8	81.4	65.7	3,009	2,609	15.3
Japan	187.2	188.4	187.1	105.7	135.0	127.6	19,931	19,806	0.6
Malaysia	64.2	76.4	64.2	120.1	73.1	60.9	7,456	6,271	18.9
Malta	85.7	113.8	85.7	148.0	138.5	93.6	10,431	7,849	32.9
Mauritius	40.0	40.8	40.0	106.9	79.8	74.6	9,482	9,287	2.1
Mexico	60.1	73.7	60.2	173.8	74.9	43.1	5,978	4,879	22.5
Netherlands	152.0	163.1	152.0	112.4	118.6	105.5	17,445	16,261	7.3
New Zealand	123.8	130.7	123.8	115.6	102.9	89.0	14,481	13,719	5.6
Niger	33.5	34.6	33.6	153.9	69.1	44.9	626	607	3.1
Philippines	46.2	46.9	46.2	117.4	79.4	67.6	2,495	2,457	1.5
Portugal	102.9	104.4	102.9	104.2	105.3	101.1	11,010	10,849	1.5
Singapore	119.3	155.5	119.1	114.1	103.1	90.3	20,960	16,077	30.4
South Africa	62.0	62.5	62.0	101.9	73.4	72.0	5,780	5,733	0.8
Spain	122.1	125.9	122.1	111.5	110.7	99.2	12,718	12,329	3.2
St. Lucia	78.0	84.1	78.0	113.3	91.9	81.2	4,956	4,595	7.8
St.Kitts and Nevis	68.4	69.1	68.4	113.3	91.9	81.2	8,786	8,701	1.0
Sweden	174.0	194.7	174.0	131.2	156.7	119.4	17,024	15,215	11.9
Switzerland	209.5	247.3	209.5	151.1	229.4	151.9	19,974	16,922	18.0
Syria	129.9	139.7	130.0	99.1	60.4	60.9	3,097	2,881	7.5
Tajikistan	20.2	20.4	20.2	104.8	51.9	49.6	776	770	0.8
Togo	50.2	50.6	50.2	99.7	46.0	46.2	695	690	0.8
Trinidad & Tbg	59.3	62.0	59.3	103.4	81.4	78.6	7,534	7,203	4.6
Turkmenistan	13.6	13.9	13.6	65.6	44.7	68.1	3,762	3,687	2.0
UK	123.8	129.5	123.8	114.5	125.8	109.8	16,331	15,611	4.6
USA	123.3	124.1	123.3	101.4	101.2	99.8	23,673	23,530	0.6
Venezuela	57.2	57.7	57.3	95.5	63.1	66.0	5,511	5,468	0.8
Zambia	53.6	54.3	53.6	108.0	69.8	64.7	667	658	1.3

Table 2: Price Levels and Real GDP, 1996 (Countries with GDP^e less than GDP^o)

