Total Economy Database

A detailed guide to its sources and methods

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Introduction

This document describes the sources and methods used to construct the variables presented in The Conference Board Total Economy Database™ (TED). It provides a detailed overview of the construction of individual variables in the database covering the period 1950-2016. Estimates for the ongoing year are either forecasts by The Conference Board (GDP) or taken from other forecasters, including the European Commission, the Organization for Economic Cooperation and Development (OECD), the International Monetary Fund (IMF) and the United Nations (UN) International Labor Organization (ILO) in the case of employment.

The TED is a comprehensive database with annual data covering Gross Domestic Product (GDP), population, employment, hours, labor quality, capital services, labor productivity, and total factor productivity (TFP) for 123 countries in the world. Chinese data is presented in two series, 'China (Alternative)' and 'China (Official)'. The latter is based on official data, while 'China (Alternative)' is from Wu (2014), revised and updated in 2017. The TED was originally developed by the Groningen Growth and Development Centre (University of Groningen, The Netherlands) in the early 1990s. Beginning in the late 1990s, it was produced in partnership with The Conference Board. In 2007, the database was transferred from the University of Groningen to The Conference Board, which has maintained and extended the database since then. In January 2010, The Conference Board expanded the database by adding a module on sources of growth, including labor quantity and quality, capital services, and total factor productivity (TFP). The extended module aims to integrate two previous data sets, namely the world economy productivity data set created by Dale Jorgenson and Khuong Vu of Harvard University and the Total Economy Growth Accounting Database of the Groningen Growth and Development Centre.

With the November 2016 release, the growth accounting module has been greatly improved and extended to increase the coverage and quality of investment as well as prices of information and communication technology investment goods.[1] The TED approach to measure investment—both ICT and non-ICT—is explained in section 2.2.1, while more details and some of the important findings can be found in Erumban, Inklaar and de Vries (2017). Due to rapid changes in technology, the prices of ICT assets fell significantly over years. It is argued that official data do not reflect the true decline in the price of ICT assets (Byrne and Corrado 2016a, 2016b). We provide an alternative version of the dataset which corrects for the rapid declines in prices of ICT goods. Our approach to account for declining ICT

[1] The update of underlying investment data by assets was done in collaboration with Robert Inklaar of the University of Groningen, as part of the Penn World Table.

prices in the growth accounting module is discussed in section 2.2.1. As a consequence of this deviation from official data, TED is released in two versions, both of which use the same underlying investment data but differ in the set of prices used to deflate ICT investments for all countries and subsequent adjustment to real GDP growth for China, Japan and the United States. The adjusted version is our preferred version, but for comparability purposes (with earlier version of TED or with official sources) an original version is presented alongside. More information on the differences between the two versions can be found in sections 1.1.5 and 2.2.1, while the box below provides a brief summary.

The first section of this document covers the sources and methods used to construct the basic income and productivity variables. These variables are GDP, employment, hours worked and population. Time series data for these variables are available from the file 'Output, Labor and labor Productivity', on the TED webpage. The second section focuses on the growth accounting variables, which are the factors that contribute to GDP growth as identified by the growth accounting method. The data are available from the file 'Growth Accounting and Total Factor Productivity'. The third and last section outlines the method of aggregation used to obtain regional growth rates, as available from the file 'Regional Aggregates'.

Box: Distinguishing between the original and adjusted version

The Total Economy Database consists of two versions, which are identical in their country and indicator coverage, but differ in terms of data:

TCB original version: *is largely consistent with previous releases of TED. ICT investment is deflated using official ICT price deflators, whenever available, and harmonized ICT deflators using official ICT deflators for the United States. GDP growth rates are consistent with official data.*

TCB adjusted version*: ICT investment in the United States is deflated using alternative ICT price deflators developed by Byrne and Corrado (2016a, 2016b), which suggests a faster decline in ICT prices compared to official data. For all other countries, a harmonized ICT deflator based on these alternative ICT deflators is used. GDP growth rates for China, Japan and the United States, which are the largest producers and exporters of ICT equipment, are adjusted to reflect the ICT price decline, and as a consequence their GDP levels are adjusted as well. GDP levels in PPP in all other countries are adjusted to reflect the relative price differences between United States and the given country.*

1 – Basic income and productivity variables

Data for the basic productivity and income variables are generally sourced from official data whenever available. The biggest exception to this rule however are the alternative data series for China (see section 1.1.4), which are presented alongside the official estimates. Furthermore, for historical data and for employment and hours data in general, non-official estimates are sourced from academic studies or international institutions (such as the ILO modeled employment estimates) whenever official data is not available. Table 1 below gives an overview of the basic sources used to construct time series of GDP, employment, hours worked and population. However, in many cases country specific sources have been used, either official or academic studies (such as Historical National Accounts). Sections 1.1 through 1.4 go deeper into particularities, such as concepts used or deviations from official data.

Table 1 – Basic overview of sources used in TED I

GDP	*Employment*	*Hours worked*	*Population*
Pre-1990 data mostly from Maddison, Historical Statistics	National Accounts data: Eurostat, OECD, UN National Accounts Official Country Data	National Accounts data: Eurostat, OECD	Pre-1990 data mostly from Maddison, Historical Statistics
Post-1990 data mostly from Eurostat and the IMF World Economic Outlook, and in some cases national statistical institutes	Labor Force Survey based: UN Economic Commission for Europe, Asian Development Bank, UN International Labor Organization	Labor Force Survey based: (only growth rates are used) Socio-Economic Database for Latin America and the Caribbean (CEDLAS and The World Bank)	Post-1990 data from Eurostat, IMF World Economic Outlook and the US Census Bureau International Data Base
	Other: Groningen Growth and Development Center—10 Sector Database, Asian Productivity Organization, UN ILO modeled estimates	Other: Asian Productivity Organization, Maddison (1982, 1995, 2001), Crafts (1997), Hoffman (1998)	

1.1 Gross Domestic Product

1.1.1 Concept and sources

The Total Economy Database uses GDP, valued at market prices, as a measure of output in a country. GDP statistics are available for most countries in the world and are collected and constructed by national statistics agencies, using international guidelines set by the United Nations (UN) in their *System of National Accounts* handbook (UN, 2009). This assures a certain level of consistency, even though the quality of the data may differ between countries.

Real GDP growth rates for the period before 1990 are obtained from Maddison Historical Statistics (Maddison, 2010). Official estimates of GDP are used for the years after 1990 and are obtained from various national (country-specific) or international sources, such as Eurostat or the International Monetary Fund World Economic Outlook. Estimates for the ongoing year are forecasts by The Conference Board, using country-specific insights from our in-house experts.

1.1.2 Converting GDP data to a common denominator

National Statistics Offices prepare GDP level estimates on a national currency basis, and as such are not internationally comparable. Exchange rate conversion is an easy method of translating national currency GDP and other economic indicators into a common currency. However, exchange rates are not reflective of purchasing power differences across countries, and therefore, a more pertinent approach is to use purchasing power parities (PPPs). PPPs are seen as better capturing the 'true' value of what a dollar can buy in goods and services in any country. In general, products and services are consumed and produced at lower prices in low-income countries than in high-income countries. Exchange rates fail to capture this, as they do not consider price differences across countries. Therefore, PPPs are preferred to exchange rates as a method of converting national currency based GDP into a common denominator. From a business point of view, PPPs are vital to understanding the market size or real standards of living of a country, while from a revenue perspective, exchange rate converted data are more useful.

