The Conference Board Total Economy Database
Methodological Notes

1. Labor Productivity and Total Factor Productivity

One of the most used measures of efficiency of an economy is labor productivity, which is the average output produced by unit of labor. Labor productivity estimates are obtained by dividing the output measure (Gross Domestic Product) by the total labor input used to produce that output.

(1) $Labor\ Productivity\ (Y/L) = \frac{Output\ (Y)}{Labor\ Input\ (L)}$

Two measures of labor productivity are included: output per person employed and (for countries for which total hours data are available) output per hour. Later sections describe how the output and labor series are obtained. The database also provides internationally comparable measures of levels of labor productivity by adjusting the output levels for differences in relative price levels by using purchasing power parities (PPPs).

Another type of productivity measure is total factor productivity, which is average output produced by a combination of multiple inputs, including labor and capital input, and with adjustments for changes in the quality of labor and changes in the composition of capital assets. To obtain the total factor productivity measures, a growth accounting framework is used to compute the contribution of these inputs to aggregate gross domestic product (GDP) growth. In the general production function below, output (Y) is produced by an input bundle X, consisting of capital services (K) and labor services (L_Q). Capital services can be decomposed into six types: computer hardware, software, telecommunications equipment, dwellings, buildings and structures, transport equipment, and machinery. Labor services (L_Q) are the product of labor quantity (L) and labor quality (Q). Input (X) is augmented by a Hicks-neutral total factor productivity (A).

(2) $Y = AX(L_Q, K)$

Under the assumption of perfect competitive factor markets where the marginal product of each input equals its price and constant returns to scale, the above general production function can be transformed into the following growth accounting framework:

(3) $\Delta lnY = \Delta lnA + v_L \Delta lnL + v_L \Delta lnQ + \sum_{i=1}^{6} v_{K_i} \Delta lnK_i$

where ΔlnX denotes the growth rate of variable X over two studying time periods, v's stand for the average input shares in total factor income and because of constant returns to scale, $v_L + \sum_{i=1}^{6} v_{K_I} = 1$. Equation (3) can be arranged to per hour/worker terms:

(4) $\Delta lny = \Delta lnA + v_L \Delta lnQ + \sum_{i=1}^{6} v_{K_i} \Delta lnk_i$

where y is labor productivity, defined as y=Y/L, the ratio of total output to labor quantity, k is capital deepening, defined as k=K/L, the ratio of capital services to labor quantity. Total hours worked is used as a measure of labor quantity. When this variable is not available in most developing and emerging economies, total employment is used instead under the assumption that the average hours worked per person do not change and the change in total hours worked equals the change in total employment. Equation (3) and (4) illustrate that the output growth is driven by a share weighted input growth and TFP growth, a residual that captures all sources of growth which are left unexplained by labor and capital services in the production function.

The accurate measurement of the variables in the productivity and growth accounting equations is the key to compare and evaluate the sources of output growth. Therefore, we discuss each of the components below.

2. Description of variables and methods

Output, GDP

The output measures in the database represent Gross Domestic Product at market prices, which are obtained from national accounts sources from international organizations and national statistical institutes. The post-1990 measures are obtained from a variety of sources, including the OECD National Accounts. Pre-1990 measures are mostly obtained from historical series, collected by Angus Maddison (2007).

Two gross domestic product (GDP) series are available in the database – GDPEKS and GDPGK. Both are expressed in constant US$ market prices and converted at purchasing power parity covering the period of 1950 - 2009. GDPEKS series are measured in constant 2009 US dollars.[1] It is updated from 2005 EKS PPPs with GDP deflator changes. These 2005 EKS PPPs are unpublished estimates from Penn World Tables (to be used in their upcoming version PWT 7), which are benchmarked on 2005 PPPs from the International Comparisons Project (ICP) at the World Bank (World Bank, 2005).[2] The adjustments made by PWT reflect:

(1) an adjustment for global weighting for individual countries using EKS weights over domestic absorption (DA) for all countries rather than over five main regions as was done in the ICP by the World Bank
(2) an adjustment for the net foreign balance using the PPP for domestic absorption (DA) rather than the exchange rate as in ICP
(3) a downward adjustment in the PPP for China, which originally was based on relatively high prices for 11 cities, in order to better reflect the impact of lower prices in rural areas in China.[3]