Country	Expenditure price level	Output-side price levels: Output price level	Final goods	Terms of Trade	Exports	Imports	Real GDPe and GDPo per capita: Real GDPe	Real GDPo	Diff (%)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Albania	34.0	30.1	34.0	76.8	43.7	56.9	2,423	2,742	-11.6
Algeria	44.4	44.2	44.4	86.7	60.4	69.6	3,685	3,702	-0.5
Angola	58.4	57.1	58.4	96.7	69.4	71.8	1,001	1,022	-2.1
Argentina	90.9	88.7	90.9	80.2	71.3	88.8	8,520	8,727	-2.4
Armenia	22.6	19.3	22.7	105.8	53.1	50.2	1,869	2,188	-14.6
Australia	121.0	119.0	121.0	94.0	84.7	90.0	18,713	19,022	-1.6
Azerbaijan	25.5	21.4	25.5	90.8	56.1	61.8	1,606	1,911	-16.0
Bahamas	94.0	76.1	94.1	64.2	46.2	72.0	13,094	16,175	-19.0
Bahrain	94.6	85.8	94.6	92.9	83.7	90.1	10,254	11,306	-9.3
Bangladesh	26.8	25.2	26.8	66.2	37.4	56.5	1,209	1,288	-6.1
Belarus	26.2	23.7	26.2	66.8	49.4	74.0	4,410	4,887	-9.8
Benin	44.4	44.1	44.4	98.9	47.6	48.1	884	890	-0.7
Bulgaria	25.7	24.1	25.8	71.9	51.3	71.4	4,560	4,871	-6.4
Burkina Faso	35.8	33.0	35.9	84.0	53.1	63.2	693	753	-7.9
Burundi	28.8	27.3	28.8	76.8	47.5	61.9	496	524	-5.3
Cambodia	30.2	25.6	30.2	57.0	33.6	58.9	958	1,132	-15.4
Cameroon	43.6	43.1	43.6	86.6	63.5	73.3	1,514	1,529	-1.0
Cent.Afr.Rep	44.5	42.8	44.6	78.9	52.0	65.8	716	745	-3.9
Chad	34.0	30.9	34.0	72.0	44.4	61.7	694	763	-9.2
Chile	66.3	63.2	66.3	81.2	78.5	96.6	7,230	7,591	-4.8
China	30.7	30.1	30.7	78.9	41.0	52.0	2,355	2,405	-2.1
Colombia	57.7	56.4	57.7	89.5	68.9	77.0	4,382	4,483	-2.2
Congo	71.5	71.1	71.6	98.9	70.4	71.2	1,349	1,356	-0.6
Costa Rica	66.2	60.3	66.2	81.2	57.1	70.4	4,063	4,460	-8.9
Cote D'Ivoire	49.4	45.7	49.5	75.6	52.5	69.4	1,556	1,685	-7.6
Croatia	76.8	72.5	76.8	87.8	79.3	90.4	5,757	6,102	-5.7
Cuba	51.0	50.8	51.1	97.2	64.8	66.7	4,050	4,071	-0.5
Czech Rep	51.0	46.5	51.0	80.9	69.9	86.4	10,963	12,038	-8.9
Dominican Rp	53.8	50.3	53.8	79.6	56.0	70.3	3,109	3,324	-6.5
Ecuador	53.4	52.4	53.4	87.4	58.4	66.8	3,052	3,110	-1.9
Egypt	38.6	37.5	38.6	93.0	60.6	65.2	2,959	3,048	-2.9
El Salvador	53.1	49.0	53.1	74.5	53.0	71.1	3,363	3,643	-7.7
Estonia	51.2	43.1	51.2	74.3	58.4	78.5	5,792	6,886	-15.9
Ethiopia	23.7	22.2	23.7	117.8	59.5	50.5	433	461	-6.1
Fiji	66.4	65.6	66.4	97.4	73.0	74.9	4,118	4,166	-1.1
Georgia	24.3	23.2	24.4	86.7	46.6	53.8	3,436	3,600	-4.5
Ghana	39.5	38.1	39.5	97.3	58.7	60.3	1,002	1,037	-3.4
Guatemala	50.4	48.4	50.5	80.4	52.2	64.9	3,054	3,182	-4.0
Guinea	26.8	26.1	26.8	95.5	52.8	55.2	2,191	2,246	-2.4
GuineaBissau	38.4	33.7	38.4	54.4	36.7	67.4	636	725	-12.2
Haiti	29.8	27.3	29.9	80.9	45.7	56.5	1,381	1,509	-8.5
Honduras	41.3	37.2	41.3	76.6	48.0	62.7	1,697	1,884	-9.9
Hong Kong	113.4	71.8	113.3	79.1	57.1	72.2	21,471	33,913	-36.7
Iceland	154.6	129.3	154.6	72.9	79.0	108.4	17,511	20,925	-16.3
India	25.6	24.5	25.6	59.8	50.2	83.9	1,642	1,714	-4.2
Indonesia	37.0	35.7	37.0	79.3	59.9	75.5	3,117	3,225	-3.3
Iran	51.7	51.4	51.7	86.2	61.7	71.6	4,245	4,271	-0.6
Jordan	53.9	52.4	53.9	104.9	70.2	66.9	2,858	2,941	-2.8
Kazakhstan	28.9	28.2	28.9	92.1	45.6	49.5	4,580	4,697	-2.5
Kenya	32.9	31.1	32.9	80.5	51.1	63.6	1,002	1,062	-5.6

