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Macro-economic Measures for a Globalised World: Global Growth and Inflation[*]

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In this paper we offer a framework for measuring global growth and inflation built on an index number theory and practice; standard national accounts principles; and the concepts and methods for international macroeconomic comparisons. Our approach provides a sound basis for the estimates of purchasing power parity and exchange-rate based global growth regularly published by IMF, the World Bank and the United Nations. It also rectifies deficiencies in the current procedures used in measuring global inflation. For illustrative purposes, we present our estimates of global growth and inflation using data for 141 countries for the years 2005 and 2011. Contribution of movements in exchange rates and purchasing power parities to global inflation are presented.

Keywords: International comparisons; world growth; world inflation; exchange rate; purchasing power parity; index number theory.
JEL Classification: C43, O47.

1. INTRODUCTION

World economic growth and inflation are terms used in the popular press and by various international organizations. Regular estimates are compiled and disseminated by these organizations. The *World Economic Outlook (WEO)*, a flagship publication from the International Monetary Fund (IMF), publishes estimates of global growth and inflation on a regular basis. The 2018 WEO (IMF, 2018) reports a global growth of 3.8 percent in 2017 which is projected to reach 3.9 in 2018. Similar estimates are published by the World Bank, Eurostat, and the OECD where estimates are provided for the whole world or for different country groups. The United Nations' *UN World Economic Situation and Prospects,* 2018 (UN, 2018, page 1, Chapter 1) reports: "In 2017, global growth is estimated to have reached 3.0 percent when calculated at market exchange rate, or 3.6 percent when adjusted for purchasing power parities" The estimated global inflation rate for 2017 is estimated to be 2.6% (UN,

[*] This paper relies on material from Rao, Rambaldi and Balk (2015). It focuses and elaborates on certain aspects of RRB 2015. Funding support from the Australian Research Council through DP 0986813 and DP170103559is gratefully acknowledged. This paper was prepared while I was visiting the Institute for Economic Research (IER), Hitotsubashi University in 2017. I am thankful to Bert Balk and Alicia Rambaldi for their suggestions and comments on an earlier version of the paper. I am responsible for any remaining errors and omissions.

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2018, p14). It is amply clear from these publications that estimates of economic growth and global inflation in the world economy represent significant economic data.

Globalization of the world economy means that multinational enterprises and businesses demand regular estimates of world growth and inflation. For example, Price Waterhouse Coopers (PWC) in its *Global Economy Watch* 2016 reported a global growth of 3.0% in 2016 in PPP terms and 2.9% in market exchange terms. Global inflation was reported to be 2.6% and 1.9% based on PPP and exchange rate terms respectively. Similarly, IECONOMICS reported EURO area inflation of 2% in November 2016. Morgan Stanley in its *Global Outlook 2017: Higher Growth, Bigger Risks* reported a projected global growth of 3.4% in 2017. These published figures on global growth and inflation get factored into decision making by both private and public entities.

The regular and high profile publication of statistics on world growth performance and global inflation should generally imply that these statistics are based on a clear and well-founded theoretical framework. From a careful search through these publications it is difficult to find formal definitions of global growth and global inflation. Global growth estimates are often presented with the labels "in PPP terms" or "market exchange rates" and global inflation is commonly computed as a simple or weighted average of inflation rates observed in different countries. Ward (2001) gives an overview of the conceptual issues concerning global inflation and its relationship with international price levels and purchasing power parities. Specifically, Ward emphasized the measurement of global growth and inflation as being complementary targets, and his paper is also interesting as it provides a brief inventory of approaches existing at that time.

In addition to the index-based measures of global inflation published by international agencies, a number of works in the literature have estimated global inflation econometrically. Cicarelli and Mojon (2010) first proposed a measure based on a static factor analysis. This approach has been followed by Mumtaz and Surico (2012) using a dynamic factor model. Indicators of inflation are constructed by mapping CPI inflation of each country onto a world factor. The resulting indicator of global inflation is a weighted average of CPI inflations with weights determined by the factor loadings. A similar methodology is used by Monacelli and Sala (2009); however, they develop the indicators using a cross-section of 948 CPI products in four OECD countries. However, these statistical approaches are not based on national accounting principles and are not designed to disentangle movements in the global economy into inflation and growth components.

The main objective of this paper is to provide an easily accessible description of the methodology developed by Rao, Rambaldi and Balk (RRB) (2015). RRB (2015) is somewhat technical in its exposition and the current paper aids readers and practitioners by providing motivation, explanation and illustrating various steps involved in measuring global growth and inflation. The reader is advised to use material in this paper in conjunction with RRB (2015).

The present paper makes several important contributions in this significant area. First and foremost, the paper provides, for the first time to the best of our knowledge, a conceptual framework for the compilation of global measures of growth and inflation. An important feature of this framework is that it is built on the principle that any discussion on global growth or inflation must begin with a notion of the size of the global economy observed at different points of time. Here we draw on the developments with respect to international macroeconomic measures compiled and published by the World Bank on a regular basis. Second, our approach is based on standard macroeconomic measurement principles of the *System of National Accounts* (SNA) of the United Nations[1] adopted by national statistical offices in their regular compilation of national accounts. Third, in developing our measures we do not assume that countries as such are decision making entities equipped with well-defined preferences, production and expenditure functions. Instead we only assume that all (or a sample of) the economic transactions of their inhabitants (economic agents such as households, firms, government institutions) are recorded such that sufficiently reliable annual national accounts (according to UN SNA regulations) are published and the index number toolbox can be used for analytic purposes. Similar to the conventional national level GDP in current prices, we begin with a measure of global GDP in each year, which in a given year is influenced by the prices of goods and services prevailing in that year. Fourth, our global measures of growth and inflation simply collapse to the standard growth rate based on constant price GDP and GDP deflator when the "world" is made up of a single country. Thus our approach is consistent with country-level practices in measuring growth and inflation. Fifth, we provide an analytical explanation and an empirical illustration as to why the market exchange rate-based growth estimates are well below the PPP based measure. Sixth, we establish here that global inflation estimates from international organizations such as the IMF and the United Nations are based on inadequate formulae which fail to appropriately account for movements in purchasing power parities or exchange rates over time. Finally, we illustrate our methodology by drawing data from the regular releases of international macroeconomic comparisons across the world by the World Bank.

The paper is organized as follows. In Section 2 we present the basic concepts of PPPs and comparisons of real gross domestic product across countries using PPPs, and contrast these with comparisons based on exchange rates, finally leading to a measure of the size of the world economy. Section 3 establishes the problem of decomposing the change in the size of the world economy into global inflation and growth. Section 4 presents the Fisher and Sato-Vartia index number-based decompositions of the change in the size of the global economy. Analytical properties of these methods are established. Section

[1] The current version in use is SNA 2008 (UN, 2009).

5 discusses the problem of consistency in aggregation across country groupings. Section 6 presents empirical results from the study based on data for 141 countries drawn from the World Bank[2]. The last section concludes with a summary of the contributions of the paper.

2. CONCEPTS FOR INTERNATIONAL COMPARISONS OF PRICES AND GROSS DOMESTIC PRODUCT

For the sake of completeness we start with the concept of gross domestic product and its components. Suppose the world or region consists of *M* countries which are indexed *j* = 1, 2, …, *M*. Denote gross domestic product of country *j* by GDP_j. Conceptually, GDP is the sum of value added of all the individual production units operating within the borders of a country; this is useful for a variety of analytical purposes. Equivalently, GDP from the expenditure side can be expressed as:

$$GDP_j = C_j + I_j + G_j + X_j - M_j \tag{1}$$

where *C, I, G, X* and *M* represent, respectively, private household consumption, investment, government consumption, exports, and imports. The link between the production and expenditure sides of GDP is presented in Appendix A.1. The sum of the first three terms, $C_j + I_j + G_j$, is called domestic absorption. GDP from the expenditure side is the concept that underpins the World Bank comparisons of prices and incomes under its International Comparison Program (ICP).[3]

Now suppose for a moment that there is a single currency across all countries in the world, and that we could sum up GDP of each country. Then, we have

$$\sum_{j=1}^{M} GDP_j = \sum_{j=1}^{M}\left(C_j + I_j + G_j\right) + \sum_{j=1}^{M} X_j - \sum_{j=1}^{M} M_j \tag{2}$$

If we suppose further that there are no import-export tax distortions, so that import prices paid are equal to export prices received, then total import cost, $\sum_j M_j$, would be equal to total export revenue, $\sum_j X_j$. Then, consequently, the sum total of GDP across countries would be equal to total (or world) domestic absorption

$$\sum_{j=1}^{M} GDP_j = \sum_{j=1}^{M}\left(C_j + I_j + G_j\right)$$

[2] In particular we draw on World Bank (2008 and 23015).

[3] The focus on the expenditure side is a choice based on practical considerations especially the possibility of collecting prices of goods and services purchased by consumers. International comparisons based on the production side of GDP were a part of the International Comparisons of Output and Productivity (ICOP) at the University of Groningen which started under the stewardship of Angus Maddison. Comparisons from the production side for EU and World KLEMS projects are obtained using a mixture of comparisons from the expenditure and output side (see Inklaar and Timmer, 2013 for details).

The share of a country's GDP in the world GDP, could then be considered as an important indicator of a country's welfare.

In reality there is no single world currency and even when it exists in groups of countries like the euro area, comparisons of GDP between countries are hindered by the fact that prices of goods and services are different across countries.

Summarizing, computation of world GDP shown in (2) requires conversion of GDP of each country into a common currency unit. There are two choices available for this purpose. First, market exchange rates can be used in converting GDP of each country into a reference currency such as the US dollar. The second option is to use a currency converter which can account for different levels of prices of goods and services such as purchasing power parities (PPPs) of currencies. In sections 2.1 and 2.2, we describe alternative measures of world GDP based on these two options which form the basis for our discussion of global growth.

2.1 World GDP based on exchange rates

GDP data are available from national accounts statistics published by national statistical organisations or agencies. These data are compiled in accordance with the System of National Accounts (SNA) principles[4]. As GDP data from different countries are expressed in their respective national currency units these cannot be added directly to yield a measure of world GDP. The obvious, and the most commonly used method is to use (market) exchange rates XR_{cj} ($j = 1, 2, \ldots, M$), expressed relative to the currency of a reference country, *c*, to convert GDP of each country. For the reference country, the exchange rate is equal to 1 by definition[5]. In the absence of arbitrage, exchange rates are transitive, so that the exchange rate between currencies of countries *j* and *k* can be obtained as the ratio of respective currency exchange rates relative to the reference country, XR_{ck} / XR_{cj} [6]. This ratio shows the number of currency units of country *k* that can be obtained for one currency unit of country *j*. As the choice of

[4] See Footnote 1.
[5] It is a common practice to use US dollar as the reference currency but it is important to note that this selection does not alter the relative sizes of economies of different countries.
[6] Transitivity of exchange rates guarantees that this ratio is the same between pairs of countries irrespective of the reference country selected for the exchange rates and it signifies the absence of arbitrage.

reference country does not influence relative sizes of GDPs of countries converted using exchange rates[7], we henceforth simply use the notation XR_j to represent exchange rate.[8]

As a general convention, GDP after conversion by means of exchange rates is termed *nominal GDP*. The reason for the use of "nominal" is to emphasize the fact that exchange rates do not necessarily reflect price level differences across countries, and therefore have limited use in making welfare comparisons across countries.

Thus nominal GDP of country *j* is defined as

$$NGDP_j \equiv \frac{GDP_j}{XR_j} \qquad j = 1, 2, ..., M \tag{3}$$

By definition $NGDP_j = GDP_j$ for the reference country. Since all the nominal GDPs are now expressed in the same currency (namely, that of the reference country), they can be added across countries. Thus, the total or *world nominal GDP*, denoted by $NGDP_W$, is defined as

$$NGDP_W \equiv \sum_{j=1}^{M} \frac{GDP_j}{XR_j} = \sum_{j=1}^{M} NGDP_j \tag{4}$$

The share of country *j* in the world nominal GDP, $NGDP_j / NGDP_W$ $(j = 1, 2, ..., M)$ is independent of the choice of the reference currency used for the exchange rate denomination.

To illustrate the notion of world nominal GDP in (4), we refer to estimates of world GDP in exchange rates (see World Bank 2008 and 2015) for the years 2005 and 2011 which are 44.308 trillion dollars and 70.294 trillion dollars,[9] respectively. We believe that global growth measures in exchange rate terms published in reports of the IMF and the World Bank need to be anchored on the nominal world GDP defined in (4).

2.2 Size of the World Economy based on Purchasing Power Parities

The size of the world economy, the world GDP, based on purchasing power parities (PPPs) is obtained by converting country-specific GDP data using PPPs. A number of international organisations,

[7] This is easy to see. Suppose *a* and *b* are two alternative choices for reference country, then relative sizes of countries *j* and *k* derived using exchanges rates with these two reference countries are identical. We have, $\frac{GDP_k / XR_{ak}}{GDP_j / XR_{aj}} = \frac{GDP_k / (XR_{ba} XR_{ak})}{GDP_j / (XR_{ba} XR_{aj})} = \frac{GDP_k / XR_{bk}}{GDP_j / XR_{bj}}$. The last step follows from transitivity property of exchange rates under the absence of arbitrage.

[8] Obviously, when countries use the same currency, as is the case in euro area, exchange rate for countries within the area equals 1.