In the TED, real GDP is expressed in 2016 PPP $, and is referred to as GDP EKS.[2] The 2016 PPPs are based on the World Bank-international comparison project (ICP) 2011 round, updated using the change in the national GDP deflator, relative to the US GDP deflator. In order to construct current price GDP series in US$, we derive such PPPs for each year using changes in relative prices:

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[2] The EKS method is a multilateral method developed by Eltoto, Kovacs and Szulc, that computes the n^{th} root of the product of all possible Fisher indexes between n countries. It has been used at the detailed heading level to obtain heading parities, and also at the GDP level. EKS has the properties of base-country invariance and transitivity. For more details, see chap. V and annex II in UN (1992).

$$PPP_t^i = PPP_{t-1}^i * e^{\Delta ln\left(\frac{p^{GDP_t^i}}{p^{GDP_t^{US}}}\right)} \quad \text{For } t > 2011 \qquad (1\text{-}A)$$

$$PPP_t^i = PPP_{t+1}^i / e^{\Delta ln\left(\frac{p^{GDP_{t+1}^i}}{p^{GDP_{t+1}^{US}}}\right)} \quad \text{For } t < 2011 \qquad (1\text{-}B)$$

where PPP_t^i is the PPP between country i and the United States in year t and $\left(\frac{p^{GDP_t^i}}{p^{GDP_t^{US}}}\right)$ is the ratio of the GDP deflator in country i and in the United States. GDP deflators are obtained from the national accounts as the ratio of current and constant GDP in a given country.

1.1.3 Adjustments to ensure comparability

Some countries report GDP based on the (country specific) fiscal year, as opposed to using the calendar year which is common for most countries. In order to ensure comparability across countries, GDP data is adjusted to reflect the calendar year. There are two ways to adjust fiscal year reported data to this end. The most straightforward way is to use quarterly national accounts data, so that calendar year based data is constructed using data from the relevant quarters. When quarterly data is not available, the average of two fiscal years are used, so that:

$$GDP_t^{CY} = \frac{GDP_t^{FY} + GDP_{t-1}^{FY}}{2} \qquad (2)$$

where CY denotes calendar year and FY fiscal year. Obviously, this method only provides relevant results when the country specific fiscal year starts at the middle of the calendar year. Table 2 presents an overview of the countries for which an adjustment is made.

Table 2 – Adjustments to fiscal year based GDP data

Country	*Start of Fiscal Year*	*Adjustment method*
Iran	March 21	Quarterly National Accounts data
India	April 1	Quarterly National Accounts data
New Zealand	April 1	Quarterly National Accounts data
Australia	July 1	Quarterly National Accounts data
Egypt	July 1	Quarterly National Accounts data
Bangladesh	July 1	Average of two years annual data
Pakistan	July 1	Average of two years annual data
Ethiopia	July 8	Average of two years annual data

The Total Economy Database is essentially an update and extension of Maddison Historical Statistics (Maddison, 2010) and as such it uses the same list of countries as apparent in that database. However, ever since 1990—which is the base year for the original Maddison Geary–Khamis (GK) PPP converted GDP data—some countries have undergone significant changes to their borders. These countries are Ethiopia, from which Eritrea seceded in 1993, Serbia & Montenegro, which separated into two independent states in 2006 and Sudan, which broke up into the Republic of Sudan and South Sudan in 2011. Data in the TED refer to the old border situation of these countries, so that Ethiopia includes Eritrea, Serbia & Montenegro are one country, as are the Republic of Sudan and South Sudan. Real GDP growth rates for the period for which these countries no longer form a union are obtained as weighted aggregate of the two countries using their nominal GDP shares.

1.1.4 Alternative GDP estimates for China[3]

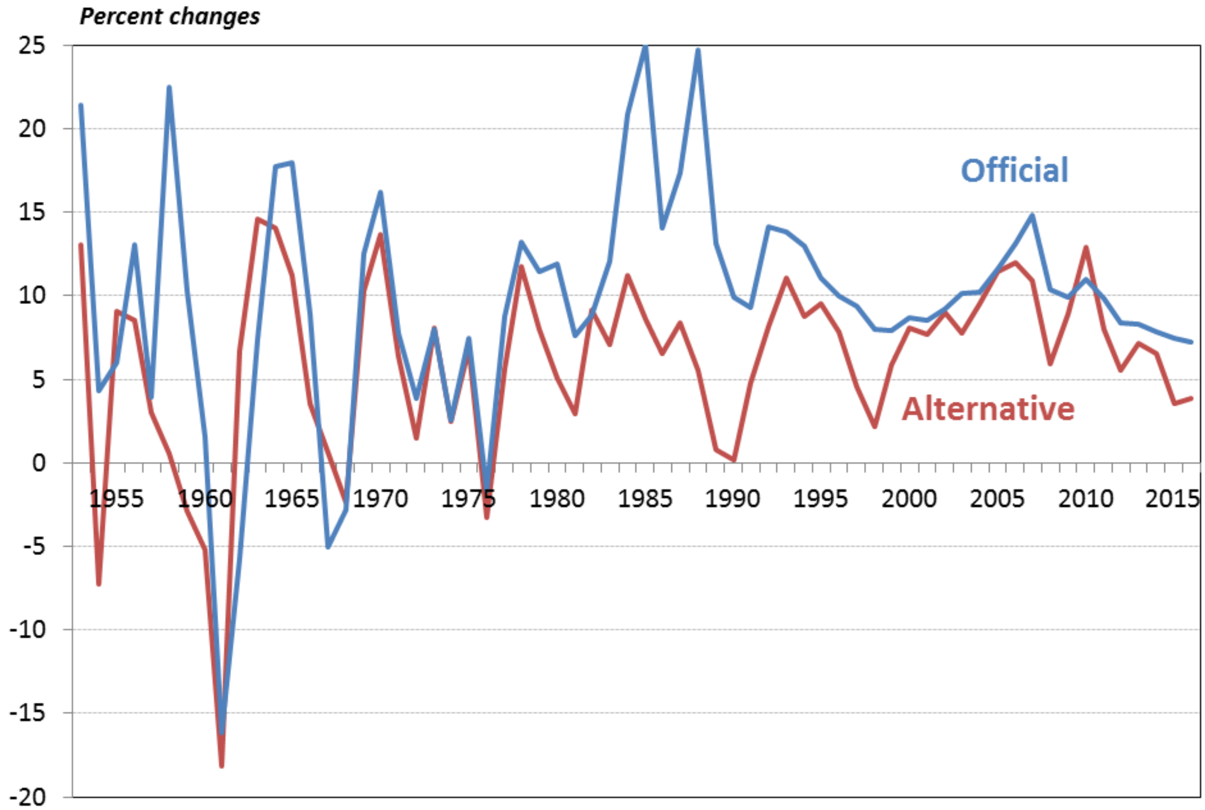
Over the years serious concerns have been expressed over the reliability of officially produced GDP data for China, by academics and policy makers alike.[4] The presumed biases are related to issues regarding misreporting at a local level, as GDP aggregated from provinces does not tally with nation-wide measures, and lack of clarity on methods especially with regards to the price deflators. TCB has therefore endeavored to reconstruct the Chinese GDP series bottom-up on a sector-by-sector basis, partly relying on official measures where those are found to be relatively unbiased, and partly constructing new estimates where there are concerns about the methodology of the published estimates (Wu, 2014).