[1] "EKS" stands for the originators of this PPP formula, Eltoto, Kovacs and Szulc, which essentially is a multilateral Fisher index.
[2] GDPEKS are available for 111 economies, the following 12 countries are not covered by the PWT PPPs thus do not have GDPEKS series: Algeria, Barbados, Costa Rica, Dominican Republic, Guatemala, Jamaica, Myanmar, St. Lucia, Trinidad & Tobago, Turkmenistan, United Arab Emirates and Uzbekistan.
[3] We thank Alan Heston for providing the PWT rework of the ICP PPP data. For a detailed description on the PWT PPPs, see Angus Deaton and Alan Heston (2008).

The effect of the first two adjustments is an upward adjustment in GDP for the global economy (all countries excluding the USA) of 7.6 percent relative to the U.S. in 2005. The China correction adds another 2 percentage points to this global correction. In the case of the China the first two effects lead to an upward adjustment in GDP of 13 percent relative to the World Bank measure, and together with the adjustment for prices even to an upward adjustment of 28.5 percent of the World Bank GDP level for China.

GDPGK series are expressed in 1990 US dollars and are available for all of the 123 countries in the database.[4] They are converted at "Geary-Khamis" purchasing power parities (PPPs). The 1990 US dollar estimates are in almost all cases derived from Maddison (2007).[5] Maddison used a PPP for China which was constructed back in the 1990s for 1986, and which is much lower than the newly PPP obtained by the ICP/World Bank. As a result Maddison's GDP level for China in US dollars is roughly 40 percent higher than that of the World Bank. To partially adjust for this we adjusted Maddison's GDP level for China downwards by 22.6 percent, which brings it relatively close to the adjustments for China in the PWT PPP index, as described above.

Labor quantity

a. Employment

From the perspective of productivity, it is very important that the measure of employment should be consistent with the measure of output. In this regard, the key point is that employment figures should cover all persons engaged in some productivity activity that fall within the production boundary of the system.[6] It needs to include employees, self-employed as well as unpaid family members that are economically engaged, apprentices and the military. The production boundary follows one of two concepts, either the national concept or the domestic concept. The national concept counts all nationals working domestically and abroad, but excludes foreign workers employed domestically. The domestic concept includes all workers employed domestically, but excludes any nationals working abroad. The domestic concept is in line with the production boundary for GDP, thus is the consistent measure of employment as an input.

[4] "GK" stand for Geary and Khamis, who were the originators of this PPP formula, which is a multilateral index similar to binary Paasche index, giving relatively large weights to large countries.

[5] These data can be obtained from Angus Maddison's *Statistics on World Population, GDP and Per Capita GDP, 1-2006 AD* (Last update: March 2009), (see http://www.ggdc.net/Maddison/Historical_Statistics/horizontal-file_03-2009.xls).

[6] Employment has been defined by the International Labour Organization (ILO) in the "Resolution concerning statistics of the economically active population, employment, unemployment and underemployment", adopted by the thirteenth International Conference of Labour Statisticians. It is defined consistently in the System of National Accounts 1993 (1993 SNA) and European System of Accounts 1995 (1995 ESA). ILO: http://www.ilo.org/public/english/bureau/stat/res/index.htm; 1993 SNA XVII: Population and Labor Inputs: http://unstats.un.org/unsd/sna1993/toctop.asp; 1995 ESA Chapter11 Population and labor Inputs: http://circa.europa.eu/irc/dsis/nfaccount/info/data/esa95/en/esa95en.htm.

The United Nations *System of National Accounts 1993* (United Nation 1993 SNA Chapter 17) prescribes that national accounts statistics must also include compatible measures of employment, as described above. Eurostat, the European Union's statistical agency, and OECD now both report these National Accounts data on employment submitted by member countries via a join Eurostat/OECD questionnaire.[7] The employment figures reported under the National Accounts (domestic concept) are therefore the main sources for the employment data in advanced economies in this database.[8] Since the National Accounts data for most countries started from 90's, employment growth rate from Labor Force Survey (LFS) is used to extrapolate the employment level for earlier years.