[9] These figures are obtained from World Bank (2008) and World Bank (2015) reporting results for the 2005 and 2011 global comparison years. We note that the country coverage was different with 146 and 177 countries respectively. However, contribution due to additional economies in 2011 is quite small.

including the IMF, World Bank, UN, OECD and EU, report world GDP in PPP terms. The world GDP based on PPPs is referred to as the *World Real GDP*.

The PPP of country *j*, $PPP_j, j = 1, 2, ..., M$, in concept represents the number of currency units of country *j* required to purchase a basket of goods and services that can be purchased with one unit of the currency of the reference country. For instance, if the PPP of the Indian rupee is 20.00 relative to the US dollar, it means that what can be purchased with one dollar in the United States can be purchased with 20 rupees in India.

The basic framework for the compilation of PPPs at the World Bank can be found in Rao (2013). Index number methods for computing PPPs based on prices and quantity data from all the countries involved, are surveyed in Balk (2008, 2009), Diewert (2013) and Rao (2013). We note here that PPPs compiled by the World Bank are based on data on prices and quantities from all the ICP participating countries. Moreover, PPPs are always published relative to the unit of a reference country[10]. The PPPs compiled by the World Bank are transitive[11], thus these numbers provide a consistent set of comparisons between all pairs of countries. PPPs are like spatial prices indices. However, unlike spatial prices indices, PPPs carry a currency dimension, i.e. units of currency *j* per reference currency unit. Thus PPPs serve the dual purpose of currency conversion as well as to account for price level differences across countries. In contrast, exchange rates help currency conversion but do not adjust for price level differences. Deaton and Heston (2010) provide an overview of the concept of PPPs and international real income comparisons.

In international macroeconomic comparisons, GDP converted using PPP is referred to as *real* GDP (RGDP). For country *j* it is defined as

$$RGDP_j \equiv \frac{GDP_j}{PPP_j} \quad (j = 1, 2, ..., M) \tag{5}$$

The term "real" signifies that by using PPPs an adjustment is being made for price level differences across countries.[12]

[10] The choice of the reference currency does not influence the relative sizes of countries in the world.
[11] Transitivity property of PPPs implies that the product of PPP for India with USA as base and PPP for United Kingdom with India as base would be the same as the PPP for United Kingdom with USA as the base.
[12] We use the same nomenclature as that in the International Comparison Program at the World Bank in labelling PPP converted GDP as RGDP. We feel that this label conveys more accurately the meaning behind the aggregate. In doing so, we deviate from the notation used in the recent versions of Penn World Table, PWT 8.0, 8.1 and 9.0 (see Feenstra, Inklaar and Timmer 2015).

We can now define world real GDP, or the size of the real world economy, using PPPs. Real GDP is comparable across countries and can thus be added. World real GDP in PPP, denoted by $RGDP_W$, is defined as

$$RGDP_W \equiv \sum_{j=1}^{M} \frac{GDP_j}{PPP_j} = \sum_{j=1}^{M} RGDP_j \qquad (6)$$

Note that the magnitude of $RGDP_W$ depends on the choice of the reference currency and is determined up to a scalar. The share of country *j* in the world GDP in PPP terms, $RGDP_j / RGDP_W$ does not depend on the reference country. This also means that relative sizes of countries *j* and *k* are unaffected by the choice of the reference currency.

The currently available estimates of the size of world real GDP as reported by the World Bank (see Footnote 2 for details) for the years 2005 and 2011 were respectively, 54.975 and 99.646 trillions of (US) dollars.

2.3 Link between World GDP in Exchange Rates and PPPs

We have two sets of instruments, exchange rates and purchasing power parities and two measures of the size of the world economy, nominal and real GDP, as described in sections 2.1 and 2.2. For the year 2011, the nominal and real GDP are 70.294 and 90.646 trillions of dollars respectively. Though these measures are obtained using completely different currency converters, exchange rates and PPPs, it is possible to establish a connection between the exchange rate based and PPP converted GDP through the concept of *price level index*, PLI, which is defined for country *j* as

$$PLI_j \equiv \frac{PPP_j}{XR_j} \quad j = 1, 2, ..., M \qquad (7)$$

The intuitive idea behind this definition is that one unit of the reference country (US) currency can be exchanged to yield XR_j units of currency of country *j,* and needs PPP_j units to purchase the goods and services that can be purchased with one US dollar. For example if the exchange rate between US dollar and Indian rupee is 72 and if the PPP is 18 Indian rupees per dollar, then the price level in India in 2017 would be 0.25. This means that roughly a quarter of 72 rupees obtained by exchanging one dollar can purchase in India what a dollar can buy in the USA. The PLI is an important indicator produced by the World Bank for all the countries participating in the International Comparison Program. PLI is often referred to as the exchange rate deviation index.

We note the following properties of the PLI. From equations (3), (5) and (7) it is clear that

,

$$PLI_j \equiv \frac{PPP_j}{XR_j} = \frac{PPP_j \cdot GDP_j}{XR_j \cdot GDP_j} = \frac{NGDP_j}{RGDP_j} \quad (j = 1, 2, ..., M) \tag{8}$$

For the reference country, USA, we have by definition

$$PLI_{USA} = 1 \iff NGDP_{USA} = RGDP_{USA} \tag{9}$$

This means that price levels in all the countries are expressed relative to the US price level which is set to 1.

From the definition in (8), we have $NGDP_j = RGDP_j \cdot PLI_j$. Therefore the world GDP in exchange rate and PPP terms are linked through the following equation.

$$\begin{aligned} RGDP_W &\equiv \sum_{j=1}^{M} RGDP_j = \sum_{j=1}^{M} NGDP_j \cdot \frac{XR_j}{PPP_j} = \sum_{j=1}^{M} NGDP_j \cdot \sum_{j=1}^{M} \frac{NGDP_j}{\sum_{j=1}^{M} NGDP_j} . \frac{XR_j}{PPP_j} \\ &= NGDP_W \cdot \sum_{j=1}^{M} \frac{NGDP_j}{\sum_{j=1}^{M} NGDP_j} . \frac{XR_j}{PPP_j} \end{aligned} \tag{10}$$

This equation suggests that world GDP in PPP terms and in exchange rates differ by a multiple which is a weighted average of the ratio of exchange rates and PPPs. If PPP's and exchange rates are close to each other, $RGDP_W$ and $NGDP_W$ tend to be close.

3. BASIC DATA FOR MEASURING GLOBAL GROWTH AND INFLATION

We consider the problem of measuring global growth and inflation from the base year, s, to the current years *t.*[13] For these two years we have measures of world GDP in real and nominal terms. These are given by:

$$\begin{aligned} RGDP_W^{\tau} &= \sum_{j=1}^{M} RGDP_j^{\tau} = \sum_{j=1}^{M} \frac{GDP_j^{\tau}}{PPP_j^{\tau}} \quad \tau = s, t \\ NGDP_W^{\tau} &= \sum_{j=1}^{M} NGDP_j^{\tau} = \sum_{j=1}^{M} \frac{GDP_j^{\tau}}{XR_j^{\tau}} \quad \tau = s, t \end{aligned} \tag{11}$$

3.1 Basic Data for the Study

The methodology proposed in this paper can be applied to any selected group or groups of countries and for any two years. For purposes of illustrating our measures, we select the years 2005 and 2011 which coincide with the years for which internationally comparable macroeconomic data are available from the World Bank as a part of its International Comparison Program as already mentioned. The

[13] This follows the standard index number practice where the year used as the reference year is termed the base period and the year for which inflation is being computed is referred to as the current period.

World Bank (2008 and 2015) data covers, respectively, 146 (in 2005) and 177 (in 2011) economies of the world. In this paper we focus on 141 countries that are common to both years. We are aware of the issues concerning differences in methodology used by the World Bank in 2005 and 2011, and data related issues concerning 2005. These concerns were discussed in some detail Deaton and Aten (2017), Inklaar and Rao (2017) and Feenstra et al (2013). We have opted to use, for our illustration, the published World Bank data without any adjustments. Appendix A.2 presents all the data used in this paper.[14]

Regional groupings considered here are the same as those in the World Bank reports (World Bank 2008 and 2015). These are: Asia and the Pacific, Africa, Commonwealth of Independent States (CIS), Eurostat-OECD, Latin America, and Western Asia. Iran and Georgia are treated as singleton countries not included in any other regions. Egypt and Sudan were included in both Africa and the Western Asian region, but for the purpose of our computations we have included them in Africa. Similarly Russian Federation is included in the Eurostat-OECD region and not in the CIS region. Readers must exercise caution in interpreting results for the Asia-Pacific region as countries like Australia, Japan, New Zealand and South Korea are included in the Eurostat-OECD region.

3.2 Real and Nominal GDP of the world in 2005 and 2011

In Table 1 we present measures of real and nominal regional and global GDP for the years 2005 and 2011.

Table I: PPP and Exchange Rate-based measures of the size of the world and regions (billions of US dollars)

	2005			2011		
Region	Real GDP	Nominal GDP	Price level Index	Real GDP	Nominal GDP	Price level Index
Asia & Pacific	11,969	5,267	0.4401	27,624	13,324	0.4823
Africa	1,501	731	0.4871	3,003	1,568	0.5221
CIS	2,413	1,005	0.4164	4,390	2,474	0.5635
EuroStat-OECD	35,313	35,913	1.0170	43,784	46,284	1.0571
Latin America	2,552	1,329	0.5210	4,408	3,483	0.7902
Iran	639	192	0.3006	1,165	528	0.4537
Western Asia	1,386	702	0.5066	3,490	1,627	0.4663
Georgia	16	7	0.4058	27	14	0.5135
World	55,788	45,145	0.8092	87,892	69,303	0.7885

Source: Authors' calculations using data from World Bank (2008) and World Bank (2015) respectively for the 2005 and 2011 international macroeconomic comparisons including PPPs. WDI for GDP data.
Notes: PPPs and Exchange Rates are all expressed with respect to the US dollar. Nominal GDP is computed using equation (3) and Real GDP is computed using equation (5). Price Level for regions and the World are defined as the ratio of nominal GDP to real GDP based on equation (7).

[14] These measures can be applied for any other years and any other data sets.

In Table 1 the size of the world economy in nominal terms measured by $NGDP_w$ was 45.15 trillion dollars in 2005 and 69.30 trillions of dollars in 2011 indicating an increase of nearly 53.49 percent. The size of the world economy in real terms measured by $RGDP_w$ increased from 55.788 trillion dollars in 2005 to 87.892 trillion dollars in 2011 representing an increase of 57.55 percent increase. Table 1 also reveals region specific differences in changes in regional world real and nominal GDP over this period.

Price Level Indices by region are also presented. Table 1 figures are all based on a normalization with the US dollar as the reference currency, hence the price level index for USA equals 1. Compared to this, for example, the price level index for the world as a whole is 0.8092 and 0.4401 in the Asia-Pacific region in 2005. In 2011, the price level index for the Asia-Pacific region has risen to 0.4823.

Price level indices for different regions show that in all regions except the Eurostat-OECD region price levels are well below unity indicating that PPPs for countries in these regions are generally well below the exchange rate. Explanations of this phenomenon can be found in Deaton and Heston (2010) and in earlier work on explaining country-specific price levels in the 1980's (Kravis and Lipsey, 1982, Clague, 1986) and in the more recent work of Hasan (2016) and Zhang (2017).

The key question we seek to answer in the ensuing sections is how to decompose these observed changes in nominal and real world GDP over the period 2005 to 2011 into growth and inflation? In the next section we propose measures of global growth and inflation which are built on standard national accounts practices. We do not underpin our decompositions on any behavioral assumptions that countries are as such decision-making entities. Instead we only assume that economic transactions within countries are recorded such that sufficiently reliable annual national accounts are published (in this case GDP and GDP deflators for the years 2005 and 2011) and we make use of the standard index number toolbox.

4. ANALYTICAL MEASURES OF GLOBAL GROWTH AND INFLATION

In this section we develop measures of global inflation and growth. In developing this framework, we begin with a review of the standard framework employed at the country level where changes in GDP over time are decomposed into quantity change and price change in the form of GDP deflators.

4.1 GDP growth and deflators over time at country level

For exposition purpose we focus on country *j*. The introduction of the temporal dimension means that we need a superscript denoting time periods (years). Thus, let GDP_j^s and GDP_j^t represent GDP in country *j* (expressed in its own currency) in periods *s* and *t* respectively (where without loss of generality it can be assumed that *s* precedes *t*). Even though GDP in periods *s* and *t* are expressed in the same, a direct comparison is considered less useful since the effects of price and quantity changes between periods *s* and *t* are intertwined. Welfare change is reflected in quantity change.

The change in the nominal value of GDP is measured by the ratio, $GDP_j^t \big/ GDP_j^s$. This ratio is decomposed as

$$\frac{GDP_j^t}{GDP_j^s} = P_{GDP}^j(t,s)Q_{GDP}^j(t,s) \quad \left(j=1,2,...,M \right) \tag{12a}$$

where $P_{GDP}^j(t,s)$ and $Q_{GDP}^j(t,s)$ measure, respectively, the price and quantity change components of the change in the nominal value of GDP. $P_{GDP}^j(t,s)$ is referred to as the GDP deflator[15]. It is understood that $P_{GDP}^j(s,s) = 1$ $(j = 1, \dots, M)$. The price index, $P_{GDP}^j(t,s)$, measures inflation and the quantity index, $Q_{GDP}^j(t,s)$ measures growth at the country level. Equation (12a) can be rewritten as

$$Q_{GDP}^j(t,s) = \frac{GDP_j^t \big/ P_{GDP}^j(t,s)}{GDP_j^s} \ . \tag{12b}$$

The numerator on the right hand side of (12b) is the GDP in period *t* adjusted for the change in prices over the period from *s* to *t*; hence the numerator is referred to as *GDP at constant period s prices*.