Table 2: (continued)

Country	Expenditure price level	Output-side price levels					Real GDPe and GDPo per capita		
		Output price level	Final goods	Terms of Trade	Exports	Imports	Real GDPe	Real GDPo	Diff (%)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Korea, Rep. of	95.5	84.4	95.4	65.4	79.2	121.0	11,962	13,529	-11.6
Kuwait	99.4	97.1	99.5	100.1	82.9	82.9	18,170	18,606	-2.3
Kyrgyzstan	20.2	17.3	20.2	86.6	43.9	50.7	1,973	2,311	-14.7
Laos	37.2	31.8	37.2	58.3	39.9	68.5	1,068	1,249	-14.5
Latvia	43.3	39.1	43.3	79.9	57.3	71.8	4,768	5,278	-9.7
Lebanon	81.6	81.1	81.6	75.6	58.0	76.7	3,908	3,928	-0.5
Lithuania	42.0	39.2	42.1	89.4	58.4	65.3	5,062	5,434	-6.8
Macao	88.3	71.5	88.3	92.3	57.8	62.7	18,578	22,952	-19.1
Macedonia	62.0	56.8	62.0	75.9	60.5	79.7	3,591	3,917	-8.3
Madagascar	45.9	45.8	45.9	106.0	63.9	60.3	635	635	-0.1
Malawi	39.5	35.2	39.5	63.1	47.1	74.6	573	643	-10.9
Mali	41.7	38.4	41.7	79.8	52.1	65.3	640	695	-7.8
Mauritania	46.1	41.9	46.1	83.1	53.0	63.8	994	1,093	-9.0
Moldova	22.5	18.0	22.5	61.3	34.6	56.5	1,739	2,171	-19.9
Mongolia	42.7	34.2	42.7	54.5	35.4	65.0	1,003	1,254	-20.0
Morocco	45.0	43.4	45.0	92.3	67.9	73.6	3,029	3,138	-3.5
Mozambique	26.1	23.0	26.1	77.9	50.1	64.3	673	764	-11.9
Nepal	20.0	16.9	20.0	42.9	27.5	64.1	1,008	1,192	-15.5
Nicaragua	31.3	26.3	31.3	75.0	55.0	73.4	1,387	1,648	-15.8
Norway	175.2	138.1	175.2	72.7	85.3	117.4	20,529	26,057	-21.2
Oman	65.3	64.4	65.4	94.6	66.7	70.5	10,564	10,711	-1.4
Pakistan	31.5	29.1	31.6	63.9	37.0	57.9	1,536	1,663	-7.6
Panama	66.7	66.1	66.6	97.6	71.6	73.3	4,574	4,615	-0.9
Papua N.Guin	43.5	42.5	43.5	88.0	67.7	77.0	2,739	2,803	-2.3
Paraguay	46.1	44.9	46.1	96.6	69.0	71.4	4,220	4,333	-2.6
Peru	70.9	70.8	70.9	99.5	75.2	75.6	3,585	3,591	-0.2
Poland	59.2	56.5	59.2	79.4	65.7	82.8	6,292	6,592	-4.6
Qatar	87.2	76.3	87.3	69.9	67.8	96.9	15,530	17,746	-12.5
Romania	39.0	35.3	39.0	67.4	57.3	84.9	3,987	4,409	-9.6
Russian Fed	50.2	49.9	50.2	89.8	63.9	71.2	5,639	5,671	-0.6
Rwanda	32.6	29.6	32.7	77.1	47.9	62.1	641	705	-9.1
Saudi Arabia	77.1	70.5	77.2	82.1	64.8	79.0	9,422	10,301	-8.5
Senegal	46.3	45.1	46.3	94.9	60.8	64.1	1,172	1,203	-2.6
Seychelles	90.2	89.7	90.1	96.9	76.2	78.6	7,356	7,394	-0.5
Sierra Leone	27.6	26.5	27.6	124.8	60.0	48.0	737	766	-3.9
Slovakia	45.4	42.5	45.4	93.4	70.0	75.0	8,105	8,654	-6.3
Slovenia	90.4	89.5	90.4	98.0	96.4	98.4	10,449	10,555	-1.0
Sri Lanka	30.2	27.6	30.2	77.1	51.4	66.7	2,521	2,756	-8.5
St. Vincent & Grn.	52.3	52.3	52.3	113.3	91.9	81.2	4,766	4,767	0.0
Sudan	33.4	31.3	33.4	74.4	44.4	59.6	912	970	-6.1
Tanzania	51.5	47.2	51.6	71.7	43.4	60.5	372	406	-8.4
Thailand	51.8	47.7	51.8	78.9	64.9	82.2	5,846	6,352	-8.0
Tunisia	46.0	44.0	46.0	85.1	71.4	83.9	4,690	4,901	-4.3
Turkey	55.9	52.1	55.9	72.6	62.8	86.5	5,180	5,558	-6.8
Uganda	44.7	42.1	44.8	70.9	43.7	61.6	663	706	-6.0
Ukraine	25.9	24.8	26.0	85.3	54.6	64.1	3,361	3,512	-4.3
Uruguay	80.6	79.2	80.6	91.7	72.6	79.2	7,346	7,472	-1.7
Uzbekistan	27.6	25.3	27.6	68.2	45.8	67.2	2,128	2,321	-8.3
Viet Nam	24.0	21.6	24.1	85.0	51.7	60.8	1,312	1,459	-10.1
Zimbabwe	33.2	32.4	33.2	86.8	62.5	72.0	2,273	2,324	-2.2