These series are labeled as China (Alternative), and are presented alongside official estimates, which are labeled China (Official). More details about the construction of the alternative GDP figures can be found in Annex 1. Figure 1 compares real GDP growth rates from both series for the period 1953-2016. The TED does not publish nominal data on any of the variables. However, the regional aggregates of most variables are obtained as a weighted average of individual countries, based on nominal GDP shares. These nominal GDP series are obtained from national sources (as listed in Table 1), and are converted using annual PPPs (see Sections 1.1.2 and Section 3). PPP converted nominal GDP data for the alternative China series are constructed using the official nominal GDP level.

[3] Previous versions of TED also used alternative GDP estimates for Argentina, sourced from ARKLEMS. However, TED switched back to using the official data with the May 2017 release onwards, ever since the official data was revised by the National Statistical Institute.

[4] The reliability of Chinese growth estimates has been debated heavily in for example in the review of income and wealth, see for example Maddison (2006) and Holtz (2006a, 2006b).

Figure 1 – Real GDP growth for China, alternative and official, 1953-2016



Source: The Conference Board Total Economy Database (Adjusted version), November 2017.

1.1.5 GDP estimates adjusted for declines in the prices of ICT goods

It is argued that prices of information and communication technology goods and services are falling faster than shown by official price statistics (Byrne and Corrado, 2016a, 2016b). This mismeasurement leads to understating the true value of investment in and production of ICT goods. Data in TED accounts for this by using alternative price measures of ICT investment goods, as developed by Byrne and Corrado (2016 a and 2016b), which suggests a faster decline in ICT prices compared to official data. In our growth accounting data, where investment in ICT plays an important part, we use these alternative price measures to deflate nominal values of ICT investment (see section 2.2.1 for more details).

Since GDP includes both ICT and non-ICT goods and services—in terms of consumption, investment and trade—a change in the prices of ICT goods has an impact on GDP prices as well. Therefore, GDP is adjusted proportionally using the following method. Consider the national income identity, $GDP = C + I + G + X - M$, where C denotes consumption, I investment, G government purchases and X exports and M imports. Leaving the G aside for now, each of the other components on the right hand side can be divided into ICT and non-ICT components, so that $GDP = (\mathrm{C}_{ICT} + \mathrm{C}_{n-ICT}) + (\mathrm{I}_{ICT} + \mathrm{I}_{n-ICT}) + (\mathrm{X}_{ICT} + \mathrm{X}_{n-ICT}) - (\mathrm{M}_{ICT} + \mathrm{M}_{n-ICT})$. Once we assume a more rapid decline in the price of ICT goods and services than what is measured by official data, this price decline is to be reflected in all these ICT components of GDP. However, the impact of the ICT price adjustment on GDP in ICT importing countries will be *minimal*, as the net impact of the ICT investment and consumption will be cancelled out when imports of ICT are subtracted from GDP.[5] Given that most economies are ICT importers rather than producers or exporters, the official GDP deflator for those countries does not need to be adjusted for ICT price declines. For countries which do produce and export ICT goods and services in significant amounts, we adjust the GDP deflator as follows:

$$\Delta\ln \mathrm{P}_{GDP}^{adj} = (\mathrm{I} + \mathrm{X} - \mathrm{M})\Delta\ln P_{ICT} + [1 - (\mathrm{I} + \mathrm{X} - \mathrm{M})]\Delta\ln \mathrm{P}_{GDP}^{na} \qquad (3)$$

where $\Delta\ln \mathrm{P}_{GDP}^{adj}$ is the change in the log of the ICT prices adjusted GDP price deflator, $\Delta\ln P_{ICT}$ is the change in the log of the ICT investment deflator (obtained from Byrne and Corrado, 2016a, 2016b) for the United States, and harmonized deflators for other countries, and $\Delta\ln \mathrm{P}_{GDP}^{na}$ is the national accounts official unadjusted GDP deflator (see section 2.2.1 for a detailed discussion on the harmonization procedure). The Tornquist weight $I + \mathrm{X} - \mathrm{M}$ consists of the share of investment, exports, and imports of ICT investment goods (hardware, communication equipment and software) in nominal GDP.

In the current version of the TED, we make the above ICT price correction only for three countries—Japan, United States and China—which are globally the top three producers and exporters of ICT goods and services.[6] Real GDP for these countries are then obtained using the adjusted GDP deflator. As a final step, the annual difference between the officially reported and adjusted real GDP growth rates are smoothed by using three-year moving averages, in order to reduce noise in the data. Finally, as the adjustment entails the incorporation of rapid declines in ICT prices, and thus an increase in the volume of ICT, the resultant GDP growth rates are higher than the official GDP growth rates (see table 3 below).

These alternative GDP growth rates are expected to better reflect true growth as compared to official statistics, but it should be noted that the current method also has a number of drawbacks. First of all, the adjustment should ideally be made for more countries, however the current approach may be inappropriate for smaller economies with a large share of ICT goods investment and production in GDP

[5] Note that for the impact to be fully zero, one has to assume a country is importing all ICT goods, and does not produce anything, and all imports are absorbed in investment. In such case no adjustment to GDP is needed, since the country's GDP consists of only non-ICT goods.

[6] The current approach deviates slightly from the November edition of TED in that the country coverage is less (previously, data for 10 countries was adjusted, including Singapore, Malaysia, Philippines, Ireland, Taiwan, South Korea, and Canada) while previously no smoothing procedure was applied.

(e.g. Singapore or South Korea). This is because the structure of their ICT goods production and investment may differ from that of the U.S., and as of yet there is no sufficient data to build country specific price deflators of ICT goods. Perhaps more importantly, the current method does not account for the ICT consumption ((C_{ICT}) part of GDP, and ideally the last term on the right hand side of equation 3 should be the deflator for the non-ICT part of GDP only. But for now it is assumed that the impact of ICT prices on the official GDP deflator is small, so that the changes in the GDP deflator are proportional to changes in the non-ICT deflator. Another rather strict assumption in the current adjustment is that ICT price changes are the same for investment, exports and imports, which may not hold. However, for now there is no other choice because of lack of more detailed data.

Obviously, the *levels* of nominal GDP in the adjusted version also differ from those of the original version for the three countries listed above. GDP levels expressed in PPPs in other countries also differ from the original version, even though their real GDP growth rates do not. This is because country specific PPPs are updated to 2016 prices, using the change in the country specific GDP deflator relative to the US GDP deflator (see equation 1-A), and the latter was adjusted as described above. Table 3 provides a comparison of official and adjusted real GDP growth rates.

Table 3 – Comparison of official real GDP growth rates and adjusted GDP growth rates

Country	*Version*	*1995-2000*	*2001-2006*	*2007-2013*	*2014*	*2015*	*2016*
China (Alternative)	Adjusted	6.3	9.6	8.5	6.6	3.6	3.9
	Original	6.1	9.3	7.9	6.0	3.0	3.3
China (Official)	Adjusted	9.2	10.5	10.4	7.8	7.5	7.2
	Original	9.0	10.3	9.9	7.3	6.9	6.7
Japan	Adjusted	2.2	1.7	0.7	0.5	1.3	1.1
	Original	1.4	1.2	0.3	0.3	1.2	1.0
United States	Adjusted	4.5	2.9	1.2	2.5	2.7	1.7
	Original	4.0	2.6	0.9	2.4	2.6	1.6

Notes: Growth rates are presented as percent changes; The adjusted growth rates correspond to the Total Economy Database (Adjusted version) and the original growth rates correspond to the Total Economy Database (Original version); Chinese data is presented in two series, 'China (Alternative)' and 'China (Official)'. The latter is based on official data, while 'China (Alternative)' is from Wu (2014), revised and updated in 2017.
Source: The Conference Board Total Economy Database, November 2017.