Our main objective is to provide a decomposition similar to (12a) at the global level

4.2 Decomposition of Growth in World Real GDP

We start with the world real GDP defined in equation (5), repeated now with a time superscript as

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$$RGDP_W^\tau = \sum_{j=1}^{M} \frac{GDP_j^\tau}{PPP_j^\tau} \qquad \tau = s,t \tag{13}$$

The change in the world GDP from period *s* to period *t* is given by

$$\frac{RGDP_W^t}{RGDP_W^s} = \frac{\sum_{j=1}^{M} RGDP_j^t}{\sum_{j=1}^{M} RGDP_j^s} = \frac{\sum_{j=1}^{M} GDP_j^t \big/ PPP_j^t}{\sum_{j=1}^{M} GDP_j^s \big/ PPP_j^s} \tag{14}$$

which is similar to the LHS of expression (12a) at the country level, the main difference being that we now have a ratio of sums of GDP's in different countries after conversion using PPPs.

[15] It is inconsequential to the general thrust of the paper whether these national accounts indices are computed as direct or chained indices. All we need of the two indices is that together they exhaust any temporal GDP ratio.

How can we decompose the ratio (14) into price and quantity change components? We propose two slightly different decompositions, one based on Fisher-type indices, and the second based on Sato (1976)-Vartia (1976) indices. As we will explain later, we have a preference for the second decomposition.

4.2.1 Fisher-type measures of global inflation and growth

In this section we derive measures of global inflation and growth based on the Fisher index. To obtain this decomposition we make use of a standard result in index number theory which states that the pairs Laspeyres-price and Paasche-quantity indices and Laspeyres-quantity and Paasche-price indices satisfy the product test, that is, their product equals the value change over two periods.

We express equation (13) in a form that can be decomposed into quantity change and price change components. Using equation (12) we can rewrite equation (14) as

$$\frac{RGDP_W^t}{RGDP_W^s} = \frac{\sum_{j=1}^{M} GDP_j^t / PPP_j^t}{\sum_{j=1}^{M} GDP_j^s / PPP_j^s} = \frac{\sum_{j=1}^{M} \frac{GDP_j^t}{GDP_j^s}.GDP_j^s \Big/ PPP_j^t}{\sum_{j=1}^{M} \frac{GDP_j^s}{GDP_j^s}.GDP_j^s \Big/ PPP_j^s}$$

$$= \frac{\sum_{j=1}^{M} P_{GDP}^j(\mathrm{t,s}) \cdot Q_{GDP}^j(\mathrm{t,s}) \cdot GDP_j^s / PPP_j^t}{\sum_{j=1}^{M} P_{GDP}^j(\mathrm{s,s}) \cdot Q_{GDP}^j(\mathrm{s,s}) GDP_j^s / PPP_j^s} \tag{15}$$

$$= \frac{\sum_{j=1}^{M} Q_j^*(t) \cdot P_j^*(t)}{\sum_{j=1}^{M} Q_j^*(\mathrm{s}) \cdot P_j^*(\mathrm{s})}$$

where

$$Q_j^*(t) = Q_{GDP}^j(t,s) \cdot GDP_j^t\,;\;\; Q_j^*(\mathrm{s}) = Q_{GDP}^j(s,s) \cdot GDP_j^s = GDP_j^s \;\; \text{since } Q_{GDP}^j(s,s) = 1 \tag{16}$$

$$P_j^*(t) = P_{GDP}^j(t,s) \big/ PPP_j^t\,;\;\; P_j^*(\mathrm{s}) = P_{GDP}^j(s,s) \big/ PPP_j^s = 1 \big/ PPP_j^s \;\; \text{since } P_{GDP}^j(s,s) = 1 \tag{17}$$

First Decomposition:

The first decomposition is derived by expressing the last term in (15) as:

$$\frac{\sum_{j=1}^{M} Q_j^*(t) \cdot P_j^*(t)}{\sum_{j=1}^{M} Q_j^*(\mathrm{s}) \cdot P_j^*(\mathrm{s})} = \left[\sum_{j=1}^{M} \left(\frac{Q_j^*(t)}{Q_j^*(\mathrm{s})} \right) \cdot \frac{Q_j^*(\mathrm{s}) \cdot P_j^*(\mathrm{s})}{\sum_{j=1}^{M} Q_j^*(\mathrm{s}) \cdot P_j^*(\mathrm{s})} \right] \times \left[\frac{1}{\sum_{j=1}^{M} \left(\frac{P_j^*(\mathrm{s})}{P_j^*(\mathrm{t})} \right) \cdot \frac{Q_j^*(\mathrm{t}) \cdot P_j^*(\mathrm{t})}{\sum_{j=1}^{M} Q_j^*(\mathrm{t}) \cdot P_j^*(\mathrm{t})}} \right]^{-1} \tag{18}$$

In equation (18), the first term on the right-hand side is the standard Laspeyres quantity index whereas the second term on the right is the Paasche price index.

After substituting for $Q_j^*(t), Q_j^*(\mathrm{s}), P_j^*(t)$ and $P_j^*(\mathrm{s})$, $j = 1, 2, ..., M$ from equations (16) and (17) and some simplification, we can express the change in world real GDP in PPP terms shown on the left side of equation (15) to yield the desired decomposition into growth and inflation components.

$$\frac{RGDP_W^t}{RGDP_W^s} = \frac{\sum_{j=1}^{M} GDP_j^t / PPP_j^t}{\sum_{j=1}^{M} GDP_j^s / PPP_j^s}$$
$$= \left[\sum_{j=1}^{M} Q_{GDP}^j(t,s) \cdot \frac{RGDP_j^s}{\sum_{j=1}^{M} RGDP_j^s} \right] \times \left[\frac{1}{\sum_{j=1}^{M} \left(P_{GDP}^j(t,s) \cdot \frac{PPP_j^s}{PPP_j^t} \right)^{-1} \cdot \frac{RGDP_j^t}{\sum_{j=1}^{M} RGDP_j^t}} \right] \quad (19)$$

The first component is a weighted average of GDP growth in all the *M* countries from period *s* to period *t*, with weights based on the shares of countries in the world real GDP in the base period *s*. Therefore, the first expression is essentially a Laspeyres-type quantity index. The second component is a Paasche-type index which is a harmonic mean of price changes in different countries, after discounting for movements in changes in PPPs, with weights given by the shares of countries in the world real GDP in period *t* real GDP.

Second Decomposition

In deriving the second decomposition, we express the last term on the right side of equation (15) as the product of Paasche quantity index and Laspeyres price indexes. We have

$$\frac{\sum_{j=1}^{M} Q_j^*(t) \cdot P_j^*(t)}{\sum_{j=1}^{M} Q_j^*(\mathrm{s}) \cdot P_j^*(\mathrm{s})} = \left[\frac{1}{\sum_{j=1}^{M} \left(\frac{Q_j^*(\mathrm{s})}{Q_j^*(\mathrm{t})} \right) \cdot \frac{Q_j^*(\mathrm{t}) \cdot P_j^*(\mathrm{t})}{\sum_{j=1}^{M} Q_j^*(\mathrm{t}) \cdot P_j^*(\mathrm{t})}} \right]^{-1} \times \left[\sum_{j=1}^{M} \left(\frac{P_j^*(t)}{P_j^*(\mathrm{s})} \right) \cdot \frac{Q_j^*(\mathrm{s}) \cdot P_j^*(\mathrm{s})}{\sum_{j=1}^{M} Q_j^*(\mathrm{s}) \cdot P_j^*(\mathrm{s})} \right] \quad (20)$$

After substituting for $Q_j^*(t), Q_j^*(\mathrm{s}), P_j^*(t)$ and $P_j^*(\mathrm{s})$, $j = 1, 2, ..., M$ from equations (16) and (17) and some simplification we obtain the second decomposition of the change in world real GDP:

$$\frac{RGDP_W^t}{RGDP_W^s} = \left[\sum_{j=1}^{M} \left(P_{GDP}^j(t,s) \cdot \frac{PPP_j^s}{PPP_j^t} \right) \frac{RGDP_j^s}{\sum_{j=1}^{M} RGDP_j^s} \right] \times \left[\frac{1}{\sum_{j=1}^{M} \left(\frac{1}{Q_{GDP}^j(t,s)} \right) \times \frac{RGDP_j^t}{\sum_{j=1}^{M} RGDP_j^t}} \right] \quad (21)$$

The first component on the right-hand side of (21) is now a Laspeyres index of price change, adjusted for PPP change, with the base period country shares in the world real GDP as weights. The second component is a Paasche quantity index, that is, a weighted harmonic mean of country-specific quantity indices (or growth rates) with period *t* real GDP shares of countries as weights.

The two decompositions in equations (19) and (21) are clearly asymmetric. We have no reason to prefer one decomposition to another. A symmetric decomposition is obtained by taking a geometric mean of the two expressions in (18) and (19) and bringing the price and quantity indices together, so that

$$\frac{RGDP_W^t}{RGDP_W^s} = \left\{\left[\sum_{j=1}^{M}\left(P_{GDP}^j(t,s)\cdot\frac{PPP_j^s}{PPP_j^t}\right)\cdot\frac{RGDP_j^s}{\sum_{j=1}^{M}RGDP_j^s}\right]\times\left[\frac{1}{\sum_{j=1}^{M}\left(P_{GDP}^j(t,s)\cdot\frac{PPP_j^s}{PPP_j^t}\right)^{-1}\cdot\frac{RGDP_j^t}{\sum_{j=1}^{M}RGDP_j^t}}\right]\right\}^{1/2} \quad (22)$$

$$\times\left\{\left[\sum_{j=1}^{M}Q_{GDP}^j(t,s)\cdot\frac{RGDP_j^s}{\sum_{j=1}^{M}RGDP_j^s}\right]\times\left[\frac{1}{\sum_{j=1}^{M}\left(\frac{1}{Q_{GDP}^j(t,s)}\right)\cdot\frac{RGDP_j^s}{\sum_{j=1}^{M}RGDP_j^s}}\right]\right\}^{1/2}$$

The expression on the right side of equation (22) shows a Fisher-type price-over-PPP change index, $P_{GDP}^j(t,s)\cdot\left(PPP_j^t / PPP_j^s\right)$ and a Fisher-type quantity index, which can be re-written to show that it decomposes changes in real GDP of the world over the period *s* to *t* as follows:

$$\frac{RGDP_W^t}{RGDP_W^s} \equiv \left(P/PPP\right)_{GDP}^F(t,s;PPP)\times Q_{GDP}^F(t,s;PPP) \ . \quad (23)$$

The inclusion of *PPP* as conditioning variable in the two functions expresses the fact that the weights used are real GDP shares which depend on PPPs.

We note that the equation (23) reduces to equation (12a) when the decomposition is applied to a single country, i.e., M = 1, which demonstrates that this approach is consistent with the standard national accounts practice at the country level and that it offers a generalization when several countries are involved.

The quantity index in equation (23) is same as the index discussed in Diewert (2014). However, Diewert (2014) proposed no counterpart for the global price change which is consistent with changes in world GDP observed. Thus our decomposition in (23) is more complete. Further, our decomposition relies solely on standard index number theory that relates value change to Laspeyres and Paasche price and quantity indexes and the use of a symmetric decomposition.

An important implication from the price index in equations (22) and (23) is that a proper measure of global inflation needs to account for country-specific price changes, $P_{GDP}^j(t,s)$, as well as PPP changes over time given by $\left(PPP_j^t / PPP_j^s\right)$. This aspect is completely missing in the current measures of global and regional inflation published by international organisations such as the IMF and the United Nations. A possible reason for this important omission could be due to the fact that these organisations do not have a framework that underpins their measures of global growth and inflation. Their measures are simply constructed as averages of growth and inflations rates observed in different countries.

Though the Fisher decomposition of change in global real GDP over periods *s* and *t* in equations (22) and (23) is useful in obtaining global growth and inflation measures, it is impossible to disentangle from equations (22) the contribution of pure country-specific price change, $P_{GDP}^j(t,s)$ for $j = 1,2,\ldots,M$ and the contribution of changes in PPPs over time, $\left(PPP_j^t / PPP_j^s\right)$. We address this problem through the use of Sato-Vartia index.

4.2.2 Sato-Vartia-type measures of global inflation and growth

In this section, we make use of the Sato-Vartia index (Sato, 1974; Vartia, 1976) which is a multiplicative index. Properties of this index are well-documented in Feenstra (1994) and Balk (2008). Our preference for Sato-Vartia index is due to the property that the Sato-Vartia is the only multiplicative index which satisfies the factor reversal test. This means that measures of price and quantity change are multiplicative and their product equals value change.