Notes to Tables 1 and 2:

All price levels are multiplied by 100.

Columns (1) and (2) are normalized so that the real value of GDP across all countries equals the nominal value of GDP in US$.

Columns (3) and (4) decompose the output price level taken from column (2).

Column (4) equals (5)/(6).

Columns (7) and (8) are computed according to equations (12) and (14), respectively.

Column (9) equals [(7)-(8)]/(8).

Figure 1: Measures of Real GDP

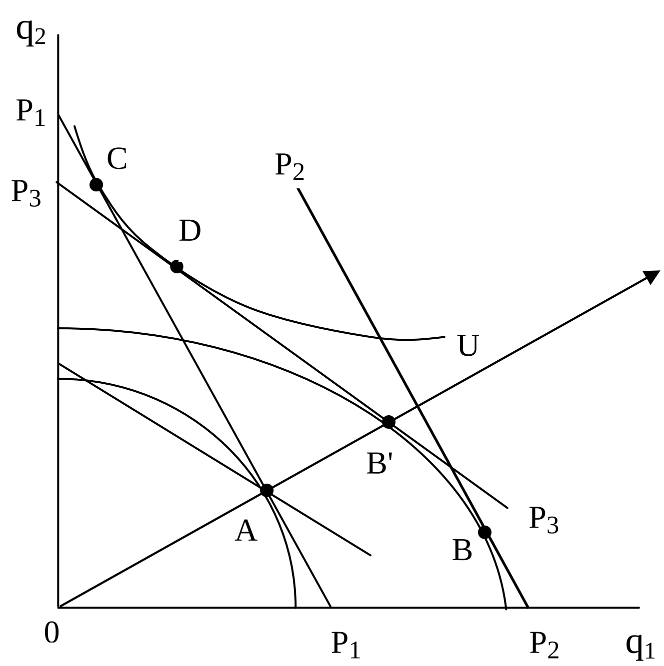


Figure 2: Terms of Trade and Real GDP per capita (1996, non-oil sample)