A consistent and comparable measure of employment for countries not covered by OECD and Eurostat is scant. For non-OECD East European countries, we made use of data from the Vienna Institute for Comparative Economic Studies (WIIW) and from United Nations Economic Commission for Europe (UNECE). The Eurostat New Cronos Database and the ILO LABORSTA database have also been used frequently for this region. For Asian and Latin American countries we used data from respectively the Asian Development Bank (Manila), GGDC Total Economy Growth Accounting Database and the Economic Commission for Latin America and the Caribbean (ECLAC), extrapolated with series on labor force from World Bank World Development Indicators 2009. Series for Africa and Middle East countries are not for employment but for labor force and were also obtained from World Bank World Development Indicators 2009. Efforts are still under way to find the best available sources for those countries whose employment measure follows the international definition and is consistent with output.

b. Total Hours worked

Output per worker is a crude measure of productivity and total hours worked is the preferred measure of labor inputs as it measures labor intensity most adequately. The United Nation 1993 SNA Chapter 17 defines total hours worked as the aggregate number of hours actually worked during the year in employee and self-employment jobs.[9]

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[7] Situation of Annual National Accounts in the OECD Database and New Features of the Joint OECD-EUROSTAT Questionnaire: www.oecd.org/dataoecd/9/29/24336184.doc.

[8] US data are from BLS. OECD LFS data are used for United Kingdom because neither OECD nor Eurostat national accounts data are consistent with measure of output. UK data in Eurostat national accounts are in terms of employees from the LFS, while those in OECD national accounts are in terms of jobs based on employer surveys supplemented with LFS data to capture the self-employed.

[9] The ILO "Resolution concerning statistics of hours of work", adopted by the tenth International Conference of Labour Statisticians, defines hours worked as follows: Statistics of hours worked should include: (a) Hours actually worked during normal periods of work; (b) Time worked in addition to hours worked during normal periods of work, and generally paid at higher rates than normal rate (overtime); (c) Time spent at the place of work on work such as the preparation of the workplace, repairs and maintenance, preparation and cleaning of tools, and the preparation of receipts, time sheets and reports; (d) Time spent at the place of work waiting or standing-by for such reasons as lack of supply of work, breakdown of machinery, or accidents, or time spent at the place of work during which no work is done but for which payment is made under a guaranteed employment contract; (e) Time corresponding to short periods of rest at the workplace, including tea and coffee breaks. Statistics of hours actually worked should

Series of hours worked are currently available for 51 countries in the database with OECD and Eurostat National Accounts being the major data sources for recent years. Such data sources ensure that the total hours worked is within the production boundary as well as is produced by the employment data used in our database. For a detailed description on data sources, please refer to Detailed Sources of the Total Economy Database.

Labor quality

The input in terms of hours worked or total employment as described above, represents a series of labor quantity. In order to measure labor's contribution to output growth, an adjustment for changes in the quality of labor is needed. A labor quality index can be constructed on the basis of weighted measures of different skill-level groupings in the labor force.

The labor quality index, which is constructed from a weighted summation of the percentage of labor force in low, medium and high skill levels with relative wages being weights for three skill levels respectively, ranges between 1 and 2.8 for developing economies and between 1 and 2.25 for advanced economies. Thus a labor quality index of 1 indicates that all working force population is of low skill and 2.8/2.25 shows that all is of high skill.

The labor force skill level distribution is compiled from three databases: Barro and Lee (2000), EUKLEMS and projections by IIASA (2008).[10] Both Barro and Lee and the IIASA projection paper classify the population of 15+ into no schooling, primary, secondary and tertiary schooling, and have data at a 5 year interval. The time period for Barro and Lee is from 1960 to 2000 and that for the projection paper is from 2000 to 2050. On the other hand, EUKLEMS categorizes the percentage of total hours worked into low, medium and high skill level with annual data between 1970 and 2005. Though we are aware of discrepancies between the three datasets in terms of both the coverage (i.e., population vs. hours worked) and the definition, we lack the information to consolidate the three datasets into a unified one due to the data limitation. Instead we

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exclude: (a) Hours paid for but not worked, such as paid annual leave, paid public holidays, paid sick leave; (b) Meal breaks; (c) Time spent on travel from home to work and vice versa.