In using a Sato-Vartia index for obtaining measures of global inflation and growth we first express change in real world GDP as a product of terms using the logarithmic mean[16] of shares of countries in the two periods:

$$\frac{RGDP_W^t}{RGDP_W^s} = \frac{\sum_{j=1}^M RGDP_j^t}{\sum_{j=1}^M RGDP_j^s} = \exp\left\{\sum_{j=1}^M \Phi^j \ln\left(\frac{RGDP_j^t}{RGDP_j^s}\right)\right\} = \prod_{j=1}^M \left[\frac{RGDP_j^t}{RGDP_j^s}\right]^{\Phi^j} \qquad (24)$$

where the weights, adding up to 1, are defined by

$$\Phi^j \equiv \frac{L\left(\dfrac{RGDP_j^t}{RGDP_W^t}, \dfrac{RGDP_j^s}{RGDP_W^s}\right)}{\sum_{j=1}^M L\left(\dfrac{RGDP_j^t}{RGDP_W^t}, \dfrac{RGDP_j^s}{RGDP_W^s}\right)} \quad j = 1,2,\ldots,M \qquad (25)$$

[16] For any two strictly positive real numbers *a* and *b* their logarithmic mean is defined as $L(a,b) \equiv (a-b)/\ln(a/b)$ if $a \neq b$ and $L(a,a) = a$. Properties of this mean are discussed in Balk (2008, 134-136). See Balk (2008, 85) for the derivation of an expression similar to that in (24).

and the function $L(.)$ is the logarithmic mean. Equation (24) says that growth in world real GDP can be expressed as a weighted geometric mean of country-specific growth rates, the weights being normalized logarithmic means of real GDP shares of countries in the two periods. Of course, when the temporal distance between s and t is large, then equation (24) may be replaced by a product of consecutive period ratios (and direct indices by chained indices); but this is immaterial to the method developed here which refers to two time periods.

Recalling that $RGDP_j^t = GDP_j^t \big/ PPP_j^t$ and using equation (12), we obtain the following decomposition of the change in the world real GDP:

$$\frac{RGDP_W^t}{RGDP_W^s} = \exp\left\{\sum_{j=1}^{M} \Phi^j \ln P_{GDP}^j(t,s)\right\} \times \exp\left\{\sum_{j=1}^{M} \Phi^j \ln\left(\frac{PPP_j^s}{PPP_j^t}\right)\right\} \times \exp\left\{\sum_{j=1}^{M} \Phi^j \ln \mathrm{Q}_{GDP}^j(t,s)\right\} \qquad (26)$$

This is a three-factor version of the Sato-Vartia index (see Balk 2002/3). The first factor represents a weighted average of domestic inflation rates; the second captures the effect of changes in PPPs for different currencies over the period; finally, the third represents world growth as a weighted average of domestic growth rates.

Combining the first two terms on the right-hand side in equation (26), the PPP-based global inflation is defined as:

$$(P\,|\,PPP)_{GDP}^{SV}(t,s;PPP) \equiv \exp\left\{\sum_{j=1}^{M} \Phi^j \ln\left(P_{GDP}^j(t,s) \times \frac{PPP_j^s}{PPP_j^t}\right)\right\}, \qquad (27)$$

the PPP-based global growth (quantity change) as the remainder,

$$Q_{GDP}^{SV}\left(t,s;PPP\right) \equiv \exp\left\{\sum_{j=1}^{M} \Phi^j \ln Q_{GDP}^j(t,s)\right\} \qquad (28)$$

so that the final decomposition of growth in world real GDP is

$$\frac{RGDP_W^t}{RGDP_W^s} = \left(P\,|\,PPP\right)_{GDP}^{SV}(t,s;PPP) \times \mathrm{Q}_{GDP}^{SV}(t,s;PPP). \qquad (29)$$

The pair of indices in equation (29) corresponds to the pair in equation (23), but the Sato-Vartia indices have a much simpler functional form than the Fisher indices. Moreover, the Sato-Vartia structure in equation (26) enables us to isolate the PPP component from the price component in a straightforward way.[17]

[17] The decomposition proposed here is also simpler than the three-way decomposition suggested by Reich (2013).

One look at the Fisher and Sato-Vartia based decompositions makes it clear that the quantity index components are invariant to the choice of the reference country for the PPPs, since this choice does not influence the real GDP shares. The price-over-PPP indices, however, are not due to the occurrence of the PPP component. Given the additional information on the contribution of changes in PPPs to global inflation measures that can be gleaned from the application of the Sato-Vartia index, it is our preferred option and recommendation for use by international organisations in their compilation of global inflation estimates.

The global inflation estimates are typically a weighted average (arithmetic, harmonic or geometric) of the following terms which appear in equation (22) for Fisher based decomposition and in equation (26) for Sato-Vartia based decomposition. These are, for each country j = 1,2,…, M

$$P_{GDP}^{j}(t,s)\cdot\frac{PPP_j^s}{PPP_j^t}$$

which is a country-specific GDP deflator for period t relative to period s adjusted for changes in the PPP of the currency of country j over the years s and t. If PPPs in the two years are the same[18], then and only then the global inflation simplifies to a weighted average of country-specific inflation. If the PPPs are different, then appropriate account of the changes in PPPs is needed in the estimation of global inflation.

4.3 Measures of Growth in World nominal GDP

In this section we essentially follow the same steps we used for world real GDP to decompose world nominal GDP over time. We apply the same arguments, but use exchange rates, *XR*s, instead of *PPP*s. For the sake of completeness we present these expressions which provide an easy reference for users interested in decomposing exchange rate converted GDP. The world GDP in nominal terms in period t is given by

$$NGDP_W^t = \sum_{j=1}^{M} NGDP_j^t = \sum_{j=1}^{M} \frac{GDP_j^t}{XR_j^t} \quad . \tag{30}$$

The changes in world *NGDP* between two periods s and t is given by:

$$\frac{NGDP_W^t}{NGDP_W^s} = \frac{\sum_{j=1}^{M} GDP_j^t \big/ XR_j^t}{\sum_{j=1}^{M} GDP_j^s \big/ XR_j^s}. \tag{31}$$

As before we offer two decompositions of this change.

[18] This scenario is very unlikely in practice and hence it is important that the PPP terms are included in global inflation measures.

4.4.1 Fisher-type decomposition

In providing a Fisher-type of decomposition, essentially we need to go through the same steps as in section 4.2.1 and derive Laspeyres and Paasche-type decompositions with only difference being that *PPP*s are replaced by *XR*s. The Fisher-type decomposition for changes in nominal GDP, similar to equation (22) is given by

$$\frac{NGDP_W^t}{NGDP_W^s} = \left\{ \left[\sum_{j=1}^{M} \left(P_{GDP}^j(t,s) \cdot \frac{XR_j^s}{XR_j^t} \right) \cdot \frac{NGDP_j^s}{\sum_{j=1}^{M} NGDP_j^s} \right] \times \left[\frac{1}{\sum_{j=1}^{M} \left(P_{GDP}^j(t,s) \cdot \frac{XR_j^s}{XR_j^t} \right)^{-1} \cdot \frac{NGDP_j^t}{\sum_{j=1}^{M} NGDP_j^t}} \right] \right\}^{1/2} \tag{32}$$

$$\times \left\{ \left[\sum_{j=1}^{M} Q_{GDP}^j(t,s) \cdot \frac{NGDP_j^s}{\sum_{j=1}^{M} NGDP_j^s} \right] \times \left[\frac{1}{\sum_{j=1}^{M} \left(\frac{1}{Q_{GDP}^j(t,s)} \right) \cdot \frac{NGDP_j^s}{\sum_{j=1}^{M} NGDP_j^s}} \right] \right\}^{1/2}$$

$$\equiv \left(P / \mathrm{XR} \right)_{GDP}^{F}(t,s;XR) \times Q_{GDP}^{F}(t,s;XR)$$

Thus we have a decomposition of the change in world GDP in nominal terms in Fisher price-over-exchange rate and quantity indices. The inclusion of *XR* as conditioning variable in the two functions indicative of the fact that the weights used are nominal GDP shares. Basically, equation (32) corresponds to the first approach of Diewert (2014).

4.4.2 Sato-Vartia index based decomposition

Here we follow the same line of argument and derivation as in section 4.2.2 where a decomposition of change in world real GDP was provided in equation (23). By simply replacing *PPP*s by *XR*s in equations (24) to (27), we obtain the following decomposition of world nominal GDP:

$$\frac{NGDP_W^t}{NGDP_W^s} = \exp\left\{ \sum_{j=1}^{M} \Psi^j \ln P_{GDP}^j(t,s) \right\} \times \exp\left\{ \sum_{j=1}^{M} \Psi^j \ln\left(\frac{XR_j^s}{XR_j^t} \right) \right\} \times \exp\left\{ \sum_{j=1}^{M} \Psi^j \ln Q_{GDP}^j(t,s) \right\} \tag{33}$$

$$= (P \mid XR)_{GDP}^{SV}(t,s;XR) \times Q_{GDP}^{SV}(t,s;XR)$$

where

$$\Psi^j \equiv \frac{L\left(\frac{NGDP_j^t}{NGDP^t} \cdot \frac{NGDP_j^s}{NGDP^s} \right)}{\sum_{j=1}^{M} L\left(\frac{NGDP_j^t}{NGDP^t} \cdot \frac{NGDP_j^s}{NGDP^s} \right)} \qquad j = 1, 2, ..., M$$

and $L(.)$ is the logarithmic mean. The Sato-Vartia index decomposition allows us to disentangle the effect of exchange rate movements from pure inflation. We also note, as we did before in the case of PPP-based decompositions, that the price-over exchange rate index is not invariant to the choice of the reference country for measuring the exchange rates. This lack of invariance reflects the fact that the choice of reference currency for the exchange rates influences the change in nominal world GDP over the years. For the case of $(P \mid XR)_{GDP}^{SV}(t,s;XR)$, the effect of this lack of invariance is convincingly demonstrated in Table I of Diewert (2014).

The global inflation measures can be seen as weighted averages of the following expression

$$P_{GDP}^{j}(t,s)\cdot\frac{XR_j^s}{XR_j^t} \quad j=1,2,...,M$$

It is important to note that the exchange rates do not remain the same and hence the ratio of exchange rates is likely to differ from unity. It is this ratio of exchange rates that is usually ignored in the computation of global inflation by international organizations such as the IMF.

4.5 Relationship between PPP- and Exchange Rate-based global growth and inflation measures

A link between exchange rate-based and PPP-based global inflation measure can be established through the concept of the price level index defined in equation (7). After simple algebraic manipulation of PPP and exchange rate based global growth and inflation measures in equations (27,28) and (32, 33), and using the price level index definition in equation (7), we can show that the measure of divergence between PPP and exchange-rate based global growth measure is given by

$$\frac{Q_{GDP}^{SV}(t,s;PPP)}{Q_{GDP}^{SV}(t,s;XR)} = \exp\left\{\sum_{j=1}^{M}\left(\Phi^j-\Psi^j\right)\cdot\ln\left(Q_{GDP}^{j}(t,s)\right)\right\} \quad (34)$$

and divergence in global inflation measures by

$$\frac{(P \mid PPP)_{GDP}^{SV}(t,s;PPP)}{(P \mid XR)_{GDP}^{SV}(t,s;XR)} = \exp\left\{\sum_{j=1}^{M}\left(\Phi^j-\Psi^j\right)\cdot\ln\left(P_{GDP}^{j}(t,s)\cdot\frac{XR^s}{XR^t}\right)\right\} \times \exp\left\{\sum_{j=1}^{M}\Phi^j\cdot\ln\left(\frac{PLI_j^s}{PLI_j^t}\right)\right\} \quad (35)$$

Divergence in global growth measures is due to differences in measures of country shares in global GDP in real and nominal terms. In the case of global inflation, what we see is that the right-hand side of equation (35) consists of two terms. The first is a covariance, between real and nominal share differences and price-over-exchange-rate index numbers; the second term is the weighted average of inverse of changes in the price level index. Equation (34) is also a covariance, but now between real and nominal share differences and country-specific growth rates.

If price changes are equal to changes in exchange rates, then the first expression on the right hand side of equation (35) would equal to 1 and the ratio of SV-based measures of global inflation would simply be equal to a weighted average of the price level indices. Similarly in equation (34), the general observation is that growth rates in GDP are higher for low income countries and, for these countries, shares in the world GDP in the world real GDP are higher than the respective shares in world nominal GDPand therefore we expect the ratio in (34) to be greater than 1.

4.4 Which decomposition to use?

In this paper we proposed two alternative methods of decomposing the change in world GDP measured in PPP or exchange rate terms over two periods. The first decomposition is based on Fisher-type indices and the second on Sato-Vartia indices. Both decompositions provide measures of price change and volume change (growth) which are consistent with the overall change in world GDP. The Fisher indices are based on weighted arithmetic averages of country-specific price and volume changes, while the Sato-Vartia indices are based on geometric averages. From a purely statistical view point, it is preferable to use geometric averages, as the country coverage is wide, and it is likely that country-specific movements are quite varied. Both decompositions have strong economic-theoretic foundations even though in the context of averaging over countries such considerations are less relevant. In empirical applications differences in global measures based on the Fisher and Sato-Vartia decompositions are likely to be small. There is one aspect relating to the contribution of changes in PPPs or exchange rates to the overall inflation measures where the Sato-Vartia based decomposition has an advantage. The formulation of the Fisher index makes it difficult to disentangle the influence of changes in PPPs and exchange rates. The geometric averaging used in the Sato-Vartia decomposition makes the decomposition of global (or regional) inflation into the contribution of country-specific inflation rates and that of changes in PPPs and exchange rates straight forward as shown in equations (23) and (29). Due to this slight comparative advantage over the Fisher-based decomposition, it is our preferred and recommended option.