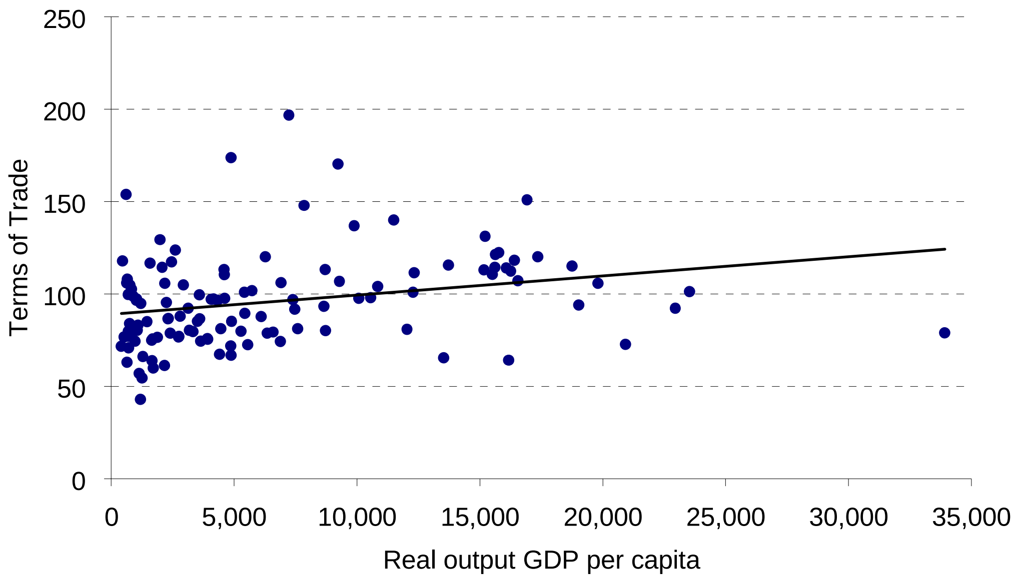
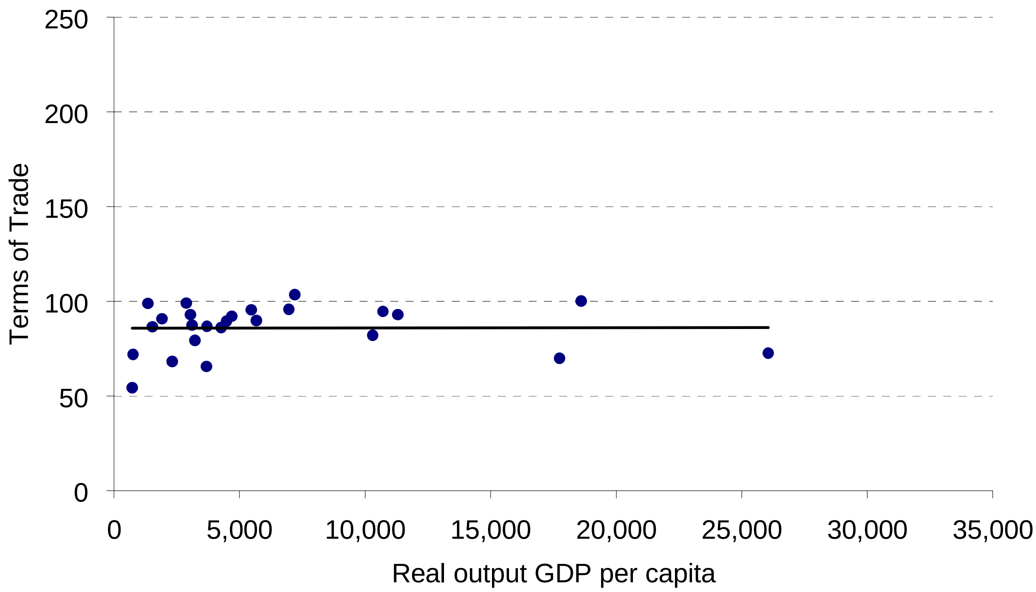