[10] Barro and Lee construct a data base on educational attainment using the perpetual inventory method. For every country they have at least one observation of educational attainment and using enrolment ratios they extrapolate backward and forward. The EUKLEMS data set is constructed from education data of the labor force for developed countries. They compared the quality of the education system between countries. The projections by the International Institute for Applied System Analysis (IIASA) are based on a demographic method and the use of different scenarios. There are four scenarios in the projection paper, i.e., Constant Enrolment Number (CEN), Constant Enrolment Ratio (CER), Fast Track (FT), and Global Education Trend (GET), CEN and CER are merely benchmark scenarios and are also dismissed as unrealistic by the authors of the paper, FT is a highly optimistic scenario and therefore we use the GET scenario in our estimation as we think it is the most reasonable one among the four.

have tried to find a statistical relationship among these three datasets and construct a yearly labor quality index for each country from 1960 to 2050.

The EUKLEMS dataset is considered to be the most accurate measure of labor quality among the three and is used as our benchmark for estimation. Specifically, we first combined the data from Barro and Lee and the IIASA projection paper based on the statistical relationship of the overlapping year 2000. Secondly, we use a seemingly unrelated regression (SUR) model to estimate the coefficients of the three skill levels between the combined dataset and EUKLEMS using the overlapping years, then use the coefficients to predict the three skill levels in the combined dataset so that the predicted combined data are more in line with the EUKLEMS dataset. As we consider EUKLEMS to be the most reliable measure of skill levels, we keep the original EUKLEMS data if available in the transformed combined dataset. This way, we get a dataset with EUKLEMS data together with the projected data of the combined dataset based on EUKLEMS for 104 countries between 1960 and 2050, divided into three skill levels. Thirdly, to smooth out the data for those EUKLEMS countries between the years covered by EUKLEMS and those not covered but are projected from the combined dataset, we use the growth rate of the projected non-EUKLEMS years to extend the EUKLEMS year levels. Finally, a linear interpolation is applied to get the skill levels in between the available 5 year intervals. Please refer to working paper "Measuring Labor Quality" (Bonthuis, 2009) for details.

The weights for three skill levels are calculated based on the EUKLEMS data. In addition to the percentage of total hours worked by low, medium and high skill workers, EUKLEMS also reports the percentage of labor compensation of three skill levels among total labor compensation. Wage levels for three groups are thus calculated by dividing the labor compensation share by hours worked share. Then wage levels of high and medium skill workers are normalized by the wage level of the low skill worker (i.e., wage level of low skill worker is normalized to 1 and used as a reference group) to get the relative wage of high and medium skill level workers. Since the relative wages are relatively stable over the years, we averaged the relative wages over the years for each of the country in EUKLEMS. We then divide the EUKLEMS countries into two groups – advanced countries and developing countries– and calculated the mean of the relative wage within these two groups. [11] Thus we get two sets of relative wages: 1, 1.42, 2.80 for developing countries and 1, 1.36, 2.25 for advanced countries.[12] We then apply these relative wages to all of the rest of the countries not covered by EUKLEMS in the TEGAD database. [13]

[11] Advanced countries include Australia, Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Japan, Luxembourg, Netherlands, Spain, Sweden, US, UK and West Germany. Italy is excluded because of the unreliable data. Developing countries include Czech Republic, Greece, Hungary, Korea, Poland, Portugal, Slovak Republic and Slovenia.

[12] The following weights are used: 1 for primary schooling, 1.4 for secondary and 2 for higher, in the paper by Ark, B. van and J. de Haan (1998), Productivity and living standards in the Netherlands: Causes and explanations of opposite trends, paper contributed to the conference 'Productivity and Living Standards', Groningen.