5. CONSISTENCY-IN-AGGREGATION OVER GROUPS OF COUNTRIES

The paper thus far has focused on measuring growth and inflation for an entire set or group of countries. Though measurement of global growth and inflation is significant as such, one is usually also interested in the contribution of single countries or groups of countries to global inflation and growth. In this section we focus on the inter-relationships between growth and inflation measures at the regional (groups of countries) level and the measures at the global level. It is here we particularly see the advantage of Sato-Vartia indices over Fisher indices. As the SV indices are essentially weighted geometric averages, the logarithmic transformation of these indices provides an additive framework which lends itself to decomposition for regional groupings of countries.

Consider the PPP-based global growth measure in equation (28). By taking logarithms on both sides, we have

$$\ln Q_{GDP}^{SV}(t,s;PPP)=\sum_{j=1}^{M}\Phi^{j}\ln Q_{GDP}^{j}(t,s) \tag{36}$$

where Φ^j represents the weight attached to country *j*. We note here that the logarithm of an index number in the neighbourhood of unity can be interpreted as a rate of growth. Equation (36) then says that the (additive) contribution of country *j* to global growth is given by the percentage growth experienced by the country itself times its share in global real GDP, Φ^j (j=1,2,…,M).

For purposes of exposition, we consider a split of the world into two non-overlapping groups of countries, say regions *A* and *B*. This means the set of *M* countries is split into two disjoint subsets *A* and *B* such that $A\cup B=\{1,2,...,M\}$ and $A\cap B=\varnothing$ (empty set). Then equation (36) can be expressed equivalently as:

$$\begin{aligned}\ln Q_{GDP}^{SV}(t,s;PPP)&=\sum_{j=1}^{M}\Phi^{j}\ln Q_{GDP}^{j}(t,s)\\&=\sum_{j\in A}\Phi^{j}\ln Q_{GDP}^{j}(t,s)+\sum_{j\in B}\Phi^{j}\ln Q_{GDP}^{j}(t,s)\\&=\Phi^{A}\cdot\sum_{j\in A}\Phi^{jA}\ln Q_{GDP}^{j}(t,s)+\Phi^{B}\cdot\sum_{j\in A}\Phi^{jB}\ln Q_{GDP}^{j}(t,s)\end{aligned} \tag{37}$$

where

$$\Phi^{A}\equiv\sum_{j\in A}\Phi^{j}\ ;\ \Phi^{B}\equiv\sum_{j\in B}\Phi^{j};\ \Phi^{jA}\equiv\frac{\Phi^{j}}{\Phi^{A}}\ (j\in A);\ and\ \Phi^{jB}\equiv\frac{\Phi^{j}}{\Phi^{B}}\ (j\in B)\ .$$

Note that Φ^{jA} and Φ^{jB} respectively are the weights of countries within the regions they belong to; per region these weights add up to 1. Similarly, Φ^A and Φ^B are the weights for regions *A* and *B* in the world, respectively, and they also add up to 1. Equation (37) simply says that the (additive) contribution of country set *A* to world growth is given by the mean percentage growth experienced by the set of countries in *A* times its share in world real GDP, Φ^A.

While equation (37) offers a nice decomposition identifying the contributions of regions *A* and *B*, it is useful to note that the expression $\sum_{j\in A}\Phi^{jA}\ln Q_{GDP}^{j}(t,s)$ is not a measure of growth in real GDP of region

A. Proper measures of growth and inflation for regions *A* and *B* can be obtained by applying equations (27) and (28) to the data for countries in respective regions. This means, for example, that growth in region *A* measured by the logarithm of the Sato-Vartia index is given by

$$\ln Q_{GDP,A}^{SV}(t,s;PPP) = \sum_{j\in A} \widetilde{\Phi}^{jA} lnQ_{GDP}^{j}(t,s) \quad where \quad \widetilde{\Phi}^{jA} = \frac{L\left(\frac{RGDP_j^t}{RGDP_A^t}, \frac{RGDP_j^s}{RGDP_A^s}\right)}{\sum_{j\in A} L\left(\frac{RGDP_j^t}{RGDP_A^t}, \frac{RGDP_j^s}{RGDP_A^s}\right)} \tag{38}$$

and $RGDP_A^{\tau} = \sum_{j\in A} RGDP_j^{\tau} \ for \ \tau = t, s$ is the real GDP of region *A* in periods *t* and *s*. We note that the weights used in expression (37), Φ^{jA}, are different from $\widetilde{\Phi}^{jA}$ in equation (38) since

$$\Phi^{jA} = \frac{L\left(\frac{RGDP_j^t}{RGDP_W^t}, \frac{RGDP_j^s}{RGDP_W^s}\right)}{\sum_{j\in A} L\left(\frac{RGDP_j^t}{RGDP_W^t}, \frac{RGDP_j^s}{RGDP_W^s}\right)} \neq \widetilde{\Phi}^{jA}. \tag{39}$$

The conclusion is that

$$\ln Q_{GDP}^{SV}(t,s;PPP) \neq \widetilde{\Phi}^{A} lnQ_{GDP,A}^{SV}(t,s;PPP) + \widetilde{\Phi}^{B} lnQ_{GDP,B}^{SV}(t,s;PPP). \tag{40}$$

Put otherwise, Sato-Vartia indices are not consistent in aggregation.[19] The magnitude of this inconsistency, represented by the difference in the right- and left-hand sides of expression (39), is likely to be small in practice. In fact this inconsistency vanishes if the shares of regions in the global real GDP are constant over time. In that case it is easy to see, using a property of the logarithmic mean, that $\Phi^{jA} \neq \widetilde{\Phi}^{jA} (j \in A)$ and $\Phi^{jB} \neq \widetilde{\Phi}^{jB} (j \in B)$. However, while regional shares are definitely not constant they do not change much over time. This means that while the discrepancy, difference between right- and left-hand side of equation (39) is non-zero, it is likely to be small. We confirm this in our empirical results reported in Table 7.

6. ESTIMATED MEASURES OF GLOBAL GROWTH AND INFLATION FROM 2005 TO 2011

Results presented in this section are based on data described in Section 3.1. We have data for 141 countries in the years 2005 and 2011. In this section we present our estimates of global and regional inflation and economic growth computed using the Fisher and Sato-Vartia index based on measures proposed in Section 4.

[19] In this respect SV indices do not differ from Fisher indices (see Balk 2008, 108-113). Fisher based measures are also not consistent in aggregation.

All the data used in computing global growth and inflation are presented in Appendix A.2. We express the national level GDP deflators relative to the year 2005 as the base year.

6.1 Estimates of World and regional growth and inflation, 2005-2011

From Table 1 we have the size of the world economy in real terms as 55.788 and 87.892 trillions of US dollars respectively in 2005 and 2011. In exchange rate converted terms, the world nominal GDP was reported to be 45.145 and 69.303 trillions of US dollars. Based on these, we have different rates of growth in world GDP over the period 2005 and 2011 depending on whether we use real or nominal world GDP. These differences can be reconciled through the use of price level indices as illustrated in equation (10). However, it is important to keep these differences in mind while interpreting and comparing global growth measures based on PPP and exchange-rate based measures of global GDP.

We present PPP and exchange-rate based estimates of inflation and growth over the period 2005 to 2011 in Tables 2 and 3. Both Fisher and Sato-Vartia type decompositions are shown in these tables.

Table 2: PPP-based Global and Regional Growth and Inflation, 2005 and 2011

ICP Region	World Real GDP 2011/World Real GDP 2005	Price change	Growth	Price change	Growth
		Fisher	Fisher	Sato-Vartia	Sato-Vartia
Asia and the Pacific	2.3081	1.4277	1.6166	1.4274	1.6170
Africa	2.0005	1.3078	1.5297	1.3075	1.5300
CIS	1.8196	1.4447	1.2595	1.4447	1.2596
EuroStat-OECD	1.2399	1.1567	1.0719	1.1567	1.0719
Latin America	1.7276	1.3034	1.3255	1.3035	1.3253
Iran	1.8233	1.4005	1.3019	1.4005	1.3019
West Asia	2.5182	1.7441	1.4438	1.7443	1.4436
Georgia	1.6919	1.2943	1.3072	1.2943	1.3072
World	1.5755	1.2653	1.2451	1.2653	1.2452

Notes: Authors calculations based on international comparison data available from World Bank (2008 and 2015). Fisher based price change and growth are based on equation (23), and the Sato-Vartia are based on equation (29)

The first column of Table 2 shows changes in real measures of the size of the regional and global economies. While at the global level there has been an increase of 57.55 percent in World real GDP over the period, there is considerable variation in this change across different regions. Unsurprisingly, the lowest change is observed for the Eurostat-OECD group of countries which were severely affected by the Global Financial Crisis. The Fisher based measures of inflation and growth are presented in the second and third columns, and the Sato-Vartia based estimates in the fourth and fifth columns. These estimates show that the Sato-Vartia index numbers are almost identical to the Fisher index numbers as expected. As discussed in Section 4, the advantage of Sato-Vartia indices is that they enable a straightforward decomposition of the price change component, column four, into a measure based on domestic inflations and another component that shows the influence of changes in PPPs in periods 2005 and 2011..

Focusing on the Sato-Vartia based measures in the last two columns of Table 2 we have, at the global level, the PPP-based global inflation and growth measures of 26.53 and 24.52 percent. Regional variations in inflation and growth are large. While the Eurostat-OECD region posted the lowest inflation during this period, the Asia and the Pacific region had the best growth performance of 61.70 per cent. As the focus of the paper is mainly on economic measurement, we make no attempt to explain these regional differences in inflation and economic growth.

Measures of regional and global growth and inflation based on exchange rate based GDP measures are presented in Table 3. Again, there appears to be little difference between the Fisher and Sato-Vartia estimates. These results, as in the case of PPP-based measures, show that the Asia and the Pacific region has the highest growth rate and the Eurostat-OECD region the lowest. This is hardly surprising since the Asia-Pacific region is home to the two most populous, large and fastest growing economies in the world. On the other hand, the influence of the global financial crisis is clearly reflected in the low growth recorded by the Eurostat-OECD region.

Table 3: Exchange Rate-based Global and Regional Growth and Inflation, 2005 and 2011

ICP Region	World nominal GDP 2011/World nominal GDP 2005	Price change	Growth	Price change	Growth
		Fisher	Fisher	Sato-Vartia	Sato-Vartia
Asia and the Pacific	2.5297	1.5722	1.6090	1.5717	1.6095
Africa	2.1443	1.4286	1.5010	1.4285	1.5011
CIS	2.4622	1.9576	1.2578	1.9577	1.2577
EuroStat-OECD	1.2888	1.2098	1.0653	1.2098	1.0653
Latin America	2.5991	1.9725	1.3177	1.9727	1.3175
Iran	2.7520	2.1138	1.3019	2.1138	1.3019
West Asia	2.3175	1.5821	1.4648	1.5821	1.4648
Georgia	2.1408	1.6377	1.3072	1.6377	1.3072
World	1.5388	1.3196	1.1661	1.3194	1.1663

Notes: Authors' calculations based on data on international comparisons from World Bank (2008 and 2015). Fisher based price change and growth are based on equation (32). The Sato-Vartia indexes are based on equation (33).

6.2 Divergence in PPP- and Exchange Rate-based growth and inflation – an explanation

The PPP and exchange rate-based global growth estimates, computed using the Sato-Vartia index, in Tables 2 and 3 are, respectively, 24.52 and 16.63 percent. Analysts need to be cautious in their choice of whether a PPP-based or an exchange-rate based measure would be used. We are indifferent about this choice as the focus of the paper is essentially methodological. However, if one is interested in standards of living and in making welfare comparisons, it is more appropriate to use the PPP-based measure of global growth.

An explanation of the difference between the PPP and exchange rates based measures of growth lies in the regional growth figures reported in the last column of Tables 2 and 3. At the regional level it appears that the choice of PPPs versus exchange rates seems to make little difference. Since regional growth rates are nearly the same, the source of difference in growth rates at the global level must stem from differences in weights accorded to different countries and regions under the PPP and exchange-rate conversions of the national GDP figures. We also draw attention to equation (34), reproduced here

$$\frac{Q_{GDP}^{SV}(t,s;PPP)}{Q_{GDP}^{SV}(t,s;\mathrm{XR})} = \exp\left\{\sum_{j=1}^{M}\left(\Phi^{j}-\Psi^{j}\right)\cdot\ln\left(Q_{GDP}^{j}(t,s)\right)\right\}.$$

It is clear from this equation that PPP- and exchange rate-based growth rates would be the same if the shares of countries in the world GDP are the same under PPP and exchange rate conversions. Essentially the differences in shares are due to the differences in per capita GDP estimates implied by PPP and exchange rate conversions. It is generally true that PPP-converted per capita incomes for low income countries are higher than the exchange-rate-converted per capita incomes and that price level indices are quite low.[20]

Table 4 shows that the real per capita GDP are significantly higher than the nominal per capita figures for low income countries like Ethiopia, India and China. However, these differences are smaller in magnitudes for high income countries. A direct implication of this is that the shares of the low income

Table 4: Real and Nominal per capita GDP in
(in US dollars)

Country	Real per capita GDP		Nominal per capita GDP	
	2005	2011	2005	2011
P.R. China	4,091	13,495	1,721	7,321
Hong Kong	36,680	50,129	16,094	35,173
India	2,126	4,735	707	1,533
Australia	32,798	42,000	37,056	65,464
Japan	30,290	34,262	35,604	46,131
Luxembourg	70,014	88,670	80,315	115,689
Ethipia	591	1,214	154	353

Notes; Data for the selected countries are drawn from World Bank (2008 and 2015). real per capita GDP is the same as PPP Converted GDP per capita and XR converted per capita represents nominal per capita GDP.

countries in the global economy are higher when PPPs are used. Consequently, global growth, which is a weighted average of country-specific growth rates with weights based on country shares in the global

[20] There is a large literature explaining why price level indices (*PPP*/*XR*) are well below unity for low income countries (Kravis and Lipsey 1980, Clague 1986, and others).

economy will be higher when PPPs are used for conversion if the low income countries post higher growth rates over the period. It is also true that countries in the Asia-Pacific region, including China and India, and countries in Africa, have been growing at a much faster rate than countries in the Eurostat-OECD countries. Table 5 shows the shares of different regions in the world economy in 2011 in real and nominal terms.