1.2 Employment

From the perspective of productivity, the measure of employment should be consistent with the measure of output. Therefore, the employment figures should cover all persons engaged in some activity that falls within the production boundary of the system of national accounts. It should include employees, self-employed as well as unpaid family members that are economically engaged, apprentices and the military. Furthermore, the domestic concept of employment should be used, as it includes all workers employed domestically, but excludes any nationals working abroad, and hence is in line with the production boundary of Gross Domestic Product.

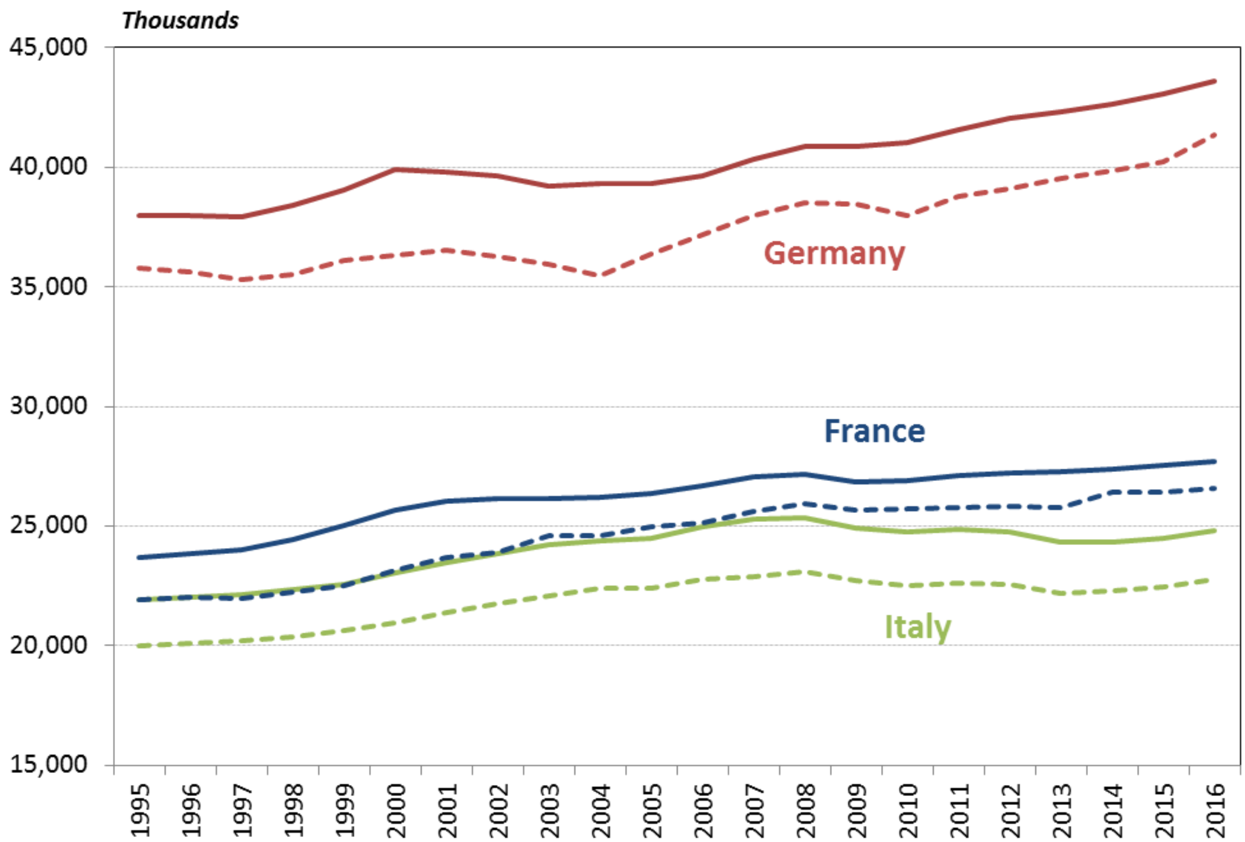
The United Nations *System of National Accounts 2008* (UN, 2008, chapter 19) prescribes that national accounts statistics should include compatible measures of employment, as described above. Both Eurostat, the OECD and the UN report National Accounts data on employment submitted by member countries.[7] The employment figures reported under the National Accounts (domestic concept) are used in TED whenever available from the the Eurostat, OECD and UN National Accounts databases. One notable exception is the United States. Employment estimates provided by the Bureau of Economic Analysis (BEA) in the framework of the National Accounts report number of jobs, and are therefore not comparable to statistics for most other countries where employment is reported in number of persons. For the US we use data on the employed (civilian) population from the Current Population Survey ("Labor Force and Employment Research Series Smoothed for Population Control Adjustments"), available from the Bureau of Labor Statistics, and data on military personnel provided by the BEA.

For most other countries, the national accounts do not provide employment statistics, or at least do not publish employment data based on all persons engaged. In those cases we rely on Labor Force Survey (LFS) data, sourced either from national statistical agencies or databases such ILOstat. The concept of employment used in the LFS may differ from one country to the other, but in general it includes every person (usually aged 15 years and over) who worked for one hour or more during the reference period (usually last week), which includes own-account and unpaid family workers. Also, employment estimates derived from LFS may differ from national accounts based estimates, since the latter integrates information from many sources, of which the LFS is only one. Furthermore, the two sources also differ conceptually. While the national accounts make a distinction between the national and domestic concept of employment, the LFS only covers resident households and thus the national concept. Another point of difference is the recording threshold. National accounts employment data do not use an age threshold, as the aim is to simply incorporate everyone who helps producing the nation's GDP, while the LFS is set up to capture the socio-economic background and therefore applies age boundaries. It is difficult to judge to which extent these factors balance out, but evidence for European

[7] In the case of Eurostat and OECD, these data are compiled via a joint Eurostat/OECD questionnaire. See 'Situation of Annual National Accounts in the OECD Database and New Features of the Joint OECD-EUROSTAT Questionnaire', available from www.oecd.org/dataoecd/9/29/24336184.doc.

countries suggest that, while the overall trend in both sources seems quite similar, the National Accounts-based employment data in general leads to higher estimates of number of employed, as shown in figure 2 below. As a result, for these three European countries, LFS-based productivity levels on a per person employed basis are higher compared with national accounts-based employment data.

Figure 2 – Employment, Labor Force Survey and National Accounts, selected countries, 1995-2016



Notes: The dotted line represents Labor Force Survey (LFS) data, and refer to persons aged 15 years and over.
Source: Eurostat.