[13] We follow IMF's definition of advanced countries when using the weights for countries. Advanced countries is composed of 33 countries: Australia, Austria, Belgium, Canada, Cyprus, Czech Republic,

Capital and its deflators, ICT and non-ICT

For the calculation of the sources of growth contribution, we obtained measures of capital based of two asset groups, each including three asset types: non-ICT capital, including non-residential construction, transport equipment and machinery, and ICT capital, including, IT hardware, telecommunication equipments and software, For each type of asset, capital stock series, $K_{i,t}$, is constructed using the investment data, $I_{i,t}$. The perpetual inventory method with a geometric depreciation rate is used.

(5) $K_{i,t} = (1 - \delta_i) * K_{i,t-1} + I_{i,t}$

All values are in the real terms (quantities) in the above equation. Same set of depreciation rates, δ_i , is used for all countries. The starting capital stock K_0 is obtained by assuming an initial value of capital-output ratio, ($\frac{K_0}{Y_0}$).

The share of capital input is derived as the residual; i.e. one minus the share of labor in total factor income.

Growth in capital services flow is measured by weighted sum of growth in different types of capital stock.

(6) $\Delta \ln K = \ln K_t - \ln K_{t-1} = \sum_i \bar{v}_{i,t} \Delta \ln K_{i,t}$

The weights in the above equation are two-period average shares of each asset type in the value of total capital compensation.

(7) $\bar{v}_{i,t} = \frac{[\, v_{i,t} + v_{i,t-1} \,]}{2}$

(8) $v_{i,t} = \frac{p_{i,t} K_{i,t}}{\sum_i p_{i,t} K_{i,t}}$

The rental price $p_{i,t}$ of capital services from asset type *i* in period *t* is defined as

(9) $p_i = r_t + \delta_i - \pi_{i,t}$

In the above rental price equation, r_t is the nominal rate of return and $\pi_{i,t}$ is the asset price inflation (or capital gains).

The *ex-post* or internal rate of return is calculated by estimating the capital revenue for each time period from the labor compensation share. If such data is not available, *ex-ante* rate of return is used from the IMF Financial Statistics.

Denmark, Finland, France, Germany, Greece, Hong Kong SAR, Iceland, Ireland, Israel, Italy, Japan, Korea, Luxembourg, Malta, Netherlands, New Zealand, Norway, Portugal, Singapore, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Taiwan Province of China, United Kingdom, and United States.

The asset price inflation is calculated using *current* price and *constant* price investment series.

Data Sources

The data on non-IT investment by asset types is based on Penn World Tables investment dataset, as described and reworked by Azeez Erumban (2008). The Jorgenson/Vu dataset is used to integrate the date for ICT investment.[14] These datasets are extended using OECD and United Nations National Accounts (for non-IT investment); and WITSA Digital Planet Report 2008 (for IT investment).

The following set of depreciation rates is used.

- Construction – 0.03, Transport – 0.2, Machinery – 0.13
- IT Hardware – 0.3, Telecom Equipments – 0.12, Software – 0.46

The initial value of the capital stock is obtained using $K_0 = \frac{I_0}{(g+\delta)}$, where g is average of GDP growth rates. The capital stock series is estimated using the Perpetual Inventory Method assuming a geometric depreciation model as shown in equation (5)

Information on Computer Software and Computer Services, obtained from WITSA Digital Planet Report 2008, are combined to get the estimates of investment in software. The estimation of business investment (out of total reported in WITSA) is based on the latest values in the Jorgenson/Vu dataset which is the year 2005. The price deflators for latest years are obtained by using the rate of asset-price inflation in 2005 for the later years as well.

For OECD countries, the Penn World Tables dataset is extended by linking it with OECD investment series in the year 2004. For non-OECD countries, the investment series by asset types are derived by assuming the same distribution as Penn World Table's (i.e. using the 2004 values for the shares of asset-type specific investments in total capital formation). The investment price deflators are obtained by using the rate of asset-price inflation in 2004 for the later years as well.

The external rate of return data is taken from IMF International Financial Statistics series on Central Bank Discount rate, Government Bond Yield and Lending Rate.