Table 5: Shares of regions in the World Economy, 2011

ICP Region	Shares in the World Economy	
	Real (PPP-based)	Nominal (XR-based)
Asia & Pacific	31.43	19.23
Africa	3.42	2.26
CIS	5.00	3.57
Eurostat-OECD	49.82	66.79
Latin America	5.02	5.03
West Asia	1.33	0.76
Other	3.97	2.35
WORLD	100.0	100.0

Notes: Shares of regions computed from Table 1.

Table 5 shows clearly the differences in weights accorded to different regions of the world when PPPs are used instead of exchange rates. This means that an estimate of world growth based on real shares gives larger weight to the growth performance in the Asia and the Pacific, Africa and West Asian regions. These are the regions where countries have been recording significantly higher growth rates than countries in the other regions. These factors explain the higher global growth of 25.25 percent compared to 18.17 per cent growth in nominal terms.

Finally, we demonstrate that exchange rate-based shares of are generally lower than PPP-based shares in the global economy for countries experiencing above average growth rates. In our data set, this is the case with large economies like China and India which experienced spectacular growth rates during the study period 2005 to 2011. In Figure 1 below we demonstrate this phenomenon by plotting ratios of XR-based and PPP-based country shares in years 2011[21] against their growth performance over the period as measured by the ratio of constant price domestic GDP in the year 2011 relative to 2005. Shares and growth rates are all computed using data provided in Appendix 2.

[21] A very similar picture emerges when we plot the ratio of XR and PPP-based shares in 2005 against growth performance over the period 2005 to 2011. We have decided to just show the figure for 2011.

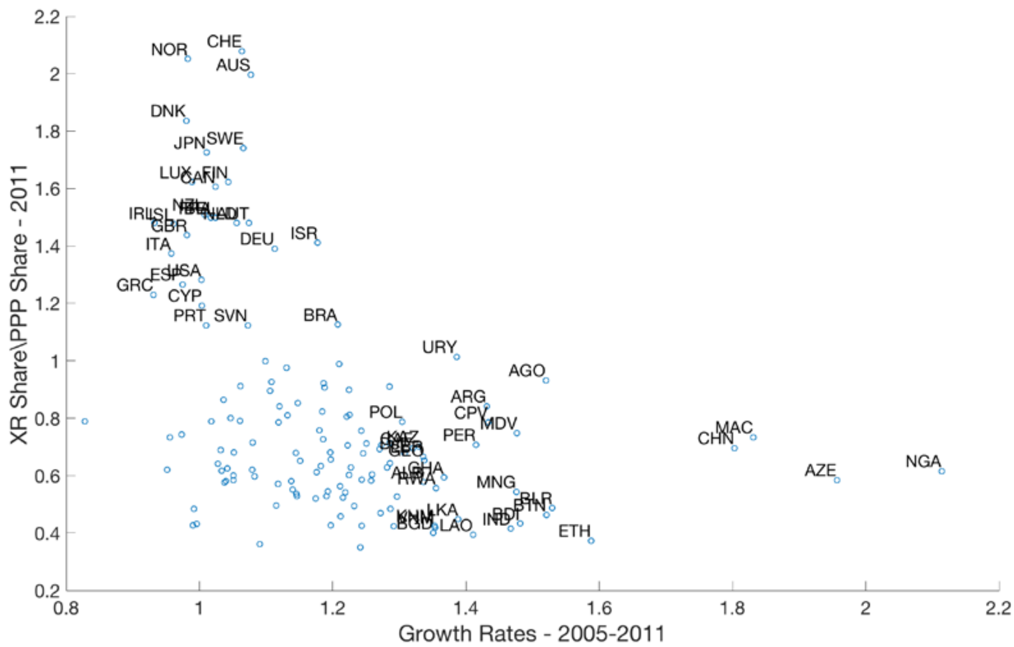

Figure 1: Ratios of XR and PPP-based shares against Growth Rates, 2005-2011

Notes: XR and PPP-based shares for countries and growth rates are computed using data drawn from the World Bank (2008, 2015) and data from World Development Indicators.

Figure 1 shows a strong negative relationship between the ratio of XR and PPP-based country shares in world GDP with growth performance of countries included in this analysis. Countries with low growth rates under 5% over the period (values less than 1.0 to 1.05 on horizontal axis) which are mostly developed economies from the OECD-Eurostat region have higher XR-based shares than PPP-based shares. Growth performance in these economies during this period was seriously affected by the Global Financial Crisis. If we focus on countries that have experienced higher growth rates (values between 1.2 and 2.1), we observe that the XR-based shares are significantly lower than PPP based shares. For example, in the case of China the XR-based share is about 70 percent of the PPP-based share and in the case of India the XR-based share is less than 50 percent of the PPP-based share. This information coupled with equation (34) clearly demonstrates the reason why the global growth rates based on exchange rates are usually well below the global growth rates based on PPPs.

6.3 Components of global inflation

We now turn our attention to global inflation, focusing on the Sato-Vartia based measures. We want to examine the contribution of domestic inflation and movements in PPPs and exchange rates to global inflation. The distinct advantage of the Sato-Vartia index is now in evidence as it allows for such a decomposition. We refer to the first two elements at the right-hand side of equations (26) and (33). Table 6 presents the desired decomposition.

The movement in domestic prices, reported in the third and sixth columns, is a weighted average of the domestic GDP deflators. The weights can be exchange rate based or purchasing power parities based. The results show that the domestic price change component is higher when using PPP-based weights. This may be explained by the fact that domestic inflation rates (like the growth rates) are higher in low income countries. The proportion of the change due to non-domestic factors appears to be higher when weights are based on exchange rates.

Table 6: Components of PPP and Exchange Rate-based Global Inflation

ICP Region	PPP Based Measure of Global Inflation			XR Based Measure of Global Inflation		
	Overall Inflation	Domestic Change component	PPP component	Overall Inflation	Domestic Change component	XR component
Asia and the Pacific	1.4274	1.4354	0.9944	1.5717	1.3945	1.1271
Africa	1.3075	1.6257	0.8043	1.4285	1.6089	0.8878
CIS	1.4447	2.1478	0.6726	1.9577	2.1326	0.9180
EuroStat-OECD	1.1567	1.1244	1.0288	1.2098	1.1104	1.0896
Latin America	1.3035	1.6172	0.8060	1.9727	1.6124	1.2235
Iran	1.4005	2.5035	0.5594	2.1138	2.5035	0.8444
West Asia	1.7443	1.6155	1.0798	1.5821	1.5661	1.0103
Georgia	1.2943	1.5237	0.8494	1.6377	1.5237	1.0748
World	1.2653	1.3002	0.9732	1.3194	1.2108	1.0897

Notes: Authors' calculations based on data from World Bank (2008 and 2015). The PPP and Exchange rate-based measures of overall inflation are drawn from Tables 2 and 3 of the paper. Decomposition of PPP-based inflation uses equation (26), and exchange rate-based decomposition is based on equations (33).

Table 6 demonstrates the difference between the current practice at international organizations such as the IMF and the World Bank with respect to the computation of global inflation and the conceptually correct measure of global inflation. Figures in columns (2) and (5) are conceptually complete and proper measures of global inflation which are consistent with national accounts practice and the standard index number theory and practice. These measures account for changes in country-specific inflation rates as well as for changes in PPPs and exchange rates. Figures in columns (3) and (6) are the measures computed and currently published and available in the public domain. Contribution of the PPP and XR components appear to influence the overall measure of global inflation in opposite directions. Exchange rate changes warrant an upward adjustment of 8.97 percent to the global inflation of 21.08 percent. In contrast, PPP changes over the period 2005 and 2011 have a downward adjustment of 2.7 percent to the global inflation. The important conclusion is that the global growth and global inflation measures are sensitive to the choice of PPP and exchange rates for conversion.

6.4 Consistency-in-aggregation over country-groupings

In this section we consider two measures of global growth: the first one treats all the countries in the world as one group and computes global growth; and the second measure is computed in two stages whereby growth rates for different regions, sub-groups of countries, are computed at first stage and aggregated to yield growth rate. The issue of consistency-in-aggregation of groupings of countries was discussed in Section 5 where we have shown that these two alternative measures of growth are likely to differ due to the weight used in the process. Equations (37), (38) and (39) demonstrate the likely source of divergence between direct and the two-stage measures of global growth. The general conclusion from our Section 5 is that the magnitude of inconsistency between global growth when measured for the world as a whole and when measured as an aggregate of regional growth rates is likely to be small. Table 7 presents results from our analysis of data.

Table 7: An Illustration of the Inconsistency-in-Aggregation Effect

ICP Region	Growth Rates with Exchange Rate-based weights			Growth Rates with PPPbased weights		
	Regional weights	Contribution at Global Weights	Contribution at regional weights	Regional weights	Contribution at Global Weights	Contribution at regional weights
Asia and the Pacific	1.6095	1.0747	1.0744	1.6170	1.1343	1.1341
Africa	1.5011	1.0078	1.0078	1.5300	1.0129	1.0129
CIS	1.2577	1.0066	1.0066	1.2596	1.0107	1.0107
EuroStat-OECD	1.0653	1.0473	1.0474	1.0719	1.0397	1.0398
Latin America	1.3175	1.0123	1.0123	1.3253	1.0158	1.0158
Iran	1.3019	1.0015	1.0015	1.3019	1.0033	1.0033
West Asia	1.4648	1.0074	1.0074	1.4436	1.0118	1.0118
Georgia	1.3072	1.0000	1.0000	1.3072	1.0001	1.0001
World	1.1663	1.1663	1.1659	1.2452	1.2452	1.2449

Notes: Authors' calculations based on data in Appendix 2; Columns (2) to (4) are XR-based results and columns (5) to (7) are PPP-based results.

Column (2) ; $=\exp\left\{\sum_{j\in A}\tilde{\Phi}^{j^A}\ln Q^j_{GDP}\right\}\ with\ \tilde{\Phi}^{j^A}\ defined\ in\,(38)$

Column (3) $=\exp\left\{\Phi^A\sum_{j\in A}\Phi^{j^A}\ln Q^j_{GDP}\right\}\ with\ \Phi^{j^A}\ defined\ in\,(37)$; and

Column (4) $=\exp\left\{\Phi^A\sum_{j\in A}\tilde{\Phi}^{j^A}\ln Q^j_{GDP}\right\}\text{with}\,\tilde{\Phi}^{j^A}\ \text{defined in}\,(36)\,\text{and}\,\Phi^A\ \text{in}\,(37)$

Columns (5) to (7) are defined similarly except that weights are based on PPP-based shares.

The main comparison is between the world growth estimates reported in columns (3) and (4) (and (6) and (7)) which show negligible difference between growth estimates when global weights as in equation (38) or regional weights as in (39) are used. Similarly, differences are negligible when regional or global weights are used arriving at estimates of global growth comparisons. From the view point of conceptual consistency, columns (4) and (7) may be preferred though the operational significance of this choice is negligible.

7. CONCLUSIONS

The main objective of the paper is to provide a conceptual framework for the compilation of highly visible and sought after global macroeconomic measures such as global growth and inflation. Such measures are currently compiled using market exchange rates or purchasing power parities (PPPs) of currencies regularly compiled by the World Bank. We first establish the need to anchor these measures on well-established concepts and measures of the size of the global economy.

The global growth and inflation measures proposed here are based on the standard index number approach used by national statistical agencies in their regular compilation of growth and GDP deflators. We derive two symmetric formula for the calculation of regional and global growth and inflation one based on the Fisher index and another based on the Sato-Vartia Index. We rely on very simple assumptions that all (or a sample of) the economic transactions of their inhabitants (economic agents such as households, firms, government institutions) are recorded such that sufficiently reliable annual national accounts (according to the UN System of National Accounts principles) are published and the index number toolbox can be used for analytical purposes. Of the two alternatives proposed, we recommend the use of Sato-Vartia index number formula which offers additional insights by allowing us to separate global inflation movements into two effects, the changes in domestic prices (inflation at national level) and the changes in the relative worth of currencies (PPPs or exchange rates). The fact that estimates of overall global growth and inflation estimates based on Sato-Vartia and Fisher index number formulae are numerically close strengthen the argument in favor of using Sato-Vartia index due to the flexibility and additional insights it provides. In doing so, we wish to point out that the current practice by international organization such as the IMF leads to incomplete measures of global inflation and, thereby, results in an inconsistency between observed changes in the size of the global economy and the published global growth and inflation estimates. The measures we propose here are fully consistent with national practices in that when our method is employed for a single country, the resulting measures of growth and inflation are identical to what the national accounts would show. Another significant feature of our approach is that we are able to offer a tangible explanation for the significantly lower global growth rates observed when exchange rates are used, compared to the growth rates derived when using PPPs. We derive an analytical expression for this difference and the conclusion is that the difference arises from the negative correlation between country specific growth rates and the differences in the country shares based on exchange rate and PPP conversions of GDP.