For a number of African and Latin American countries TED uses employment data provided by the Groningen Growth and Development Center (Timmer, de Vries and de Vries, 2016)[8], and for some Asian countries we rely on the Asian Productivity Organization's *Productivity Database*.[9] The employment estimates from these databases are carefully constructed using (historical) data from

[8] Data is available from http://www.rug.nl/ggdc/productivity/10-sector/ and is used in TED for the following countries (by region): Botswana, Ethiopia, Ghana, Kenya, Malawi, Nigeria, Senegal, South Africa, Tanzania, Zambia, Egypt, Morocco, Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Mexico, Peru, Venezuela.
[9] Data is available from http://www.apo-tokyo.org/wedo/measurement and is used in TED for the following countries: Bangladesh, Cambodia, Hong Kong, Indonesia, Malaysia, Myanmar, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Vietnam.

population censuses, labor force surveys and establishment surveys, and pertain to all persons engaged in production and thus correspond closely with GDP estimates for these countries. As these series are not regularly updated, data for the recent years is sourced from labor force survey data from either national or international sources.

With regard to employment data for the remaining countries, which are mainly in the Middle East and Africa, TED employment series are based on modelled estimates of the employed population from the UN ILO available through ILOStat. Employment data in ILOStat is constructed using the ILO estimates of the labor force, after subtracting the number of unemployed persons. Data on the unemployed are collected from LFS data whenever possible, and are otherwise estimated using econometric techniques (ILO, 2015).

The employment data for Australia and New Zealand, obtained from their national accounts, pertain to the fiscal year—as their National Accounts do. Therefore, we adjust the fiscal year series using equation (2)—i.e. the average of two fiscal year series—to obtain calendar year data. As is evident from Table 2, calendar year GDP in these two countries are obtained by aggregating quarterly data, an approach which is not feasible in the case of employment due to lack of quarterly data. The second adjustment noted under section 1.1.3, referring to the redefinition of geopolitical boundary, also holds for the employment estimates in TED, so that Ethiopia includes Eritrea, Serbia & Montenegro are one country, as is the Republic of Sudan and South Sudan.

Most countries do not provide employment series for the complete historical period as covered in the TED, which includes data from 1950 onwards. Whenever no data is available from the abovementioned sources, growth rates from ILO estimates of the Labor Force (ILO, 2013, 2011, 1996) are used to provide a complete history back to 1950.

1.3 Total hours worked

Estimates of working hours involve serious measurement problems and international comparability is difficult (OECD, 2009; Ypma and van Ark, 2006; Bick, Brüggemann and Fuchs-Schündeln, 2016). The TED approach to hours worked data follows the same logic as the employment data, as described in section 1.2. Preference is given to national accounts based data, which is generally only available for advanced countries. Some authors have raised severe criticism about the comparability of national accounts based hours data across countries. Even though there have been several efforts to harmonize the methods to collect and calculate hours data, including the joint Eurostat/OECD questionnaire mentioned in the previous section, country practices still vary. Some countries use mainly labor force survey based estimates, others rely more heavily on establishment type surveys, while all are making adjustments which are generally not very transparently reported.

Some studies have suggested labor force survey-based hours worked measures are more comparable across countries, as the concept and methods of these surveys are relatively similar across countries (Bick, Brüggemann and Fuchs-Schündeln, 2016; Bick, Fuchs-Schündeln and Lagakos, 2016). While this may be true from a socio-economic perspective, it is questionable whether it is also the case for productivity analysis. Measures of hours worked in productivity analysis should be compatible with the output measure used. If the country specific adjustments that national statistical offices often make are aimed to ensure the consistency of the hours worked data with the other indicators available from the national accounts, such national adjustments are an essential part of the hours worked data used in productivity analysis. Since we have no way to ensure the comparability of national accounts statistics output and LFS hours data, in TED we opt to use the national account based employment and hours data whenever available.

TED uses estimates from other databases and academic studies as well in order to increase the country coverage of the total hours worked series. However, it should be noted that the quality and comparability of these series are even more questionable than the national accounts based hours, and users are warned to handle these data with care. These estimates are provided to give a rough idea of productivity levels, and are usually more reliable in terms of their trend. TED uses estimates of average annual working hours from the Asian Productivity Organization's *Asian Productivity Database*, and publications from Maddison (1982, 1995, 2001), Crafts (1997) and Hoffman (1998) for a number of Asian and Latin American countries. For Latin American countries, these benchmark estimates are extrapolated using growth rates from Labor Force Survey-based weekly hours worked, sourced from the Socio-Economic Database for Latin America and the Caribbean (CEDLAS and The World Bank). Estimates for South Africa and Nigeria are taken from country specific sources.[10]

The measure used in TED is actual hours worked, so it includes paid overtime and excludes paid hours that are not worked due to sickness, vacation and holidays, etc. Series on actual hours worked per person are available for 68 countries. As in the case of GDP and employment, hours data for Australia are adjusted to reflect the calendar year, by taking the average of two fiscal year series (equation 2).

[10] Data for South Africa are taken from the publication 'Labour Market Dynamics in South Africa', available from Statistics South Africa (http://www.statssa.gov.za/); data for Nigeria are taken from the 'Labour Productivity' reports, available from Nigeria's National Bureau of Statistics (http://nigerianstat.gov.ng).

New Zealand data is sourced from the OECD labor market database, and pertains to the calendar year, hence no adjustment is made.

1.4 Population

The population figures reported in the TED refer to mid-year estimates, and include all people usually present in a country (nationals and non-nationals alike). Population estimates are mostly sourced from Maddison Historical Statistics (Maddison, 2010) for the period 1950-1990. Data for the years after that are obtained from various sources, including Eurostat, IMF World Economic Outlook and the US Census Bureau International Data Base.

1.5 Per capita income and labor productivity

So far this document discussed the concepts, sources and methods used to construct the basic variables in the Total Economy Database. These basic variables are used in turn to construct per capita income and labor productivity, the two variables that are discussed in this subsection.

One of the most widely used measures to compare living standards between countries and over time is GDP per capita or per capita income (PCI), which is calculated by dividing the total income earned in a country (as measured by GDP) by the total population as:

$$PCI = \frac{GDP}{POP} \tag{4}$$

where GDP denotes Gross Domestic Product measured in PPP terms and POP total population. The use of PPP converted GDP is of vital importance for international comparisons of PCI, as it adjusts for the difference in price levels between countries, as outlined in section 1.1.2. Note, however, that by definition, PCI does not account for the inequality in the distribution of income, as it is a measure of average income per person as if total income is equally distributed.

The most important source of rising living standards, as measured for example by PCI, is productivity. As countries become more productive, they are essentially producing more value with the same effort. Labor productivity y, a measure of partial productivity, can be measured either as output per hour or output per person, so that,

$$y = \frac{GDP}{L} \tag{5}$$

where L is labor input, measured either as persons employed or total hours worked.

Output per hour is the preferred measure of labor productivity since it measures labor intensity more effectively. For example, it adjusts for differences in average working time per person employed between countries. However, as stated in section 1.3.1, the availability of reliable and comparable data on total hours worked is limited. Estimates of labor productivity based on GDP per person employed are available for all countries in the database. While this is a relatively robust measure, it does not correct for part-time jobs as it merely counts people who are employed. Hence, GDP per person employed is somewhat underestimated in countries with a higher share of part-time workers, which are mostly OECD countries.