Labor Share

The labor share in total compensation, which is used to assign weights to labor and capital, has been constructed from various sources. The labor shares (ratio of labor compensation to gross value added at basic price) from EUKLEMS are used whenever the data is available. OECD and Eurostat report data on labor compensation for

[14] These data are available as "kuznets Data Set" on Dale Jorgenson's website (Data page) at Harvard University: http://www.economics.harvard.edu/faculty/jorgenson/recent_work_jorgenson.

employees and GDP at basic prices (which is GDP at market price minus taxes less subsidies). Under the assumption that the labor compensation for self-employed can be imputed from the average compensation for employees, we adjust the employee labor compensation share by dividing the employee share among total employment to obtain the total labor compensation share among GDP. For a few large non-OECD, non-EU countries, we estimated the labor share using other sources. In the case of China, the labor share is estimated from I/O tables. For Brazil, India and Russia the labor share is calculated using compensation data from the ILO.

A few adjustments were made for missing years in the above sources. The latest year in EUKLEMS data (March 2008) is 2005. For years after 2005 we use the growth rate of the computed labor share from OECD and/or Eurostat to extrapolate the EUKLEMS series. We use EUKLEMS country average labor share growth rate to extrapolate missing years before 2005 in various sources.[15]

For the other emerging and developing economies, we simply use 0.5 as the labor share. In much of the growth accounting literature, a labor share of 0.7 is widely used across time and countries. Gollin (2002) identified and compared several adjustments for calculating labor shares and concluded that factor shares are approximately constant across time and countries within a range of 0.65 to 0.80. However, we use labor share 0.5 for emerging and developing economies because in those economies capital is scarce thus its return is high, and the labor is cheap compared to advanced countries, leading to a lower labor share. Moreover, much depends on the labor share that is allocated to self-employed especially in emerging and developing economies where that group is still relatively large.

3. Aggregation of Growth Rates

Growth rates for individual countries are calculated using the log difference. This is necessary in order to facilitate aggregation as well as decomposition of the growth for individual countries and components. With regard to the aggregation to country groups, the following formulas are used for GDP, labor input and labor productivity growth respectively:

$$\Delta \ln Y_{region} = \sum_i \overline{w_i}\, \Delta \ln Y_i \tag{10}$$

$$\Delta \ln L_{region} = \Delta \ln \sum_i L_i \tag{11}$$

$$\Delta \ln y_{region} = \sum_i \overline{w_i}\, \Delta \ln y_i + \left(\sum_i \overline{w_i}\, \Delta \ln L_i - \Delta \ln \sum_i L_i\right) = \sum_i \overline{w_i}\, \Delta \ln y_i + R \tag{12}$$

with w_i as the country share in PPP adjusted nominal GDP of the region for each year and a bar denoting the two-period average. Hence aggregate GDP growth is the weighted sum of the country GDP growth. Growth in labor quantity (employment or hours) is simply the log difference of summed total labor quantity of all the countries in one region. The

[15] 2008 data for Australia, Canada, Japan, New Zealand and US, 2006-08 for Brazil, 2007-08 Russia is extrapolated using the latest 5 year average growth rate of its own country. In November 2009, EUKLEMS released updates to 2007, which will be integrated in the next round of the Total Economy Database (September 2010).

aggregate labor productivity growth is the weighted sum of country productivity growth plus a reallocation term R. The reallocation term is positive if employment shifts from low productivity countries towards high productivity countries.

Aggregate Total Factor Productivity (TFP) growth rates for various country groups are calculated using the following steps.

1. Aggregate labor input growth rates and aggregate capital services growth rates are calculated by taking the weighted average of individual country growth rates. The weights used are two period averages of the country shares in PPP-adjusted nominal GDP of the group for each year.

2. Aggregate labor compensation share for each year is obtained by summing up the labor compensation (PPP adjusted) of individual countries and then dividing this sum by total nominal GDP (PPP adjusted) of the group.

3. TFP growth rates are calculated using

(13) $$\Delta \ln A_{region} = \Delta \ln Y_{region} - \bar{\alpha}_{region} \Delta \ln L_{region} - \left(1 - \bar{\alpha}_{region}\right) \Delta \ln K_{region}$$

where $\bar{\alpha}_{Region}$ is the two period average of the regional labor compensation shares, and $\Delta \ln Y_{region}$ is defined in equation (10).

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