Figure 3: Terms of Trade and Real GDP per capita (1996, oil sample)



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[1] When the "technology gap" models are applied to *industry* data, then it is automatic that real industry output and hence output-side productivity are used to measure the gap between countries, as in Griffith, Redding and Van Reenen (2004) and Cameron, Proudman and Redding (2005). The measure of real GDP on the output-side that we are proposing should be viewed as the natural analogue to real industry output, when applied to the entire economy.

[2] The International Comparisons of Output and Productivity (ICOP) project at the University of Groningen constructs real GDP by sector from the output side using the industry-of-origin approach (see van Ark and Timmer, 2001, for example). Sectoral real output can be aggregated to obtain real output GDP , but his has only been done for a limited number of countries so far. The short-cut proposed here, which requires the use of only international and not domestic prices of intermediates, is much easier to implement for a larger set of countries.

[3] The Appendix is available at: http://www.econ.ucdavis.edu/faculty/fzfeens/papers.html, and, http://www.ggdc.net/pub/gd95.shtml, and, http://pwt.econ.upenn.edu/papers/paperev.html.

[4] See http://unstats.un.org/unsd/sna1993/introduction.asp , paragraph 16.154. The other definitions of real GDI depend on the deflator used for (X-M); see Neary (1997).

[5] In the remainder of this paper "final demand" denotes "final domestic demand" as it does not include exports.

[6] In principle we should also distinguish producer from consumer prices, which can differ due to taxes and retail margins, but do not incorporate that distinction here.

[7] See http://unstats.un.org/unsd/sna1993/introduction.asp, paragraphs 6.235, 6.237 and 15.35.

[8] The SNA recommends that transport costs also be removed from import prices, but that is not possible using the unit-values from UN data, where imports are measured c.i.f. (cost, insurance, freight).

[9] Assumption 2 did not hold over our entire sample of 152 countries, because initially we obtained some negative reference prices. As a result we dropped Nigeria, resulting in positive prices for all other 151 countries.

[10] However, in a two-good, two-country Ricardian model, a unique country imports each good. Say country j exports good j and imports good i≠j. Then (14) becomes $\pi_i^m = p_{ij}^m / PPP_j^o$, for i = 1,2, i≠j, so that $PPP_j^m = PPP_j^o$ from (19). Since $PPP_j^x = PPP_j^o$ also, it follows by comparing (8)-(10) with (12)-(15) that $PPP_j^e = PPP_j^o$ and so real GDP_j^e = real GDP_j^o. Thus, the two concepts of real GDP do not differ in this case. We thank a referee for alerting us to this example.

[11] The only country excluded is Nigeria, because it resulted in some negative reference prices.

[12] We also experimented with a looser criteria, omitting only unit values greater than 10 or less than one-tenth, and found the overall results are similar to those reported here.

[13] Note that the number of countries having real GDP^e greater or less than real GDP^o depends on our normalization procedure, which is that "world" real GDP^e equals "world" real GDP^o for the countries in the sample, but the ranking of countries does not depend on the normalization.

[14] For example, electronic microcircuits (SITC 7764), sell for $1.09 from Hong Kong, but $1.43 from Japan and $1.74 from the U.S. Lower Hong Kong export prices also hold for many other electronic products.

[15] Outside of a benchmark year, real GDP in the PWT is neither a pure expenditure-based nor output-based measure, as shown in the Appendix, and alternative estimates along the lines in this paper are needed.