2 – Growth accounting variables

The growth accounting module in TED contains annual data on the sources of growth for the years 1990 onwards for the same set of countries as discussed in section 1. The data coverage in terms of years is less than compared with the basic productivity and income variables, due to the availability of underlying source data. Furthermore, data for advanced economies is generally of better quality compared to emerging economies, though there are some exceptions to this rule. TED does not produce estimates for the ongoing year on the sources of growth, while figures for the previous year (last year as shown in the database) should be regarded as very preliminary estimates.

In the growth accounting framework, GDP growth is decomposed into contributions from capital, labor and total factor productivity growth. The contribution of factor inputs labor and capital can be disaggregated into quantity (hours or employment and capital stock) and quality or composition (composition of workers in terms of educational attainment and composition of capital in terms of various asset types or asset groups such as ICT and non-ICT assets). Capital measures in TED are based on investment data obtained mostly from national accounts statistics. The sources of labor quantity measures are explained in sections 1.2 and 1.3. Labor quality or composition data are constructed using data on employment and compensation by educational attainment. These data are collected from various sources, including Eurostat, World Input Output Database (WIOD) and various country-specific KLEMS (capital, labor, energy, material and services) databases. For countries for which no data was available from these sources, an econometric approach is followed (see annex 4). Total factor productivity growth is derived as a residual, after the contributions of factor inputs labor and capital are deducted from GDP growth. The construction of data on these inputs is discussed in more detail in the following sections.

Table 4 – Basic overview of sources used in TED II

Input	Source data	Estimations
1. GDP	See section 1.1	
2. Labor Quantity	See section 1.2 and 1.3	
3. Labor Quality	*Employment by educational attainment:*	
	EUKLEMS, Eurostat, UN ILO, WIOD, Socio-Economic Database for Latin America and the Caribbean (CEDLAS and The World Bank), UN Economic Commission for Europe, country specific sources	When no data is available, employment distribution is proxied by the distribution of population by educational attainment from the Wittgenstein Centre for Demography and Global Human Capital Data Explorer
	Compensation by educational attainment:	
	EUKLEMS, WIOD, Socio-Economic Database for Latin America and the Caribbean (CEDLAS and The World Bank), country specific sources	When no data is available, compensation by educational attainment is estimated using a regression analysis
4. ICT Capital	Eurostat, OECD, KLEMS (various), country specific sources	Estimations based on World Information Technology Services Alliance (WITSA) Digital Reports; Estimations based on trade data using the commodity flow method
5. Non-ICT Capital	Eurostat, OECD, KLEMS (various), country specific sources	Estimations based on trade and production data using the commodity flow method
6. Total factor productivity	Derived as a residual, so that $6 = 1 - 2 - 3 - 4 - 5$	

2.1 Total factor productivity[11]

The measure of labor productivity discussed in the previous section is a partial measure of productivity. A more complete measure is total factor productivity TFP, which takes into account not only labor as an input but also the contributions of physical, human and other intangible capital to the production of goods and services. As will become apparent later in this section, TFP growth is in essence a subcomponent of Labor Productivity growth. TFP is not measured directly; rather, it is obtained as a residual after accounting for the contributions of all other factors of production to growth in output.

Using the standard growth accounting framework, GDP growth can be decomposed into contributions from factor inputs, capital (K), and labor (L) and total factor productivity (TFP) growth as:

[11] This section draws on Jorgenson et al (2007) and Erumban and Das (2016).

$$\Delta \mathrm{lnGDP} = \bar{\mathrm{v}}_{\mathrm{K}} \Delta \mathrm{lnK} + \bar{\mathrm{v}}_{\mathrm{L}} \Delta \mathrm{lnL} + \Delta \mathrm{lnTFP} \tag{6}$$

where $\Delta\mathrm{lnX}$ indicates the growth rate (measured in log changes) of any given variable X (GDP, K, L and TFP). $\bar{\mathrm{v}}_{\mathrm{K}}$ and $\bar{\mathrm{v}}_{\mathrm{L}}$ denote respectively the share of capital compensation and labor compensation in nominal GDP, both averaged over the current and previous year. Under constant returns to scale $\bar{\mathrm{v}}_{\mathrm{K}}$ + $\bar{\mathrm{v}}_{\mathrm{L}}$=1, the capital compensation share can be obtained by subtracting labor compensation from nominal value added.

The contribution of labor input to GDP growth in TED is split into the contribution of employment quantity (H) and labor composition or quality (LQ), and the contribution of capital services is split into ICT capital services (K_{it}) and non-ICT capital services ($\mathrm{K}_{\mathrm{nit}}$). Then, equation (6) can be re-written as

$$\Delta \mathrm{lnGDP} = \bar{\mathrm{s}}_{\mathrm{K,it}} \Delta \mathrm{lnK}_{\mathrm{it}} + \bar{\mathrm{s}}_{\mathrm{K,nit}} \Delta \mathrm{lnK}_{\mathrm{nit}} + \bar{\mathrm{s}}_{\mathrm{L}} \Delta \mathrm{lnH} + \bar{\mathrm{s}}_{\mathrm{L}} \Delta \mathrm{lnLQ} + \Delta \mathrm{lnTFP} \tag{7}$$

where K_{it} is the ICT capital services, $\mathrm{K}_{\mathrm{nit}}$ is the non-ICT capital services, and $\bar{\mathrm{s}}_{\mathrm{K,it}}$ and $\bar{\mathrm{s}}_{\mathrm{K,nit}}$ are respectively the shares of ICT capital and non-ICT capital income in nominal GDP (more on that in section 2.4).

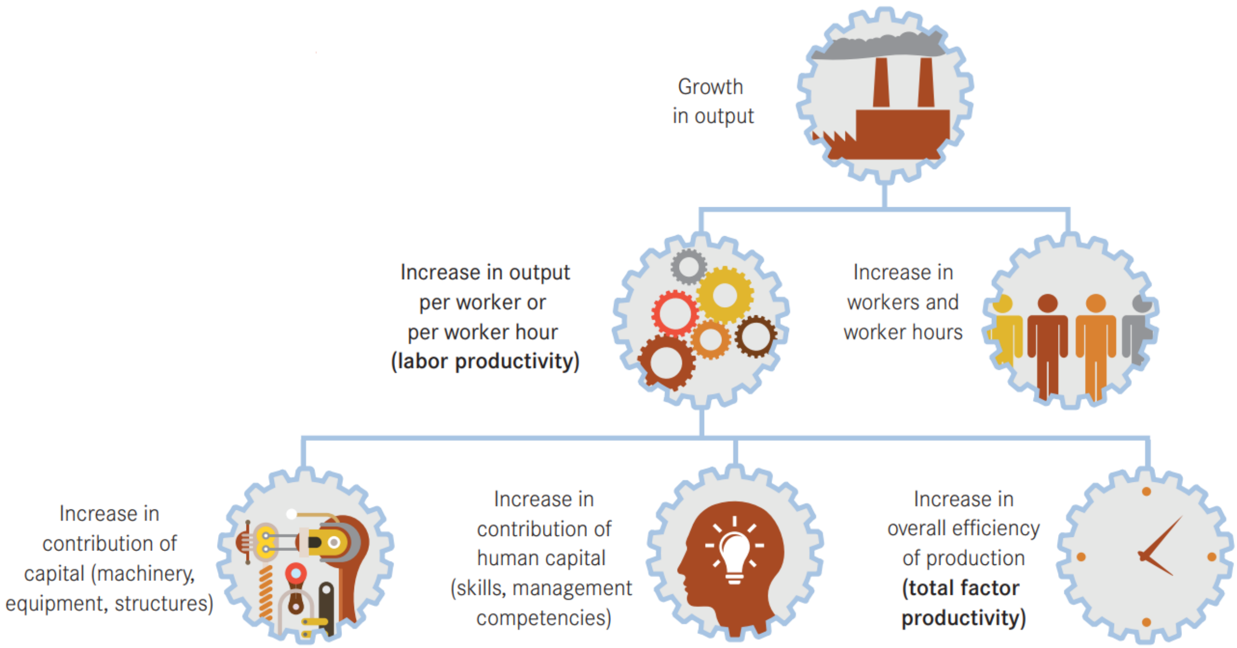
Subtracting the growth rate of labor quantity (H) from (7), labor productivity growth can be decomposed into capital deepening and TFP as:

$$\Delta \mathrm{lny} = \Delta \ln GDP - \Delta \ln H = \bar{\mathrm{s}}_{\mathrm{K,it}} \Delta \ln \mathrm{k}_{\mathrm{it}} + \bar{\mathrm{s}}_{\mathrm{K,nit}} \Delta \ln \mathrm{k}_{\mathrm{nit}} + \bar{\mathrm{s}}_{\mathrm{L}} \Delta \mathrm{lnLQ} + \Delta \mathrm{lnA} \tag{8}$$

where $\Delta\mathrm{ln}y$ denotes labor productivity growth, measured as the difference between GDP growth and labor quantity growth, and k is capital deepening, measured as the difference between capital service growth for the relevant asset type (ICT or non-ICT) and labor quantity growth (more on capital services in the following section).

To summarize, equation (7) decomposes the growth in GDP into contributions from labor and capital inputs (weighted by their respective shares in nominal GDP) and a residual labelled TFP growth. The relationship between labor productivity growth and TFP growth becomes clear from equation (8), suggesting that the latter is a broader measure of productivity growth. The equation suggests that growth in labor productivity depends on three proximate factors, which are growth in capital deepening, labor quality and TFP (also see Figure 3). Growth in capital deepening arises from increases in the amount of capital available per worker. Improvements in labor quality can be accomplished by increasing the skill level of workers, as well as through education, training or experience. TFP growth captures what is left unexplained, which is, under neoclassical assumptions, referred to as technological change or the overall efficiency of the economy.[12]

Figure 3 – Defining labor productivity and total factor productivity



Source: The Conference Board (2015), Prioritizing Productivity to Drive Growth, Competitiveness and Profitability.

The accurate measurement of the variables in the productivity and growth accounting equations is key to comparing and evaluating the sources of GDP growth. Sections 1.1 through 1.3 discussed in detail the construction of GDP and labor quantity (both in terms of hours worked and number of persons employed). The sources and methods used to construct the remaining variables in equation (7), which are capital services (ICT and non-ICT), labor quality, and labor compensation as a share of GDP, are discussed in the remaining sections of this chapter.

2.2 Capital services

2.2.1 Investment data by asset types[13]

Capital services as defined in the growth accounting framework is essentially a measure of how much use is being made in the production process of machines, buildings and intangible assets by all

[12] However, TFPG growth, measured under strict neoclassical assumptions such as perfect competition and constant returns to scale, could also account for any deviations from such assumptions in the real world. For instance it could also be a measure of monopoly power, or increasing returns to scale, if perfect competition and constant returns to scale assumptions are violated.
[13] The discussion in this section draws heavily on Erumban, Inklaar and de Vries (2017).

companies and households. The national accounts framework only considers flows of goods and services, hence capital stock measures and the cost of using capital are measured using data on investment flows, depreciations rates, rate of return to capital and investment prices. Data on investment flows by individual assets (such as machines and buildings) are collected from official sources, including international databases but mostly from country statistical offices. However, not all countries produce data on investment by detailed asset types, especially countries in Africa and the Middle East.[14] In those cases TED uses the commodity flow method (CFM), which essentially uses trade and production data to proxy investment by asset types.[15] This method is explained in more detail in Annex 2.

The national sources and CFM approaches works relatively well in the case of investment in non-ICT assets, while due to a lack of data they are less feasible for ICT assets. It is widely acknowledged that investment in ICT is an important contributor to overall economic growth, and therefore their contributions should preferably be accounted for separately (e.g. Jorgenson and Vu, 2013, 2016). Nevertheless, actual data on ICT investment is sparsely available due to difficulties in obtaining such information for the entire economy. Even though the National Accounts guidelines distinguish three ICT assets—computer hardware and communication equipment as part of machinery and software as part of intangible assets—only around 50 countries produce official data on one or more of the above-mentioned ICT assets for at least one year. In TED, whenever available, these data are obtained either from National Statistical Institutes or from cross-country sources that rely primarily on detailed official data, such as Eurostat or OECD. In order to extent these official series back and forth to fill the missing years, and also for countries for which the official data is not available, TED relies on a range of alternative sources and methods.

To complement the National Accounts based estimates for investment in ICT goods, first consideration is given to sources which are most closely in line with National Accounts data. Examples are research initiatives such as KLEMS, in which there is close collaboration with national statistical agencies and/or national policy institutes and thus have access to detailed and often unpublished official data. Series for European economies are further extended using historical trends from older vintages of the Total Economy Growth Accounting database originally set up by the Groningen Growth and Development Center. For a number of Latin American countries, TED relies on data originally compiled

[14] TED uses national-accounts based gross fixed capital formation data by assets for at least one year for 107 out of 123 countries.

[15] See Erumban, Inklaar and de Vries (2017).

by de Vries et al. (2010). Table 5 provides an overview of various sources used to compile the ICT investment data.

Table 5 – Sources of ICT investment data

Country	Source	Coverage
Official sources		
European economies	Eurostat	1995 onwards*
Other advanced economies	OECD	1995 onwards*
Remaining advanced and emerging economies	National Statistical Institutes	**
Semi-official sources		
Austria, Denmark, Finland, France, Germany, Italy, Netherlands, UK	EU-KLEMS 2009 release	1970-2007*
India	Erumban and Das (2016)	1973 onwards
Russia	Russia KLEMS	1995 onwards
Mexico	Mexico KLEMS	1990 onwards
Japan	JIP	1970 onwards
China	Underlying WIOD data	1995-2009
Belgium, Greece, Ireland, Portugal, Sweden	GGDC TED	1980-2004*
Argentina, Brazil, Chile, Costa Rica, Uruguay, Venezuela	De Vries et al (2010)	1994-2004*

Notes: *Coverage varies across countries, but this is the most common period for which data is available; **Variation across countries is too large to provide a common period for which data is available.
KLEMS: Capital (K), Labor (L), Energy (E), Material (M) and Services (S).
JIP: Japan Industrial Database.
WIOD: World Input Output Database.

The above mentioned official and semi-official sources provide a reasonably good coverage in terms of countries and years, but not complete. Expenditure data on ICT goods is used to estimate investment in ICT for countries where investment data from the above-mentioned sources are not available. The *Digital Planet Report on Global ICT spending* published by World Information Technology and Services Alliance's (WITSA) provides detailed data on total national spending on ICT goods (computer hardware, communication equipment and software) across 73 countries since 1992 until 2013, of which 2010 to 2013 are forecasts. This data has been used by Jorgenson and Vu (2013, 2016) in their global growth accounting analysis, in order to quantify the contribution of ICT to global growth. It has also been the primary source of ICT capital data in the previous versions of the Conference Board Total Economy Databases for all countries except those covered by EU-KLEMS. More details on the method to extract actual business investment data from the WITSA series can be found in annex 3.