In our empirical illustration for 141 countries, we find the exchange rate based growth of the world from 2005 to 2011 to be 18%, while the PPP based growth is 25%. The fastest growing region during this period was Asia and the Pacific (57%), while the region with the slowest growth was Eurostat-OECD (7%). Global inflation movements are affected by changes in domestic prices (inflation at national level) and in the relative worth of currencies (PPPs or exchange rates). When using exchange rate-based weights to compute movements, the measured domestic price change components are smaller for all regions compared to the changes observed when purchasing power parities are used. We demonstrate the importance of using appropriately derived weights when measuring regional growth, and the effect of the inconsistency-in-aggregation of the Sato-Vartia indices, which we found to be negligible.

The main focus of the paper has been at the level of gross domestic product. However, these measures are equally applicable to components of GDP like household consumption, government expenditure, and gross fixed capital formation. A framework to ensure consistency between component growth and overall GDP growth and related issues is the subject of ongoing research. We strongly endorse and recommend that in the future measures of global growth and inflation are anchored on well-defined measures of the size of the world economy and on the measures proposed in the paper.

REFERENCES

Balk, B. M., 2002/3, "Ideal Indices and Indicators for Two or More Factors", Journal of Economic and Social Measurement 28, 203-217.

Balk, B. M., 2008, Price and Quantity Index Numbers: Models for Measuring Aggregate Change and Difference (Cambridge University Press, New York).

Balk, B. M., 2009, "Aggregation Methods in International Comparisons: an Evaluation", in Purchasing Power Parities: Recent Advances in Methods and Applications, edited by D. S. P. Rao (Edward Elgar, Cheltenham UK, Northampton MA).

Cicarelli, M. And B. Mojon, 2010, "Global Inflation", The Review of Economics and Statistics 92, 524-535.

Clague, C. 1986. "Determinants of the National Price Level: Some Empirical Results", Review of Economics and Statistics, Vol. 68, No. 2 (May, 1986), pp. 320-323.

Deaton, Angus and Bettina Aten, 2017. "Trying to Understand the PPPs in ICP 2011: Why Are the Results So Different?," American Economic Journal: Macroeconomics, American Economic Association, vol. 9(1), pages 243-264

Deaton, Angus, and Alan Heston, 2010, "Understanding PPPs and PPP-Based National Accounts", American Economic Journal: Macroeconomics 2(4): 1-35

Diewert, W. E., 2013, "Methods of Aggregation above the Basic Heading Level within Regions", Chapter 5 in World Bank (2013)

Diewert, W. E., 2014, Alternative Measures of OECD Output Growth and Inflation, Discussion Paper 14-01 (School of Economics, University of British Columbia, Vancouver BC, Canada).

Feenstra, R., 1994, "New Product Varieties and the Measurement of International Prices", The American Economic Review 84, 157-177.

Feenstra, R., R. Inklaar AND M. P. Timmer, 2013, PWT 8.0 – A User Guide, http://www.rug.nl/research/ggdc/data/pwt/v80/pwt_80_user_guide.pdf.

Feenstra, Robert C., Hong Ma, J. Peter Neary and D.S. Prasada Rao, (2013) "Who Shrunk China" Puzzles in Measurement of Real GDP", *Economic Journal*, Vol. 123, Issue 573, pp. 110-1129.

Hasan, F, 2016. "The price of development: The Penn–Balassa–Samuelson effect revisited", Journal of International Economics, Volume 102, September 2016, Pages 291-309.

IMF, 2018, World Economic Outlook, 2018. Washington DC.

Inklaar, R. and D.S. Prasada Rao (2017), "Cross-country Income Levels Over Time: Did the Developing World Suddenly Become Much Richer?, *American Economic Journal (Macroeconomics),* Vol. 9, No. 1, January, 2017, pp. 265-90.

Inklaar, R. And M. P. Timmer, 2014, "The Relative Price of Services", The Review of Income and Wealth 60, 727-746.

Kravis, I.G and R. Lipsey, 1982, “Towards an Explanation of National Price Levels”, NBER Working Paper 1034, NBER, Boston.

Monacelli, T. and L. Sala, 2009. “The International Dimension of Inflation: Evidence from Disaggregated Consumer price Data”, Journal of Money, Credit and Banking, Supplement to Vol. 41, No. 1.

Mumtaz, H. and P. Surico, 2012. :Evolving International Inflation Dynamics: World and Country-Specific factors”, Journal of the European Economic Association, 10(4): 716-734. DOI: 10.1111/j.1542

Rao, D. S. P., 2013, “The Framework of the International Comparison Program”, Chapter 1 in World Bank (2013).

Rao, D. S. P. and B. M. BALK, 2013, “Concepts and Terminology for International Comparisons of Prices and Real Incomes”, Paper presented at the Ottawa Group Meeting on Price Statistics, Copenhagen, 1-2 May 2013.

Rao, D.S.P., A.N. Rambaldi and B.M, Balk entitled “On Measuring Regional or Global Growth and Inflation,” Discussion Papers Series 552, School of Economics, University of Queensland, Australia

Reich, U.-P., 2013, “PPPs for SDRs? Some Theoretical Observations on How to Normalise, Capture the Dynamics, and Extend the Application of, Global Purchasing Power Parities”, Journal of Economic and Social Measurement 38, 171-185.

Sato, Kazuo (1976) “The Ideal Log-Change Index Number,” Review of Economics and Statistics, 58(2), 223- 228.

Vartia, Yrjo (1976) “Ideal Log-Change Index Numbers,” Scandinavian Journal of Statistics, 3(3), 121-126.

Ward, M., 2001, “International Price Levels and Global Inflation”, Statistical Journal of the United Nations Economic Commission for Europe (continued as Statistical Journal of the IAOS) 18, 65-75.

World Bank, 2008, Global Purchasing Power Parities and Real Expenditures 2005, International Comparison Program (The World Bank, Washington DC).

World Bank, 2013, Measuring the Real Size of the World Economy: The Framework, Methodology, and Results of the International Comparison Program – ICP (The World Bank, Washington DC).

World Bank, 2015, Purchasing Power Parities and Real Expenditures of World Economies: Summary of Results and Findings of the 2011 International Comparison Program (The World Bank, Washington DC).

United Nations (2009), *System of National Accounts 2008*, New York, 2009.

United Nations, 2018. World Economic Situation and Prospects, 2018. New York.

Zhang, Q, 2017. “The Balassa–Samuelson relationship: Services, manufacturing and product quality”, Review of International Economics, Volume 106, pp. 55-82.

Appendix A.1: National Accounts Framework for International Comparisons from the Expenditure Side

International economic comparisons of countries (or regions) are conceptually based on considering each country as an aggregate, consolidated production unit. Using the KLEMS-Y framework, the accounting relation of each country for each time period (conventionally assumed to be a year is given by

$$C_K + C_L + M_{EMS} + \Pi = R, \tag{A.1}$$

where C_K denotes capital input cost, C_L denotes labour input cost, M_{EMS} denotes the cost of imported intermediate commodities (energy, materials, and services), R denotes the revenue obtained from all the goods and services produced, and Π is a remainder term which may or may not be equal to 0, dependent on the way capital input cost has been calculated (see Balk 2010 and Jorgenson and Schreyer 2013 for explanation). It is good to note here that by intermediate commodities are understood all those commodities that need further processing before becoming available for final demand. As Kohli and Natal (2014) observe, also ``almost all so-called ``finished'' products must transit through the domestic production sector and go through a number of changes -- such as unloading, transporting, storing, assembling, testing, cleaning, financing, insuring, marketing, wholesaling and retailing -- before reaching final demand." Put otherwise, imported intermediate commodities comprise all those commodities to which value is added through the domestic production process.

There are, however, imports that don't need domestic value added to them, such as imported services. Let the import cost of those commodities be denoted by M_F , and let total import cost then be defined as $M \equiv M_{EMS} + M_F$.

The fundamental supply-demand equality, firmly entrenched in the National Accounts, is given by

$$M_F + R = E + I + G + X, \tag{A.2}$$

where, respectively, E is the value of private household consumption, I is the value of investment, G is the value of government consumption, and X is the value of exports. The sum of the first three terms, $E + I + G$ is called domestic absorption.

Using the definition of total import cost M equation (A.2) can be rewritten as

$$M + R - M_{EMS} = E + I + G + X. \tag{A.3}$$

For each production unit, revenue minus intermediate input cost is called value added, which at the country level is called gross domestic product (GDP):

$$GDP \equiv R - M_{EMS}. \tag{A.4}$$

Since value added is additive, GDP is the sum of value added of all the individual production units operating within the borders of the country, which is useful for a variety of analytical questions. Inserting the GDP definition (A.4) in the supply-demand equation (A.3) we get the familiar result

$$M + GDP = E + I + G + X. \tag{A.5}$$

Now suppose for a moment that there is a single world currency and that there are no import-export tax distortions, so that import prices paid are equal to export prices received, then total import cost $\sum M$ would be equal to total export revenue $\sum X$, where the sum is taken over all the countries. Then, consequently, total (or world) GDP would be equal to total (or world) domestic absorption,

$$\sum GDP = \sum (E + I + G). \tag{A.6}$$

Relative GDP, that is the ratio of a country's GDP to world GDP, could then be considered as an important indicator of a country's welfare.

Unfortunately, even if there were a single world currency, the comparison of GDPs between countries is hindered by the fact that for the same commodities different prices are charged in different countries. Thus, before comparing GDPs, any price effects must be removed.

Summarizing, the international comparison of GDPs (or their components) is plagued by currency differences and price differences.

Appendix A.2. Data Used in the Computations

	2005					2011					
WB code	**GDP**	**XR**	**PPP**	**NGDP**	**RGDP**	**GDP**	**XR**	**PPP**	**NGDP**	**RGDP**	**PGDPts**
USA	$13,030	1	1	$13,030	$13,030	$15,480	1	1	$15,480	$15,480	1.122
GBR	$1,272	0.55	0.65	$2,313	$1,957	$1,526	0.62	0.7	$2,445	$2,180	1.171
AUT	$242	0.8	0.87	$301	$278	$295	0.72	0.83	$410	$355	1.112
BEL	$299	0.8	0.9	$372	$333	$364	0.72	0.84	$507	$434	1.127
DNK	$1,540	6	8.52	$257	$181	$1,797	5.37	7.69	$335	$234	1.151
FRA	$1,712	0.8	0.92	$2,129	$1,860	$1,998	0.72	0.84	$2,780	$2,379	1.107
DEU	$2,228	0.8	0.89	$2,771	$2,504	$2,603	0.72	0.78	$3,622	$3,338	1.063
ITA	$1,438	0.8	0.87	$1,789	$1,653	$1,568	0.72	0.77	$2,182	$2,037	1.109
LUX	$30	0.8	0.92	$38	$33	$42	0.72	0.91	$59	$46	1.251
NLD	$513	0.8	0.9	$638	$570	$601	0.72	0.83	$836	$724	1.08
NOR	$1,915	6.44	8.84	$297	$217	$2,617	5.6	8.97	$467	$292	1.334
SWE	$2,770	7.47	9.24	$371	$300	$3,417	6.49	8.82	$526	$387	1.127
CHE	$485	1.25	1.74	$389	$279	$572	0.89	1.44	$644	$397	1.08
CAN	$1,396	1.21	1.21	$1,152	$1,154	$1,753	0.99	1.24	$1,771	$1,414	1.15
JPN	$503,600	110.22	129.55	$4,569	$3,887	$473,800	79.81	107.45	$5,937	$4,410	0.924
FIN	$155	0.8	0.98	$192	$158	$186	0.72	0.91	$259	$205	1.119
GRC	$194	0.8	0.7	$241	$277	$210	0.72	0.69	$292	$304	1.159
ISL	$1,028	62.98	97.06	$16	$11	$1,627	115.95	133.56	$14	$12	1.537
IRL	$163	0.8	1.02	$203	$160	$160	0.72	0.83	$223	$193	0.973
MLT	$5	0.81	0.58	$6	$9	$7	0.72	0.56	$9	$12	1.207
PRT	$154	0.8	0.71	$191	$216	$170	0.72	0.63	$237	$270	1.093
ESP	$909	0.8	0.77	$1,130	$1,180	$1,064	0.72	0.71	$1,481	$1,499	1.103
TUR	$655	1.34	0.87	$487	$753	$1,275	1.67	0.99	$762	$1,288	1.571
AUS	$993	1.31	1.39	$758	$714	$1,467	0.97	1.51	$1,513	$972	1.292
NZL	$162	1.42	1.54	$114	$105	$205	1.27	1.49	$162	$138	1.19
ZAF	$1,557	6.36	3.87	$245	$402	$2,954	7.26	4.77	$407	$619	1.531
ARG	$536	2.9	1.27	$185	$422	$1,773	4.11	2.7	$431	$657	2.296
BOL	$76	8.07	2.23	$9	$34	$165	6.94	2.95	$24	$56	1.638
BRA	$2,137	2.43	1.36	$878	$1,572	$4,126	1.67	1.47	$2,466	$2,807	1.511
CHL	$68,540	559.77	333.69	$122	$205	$120,000	483.67	348.02	$248	$345	1.389
COL	$338,700	2320.83	1081.9	$146	$313	$618,600	1848.14	1161.91	$335	$532	1.373
ECU	$41	1	0.42	$41	$98	$78	1	0.53	$78	$147	1.46
MEX	$9,274	10.9	7.13	$851	$1,301	$14,320	12.42	7.67	$1,153	$1,867	1.33
PRY	$54,250	6177.96	2006.8	$9	$27	$110,800	4191.42	2227.34	$26	$50	1.514
PER	$263	3.3	1.49	$80	$177	$496	2.75	1.52	$180	$326	1.259
URY	$420	24.48	13.28	$17	$32	$893	19.31	15.28	$46	$58	1.496
VEN	$296	2.11	1.15	$140	$257	$1,285	4.29	2.71	$300	$474	3.572
BHR	$6	0.38	0.25	$16	$24	$11	0.38	0.21	$29	$52	1.359
CYP	$14	0.79	0.72	$17	$19	$18	0.72	0.67	$25	$27	1.178
IRN	$1,697,000	8963.96	2674.8	$189	$634	$5,317,000	10616.31	4657.46	$501	$1,142	2.503

	2005					2011					
WB code	**GDP**	**XR**	**PPP**	**NGDP**	**RGDP**	**GDP**	**XR**	**PPP**	**NGDP**	**RGDP**	**PGDPts**
IRQ	$47,320	1472	558.7	$32	$85	$192,100	1409.48	516.52	$136	$372	2.062
ISR	$585	4.49	3.72	$130	$157	$880	3.58	3.94	$246	$224	1.165
JOR	$9	0.71	0.38	$12	$23	$20	0.71	0.29	$28	$70	1.653
KWT	$23	0.29	0.21	$79	$110	$43	0.28	0.17	$158	$256	1.668
LBN	$33,890	1507.5	847.5	$22	$40	$59,390	1507.5	839	$39	$71	1.298
OMN	$12	0.38	0.23	$32	$53	$29	0.38	0.19	$75	$151	1.597
QAT	$158	3.64	2.75	$44	$58	$624	3.64	2.42	$172	$258	1.492
SAU	$1,221	3.75	2.41	$326	$507	$2,407	3.75	1.84	$642	$1,308	1.415
SYR	$1,576	53.05	19.72	$30	$80	$2,910	47.4	21.3	$61	$137	1.624
EGY	$543	5.78	1.62	$94	$335	$1,367	5.93	1.62	$231	$844	1.854
BGD	$4,208	64.33	22.64	$65	$186	$8,917	74.15	23.15	$120	$385	1.49
BTN	$32	44.1	15.74	$1	$2	$87	46.67	16.86	$2	$5	1.389
BRN	$15	1.66	0.9	$9	$17	$21	1.26	0.72	$17	$29	1.228
KHM	$25,820	4092.5	1278.55	$6	$20	$51,730	4058.5	1347.11	$13	$38	1.367
LKA	$2,365	100.5	35.17	$24	$67	$6,356	110.57	38.65	$57	$164	1.809
HKG	$1,418	7.78	5.69	$182	$249	$1,917	7.78	5.46	$246	$351	1.079
IND	$36,110	44.1	14.67	$819	$2,461	$85,180	46.67	15.11	$1,825	$5,638	1.534
IDN	$2,786,000	9704.74	3934.3	$287	$708	$7,194,000	8770.43	3606.57	$820	$1,995	1.901
KOR	$857,400	1024.12	788.92	$837	$1,087	$1,204,000	1108.29	854.59	$1,086	$1,409	1.141
LAO	$28,700	10655.17	2988.38	$3	$10	$65,530	8030.06	2467.75	$8	$27	1.437
MAC	$94	8.01	5.27	$12	$18	$290	8.02	4.59	$36	$63	1.462
MYS	$543	3.79	1.73	$143	$314	$875	3.06	1.46	$286	$600	1.243
MDV	$13	12.8	8.13	$1	$2	$34	14.6	8.53	$2	$4	1.511
NPL	$552	71.37	22.65	$8	$24	$1,146	74.02	24.63	$15	$47	1.815
PAK	$6,918	59.51	19.1	$116	$362	$17,950	86.34	24.35	$208	$737	2.314
PHL	$5,592	55.09	21.75	$102	$257	$9,546	43.31	17.85	$220	$535	1.296
SGP	$211	1.66	1.08	$127	$196	$332	1.26	0.89	$264	$373	1.109
THA	$7,310	40.22	15.93	$182	$459	$10,790	30.49	12.37	$354	$873	1.246
VNM	$899,900	15858.92	4712.7	$57	$191	$2,642,000	20509.75	6709.19	$129	$394	2.108
DJI	$126	177.72	84.69	$1	$1	$219	177.72	94	$1	$2	1.225
AGO	$2,847	87.16	44.49	$33	$64	$9,705	93.93	68.31	$103	$142	2.144
BWA	$51	5.11	2.42	$10	$21	$96	6.84	3.76	$14	$25	1.592
BDI	$1,208	1081.58	343	$1	$4	$3,018	1261.07	425.77	$2	$7	1.352
CMR	$8,633	527.47	251	$16	$34	$12,550	471.87	227.21	$27	$55	1.14
CPV	$91	88.67	69.36	$1	$1	$153	79.32	48.59	$2	$3	1.041
CAF	$711	527.47	264	$1	$3	$1,022	471.87	255.86	$2	$4	0.992
TCD	$2,948	527.47	208	$6	$14	$4,949	471.87	250.44	$10	$20	1.29
COG	$3,198	527.47	269	$6	$12	$6,671	471.87	289.3	$14	$23	1.589
ZAR	$3,411	473.91	214	$7	$16	$14,840	919.49	521.87	$16	$28	3.02
BEN	$2,331	527.47	219.58	$4	$11	$3,419	471.87	214.03	$7	$16	1.205
GNQ	$3,800	527.47	287.42	$7	$13	$7,223	471.87	294.57	$15	$25	1.474

	2005					2011					
WB code	**GDP**	**XR**	**PPP**	**NGDP**	**RGDP**	**GDP**	**XR**	**PPP**	**NGDP**	**RGDP**	**PGDPts**
ETH	$101	8.67	2.25	$12	$45	$506	16.9	4.92	$30	$103	2.577
GAB	$5,012	527.47	256	$10	$20	$8,923	471.87	318.16	$19	$28	1.618
GMB	$18	28.58	7.56	$1	$2	$27	29.46	9.94	$1	$3	1.234
GHA	$16	0.91	0.37	$17	$43	$59	1.51	0.7	$39	$84	3.876
GNB	$309	527.47	217	$1	$1	$467	471.87	220.08	$1	$2	1.221
GIN	$10,650	3644.33	1219	$3	$9	$36,730	6658.03	2518.39	$6	$15	2.727
CIV	$8,817	527.47	287	$17	$31	$12,120	471.87	228.23	$26	$53	1.241
KEN	$1,453	75.55	29.52	$19	$49	$2,817	88.81	34.3	$32	$82	1.61
LSO	$8	6.36	3.49	$1	$2	$19	7.26	3.92	$3	$5	1.573
LBR	$0	1	0.49	$0	$1	$1	1	0.52	$1	$1	1.132
MDG	$10,090	2003.03	650	$5	$16	$20,050	2025.12	673.73	$10	$30	1.695
MWI	$403	118.42	39.46	$3	$10	$1,107	156.52	76.26	$7	$15	2.164
MLI	$2,699	527.47	240	$5	$11	$4,979	471.87	210.19	$11	$24	1.334
MRT	$565	265.53	99	$2	$6	$1,280	281.12	115.85	$5	$11	1.535
MUS	$189	29.5	14.68	$6	$13	$316	28.71	15.94	$11	$20	1.347
MAR	$520	8.87	4.88	$59	$107	$760	8.09	3.68	$94	$207	1.134
MOZ	$150	23.06	10.91	$7	$14	$363	29.07	16.03	$13	$23	1.617
NER	$1,755	527.47	227	$3	$8	$3,023	471.87	221.09	$6	$14	1.28
NGA	$15,010	131.27	60	$114	$250	$37,980	154.74	74.38	$245	$511	1.746
RWA	$1,458	557.82	186	$3	$8	$3,871	600.31	260.75	$6	$15	1.654
STP	$1,371	10557.97	5558	$0	$0	$4,675	17622.94	8527.16	$0	$1	2.727
SEN	$4,540	527.47	252	$9	$18	$6,626	471.87	236.29	$14	$28	1.221
SLE	$4,751	2889.59	1074	$2	$4	$12,750	4349.16	1553.14	$3	$8	1.958
NAM	$44	6.36	4.26	$7	$10	$88	7.26	4.66	$12	$19	1.532
SDN	$65	2.44	1.08	$27	$60	$163	2.67	1.22	$61	$134	2.022
SWZ	$16	6.36	3.29	$3	$5	$30	7.26	3.9	$4	$8	1.549
TZA	$15,980	1128.93	396	$14	$40	$36,390	1572.12	522.48	$23	$70	1.584
TGO	$1,109	527.47	240	$2	$5	$1,705	471.87	215.06	$4	$8	1.27
TUN	$42	1.3	0.58	$32	$72	$64	1.41	0.59	$45	$108	1.281
UGA	$17,720	1780.67	620	$10	$29	$46,060	2522.75	833.54	$18	$55	1.541
BFA	$2,755	527.47	200	$5	$14	$5,014	471.87	213.66	$11	$23	1.256
ZMB	$32,300	4.46	2.42	$7,236	$13,350	$85,810	4.86	2.38	$17,650	$36,050	1.997
FJI	$5	1.69	1.43	$3	$3	$6	1.79	1.04	$4	$6	1.289
ARM	$2,272	457.69	178.58	$5	$13	$3,743	372.5	187.1	$10	$20	1.332
AZE	$13	0.95	0.33	$14	$39	$52	0.79	0.36	$66	$145	1.945
BLR	$65,060	2153.82	779.33	$30	$83	$293,200	4974.63	1889.31	$59	$155	3.046
ALB	$825	99.87	48.56	$8	$17	$1,287	100.89	45.45	$13	$28	1.185
GEO	$11	1.81	0.74	$6	$15	$23	1.69	0.86	$14	$27	1.524
KAZ	$7,439	132.88	57.61	$56	$129	$26,110	146.62	80.17	$178	$326	2.499
KGZ	$101	41.01	11.35	$2	$9	$282	46.14	17.76	$6	$16	2.153
BGR	$45	1.57	0.59	$28	$76	$76	1.41	0.66	$54	$115	1.424

	2005					2011					
WB code	**GDP**	**XR**	**PPP**	**NGDP**	**RGDP**	**GDP**	**XR**	**PPP**	**NGDP**	**RGDP**	**PGDPts**
MDA	$35	12.6	4.43	$3	$8	$82	11.74	5.53	$7	$15	1.754
RUS	$21,310	28.28	12.74	$753	$1,673	$54,280	29.38	17.35	$1,847	$3,128	2.08
TJK	$6	3.12	0.74	$2	$9	$25	4.61	1.74	$5	$14	2.824
CHN	$18,380	8.19	3.45	$2,243	$5,328	$46,040	6.46	3.51	$7,125	$13,120	1.376
UKR	$438	5.12	1.68	$86	$261	$1,274	7.97	3.43	$160	$372	2.666
CZE	$3,091	23.96	14.4	$129	$215	$3,818	17.7	13.47	$216	$283	1.056
SVK	$48	1.03	0.55	$47	$88	$67	0.72	0.51	$94	$132	1.083
EST	$11	0.8	0.5	$14	$22	$16	0.72	0.52	$22	$30	1.325
LVA	$8	0.56	0.3	$14	$27	$13	0.5	0.35	$27	$38	1.549
HUN	$21,590	199.58	128.51	$108	$168	$27,200	201.06	123.65	$135	$220	1.247
LTU	$72	2.77	1.48	$26	$49	$104	2.48	1.57	$42	$66	1.322
MNG	$2,748	1205.22	417.22	$2	$7	$9,704	1265.52	537.13	$8	$18	2.267
HRV	$261	5.95	3.94	$44	$66	$329	5.34	3.8	$62	$87	1.21
SVN	$28	0.8	0.61	$35	$46	$36	0.72	0.63	$50	$57	1.144
MKD	$281	49.28	19.06	$6	$15	$436	44.23	18.68	$10	$23	1.276
BIH	$18	1.57	0.73	$12	$25	$27	1.41	0.72	$19	$38	1.259
POL	$971	3.24	1.9	$300	$511	$1,491	2.96	1.82	$503	$819	1.18
SRB	$1,586	66.72	27.21	$24	$58	$3,157	73.33	37.29	$43	$85	1.68
ROM	$290	2.91	1.42	$100	$205	$550	3.05	1.61	$181	$342	1.637

GDP figures are in billions of Local Domestic Currency; NGDP and RGDP are in billions of US dollars.