By combining official, semi-official and WITSA-based data, we construct ICT investment series for as many as 85 countries. CFM-based data—as discussed above—is used for remaining countries, and also for years and or assets for which we could not obtain data according to the abovementioned sources and methods. The resulting dataset on investment in ICT assets is unique in its quality and coverage, and provides a good basis to understand the dynamics of ICT investments and its impact on growth across countries and time. [16]

The final investment data, as obtained from the sources and methods described above, are organized according to the following set of assets (see table 6), including both ICT and non-ICT assets.

Table 6 – Asset breakdown of source data

1 - Machinery and Equipment	2- Construction	3- Other Products
Transport equipment	*Residential construction*	*Cultivated Assets*
Machinery	*Non-residential construction*	Intangible Assets
Computer hardware		**Software**
Communication equipment		*Intellectual Property products (IPP)*
Other machinery		

Note: Assets that are shown in **bold** are ICT assets, and those in *italics* are non-ICT assets.

Investment price deflators of individual assets are obtained from national accounts. When asset-specific deflators are not available from official data we use aggregate investment (Gross Fixed Capital Formation) deflators. Investment price deflators for ICT assets are obtained from National Accounts whenever available. For most advanced economies, these deflators are quality adjusted hedonic prices, which are assumed to be taking into account the rapid changes in the quality of ICT goods, and hence the price decline. However, as is the case with ICT investment itself, such data is not always available. For such countries, the ICT price deflator is obtained using a Harmonization procedure as suggested by Schreyer (2002). This approach uses the US ICT prices as the benchmark price, and adjusts it for domestic inflation (harmonization procedure). Assuming the difference in growth rates between ICT and non-ICT prices in country i to be equivalent to that in the US:

$$\Delta lnP_{ict}^{i} = \Delta lnP_{nict}^{i} + (\Delta lnP_{ict}^{US} - \Delta lnP_{nict}^{US}) \qquad (10)$$

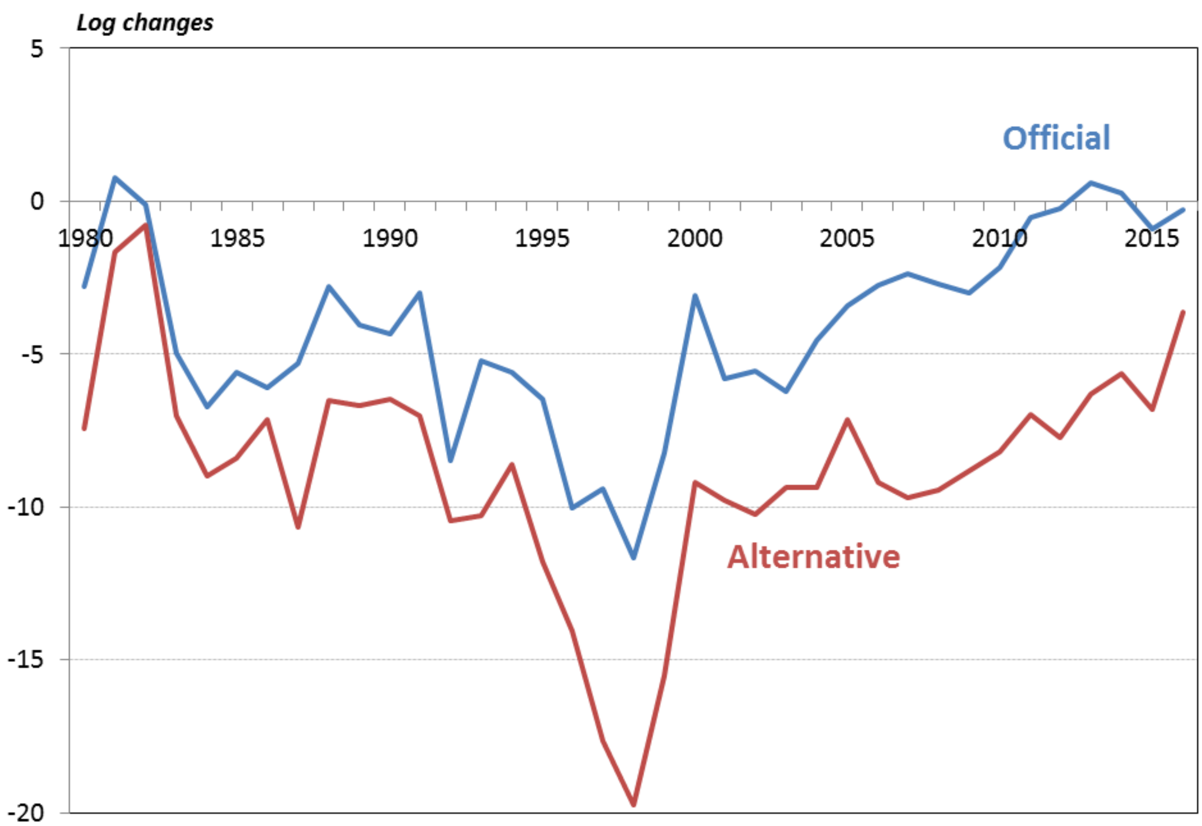
where P_{ict}^{i} denotes the investment price deflator for ICT goods in country i, P_{ict}^{US} the hedonic ICT prices in the United States, P_{ict}^{i} the price of non-ICT machinery investment in country i and P_{ict}^{US} non-ICT machinery investment prices in the United States. The non-ICT machinery prices are proxied by official machinery prices.

As mentioned before, the approach discussed above relies on official ICT price deflators for the United States, and other countries whenever available. However, it is argued that the official hedonic

[16] As compared to the November 2016 release of TED, ICT investment data for Armenia, Ethiopia, Belarus and Sudan was removed due to data issues, and are currently under review to be included in the next release.

prices for ICT goods still understate the rapid declines in prices (Byrne and Corrado, 2016a, 2016b). Byrne and Corrado (2016) have developed an alternative set of ICT deflators, which suggests a much faster decline in ICT prices in the United States. Figure 4 depicts the official price deflators for aggregate ICT investment goods (hardware, communication equipment and software) in the United States, along with the alternative deflator series developed by Byrne and Corrado. It is quite evident that the alternative series show much faster price declines compared to the official series.

Figure 4 – ICT investment goods price deflators (official and alternative), United States, 1980-2016



Note: The aggregate ICT deflators are obtained using weighted growth rate of individual assets—hardware, software and communication equipment—with the weights being their nominal share in total ICT investment.
Sources: Bureau of Economic Analysis, Byrne and Corrado (2016a, 2016b), updated and revised in 2017.

To take the impact of this rapid price declines into account, we construct an alternative set of investment, capital stock, and thus the entire growth accounting variables in the TED using this alternative ICT price deflators to deflate ICT investment goods (hardware, communication equipment and software). These deflators are, however, available only for the United States, and therefore, for all other countries we use the harmonization procedure as in equation (10), but with the US deflator (P_{ICT}^{US}) replaced by the alternative deflators from Byrne and Corrado.

The TED growth accounting data based on the official ICT prices—i.e. official ICT investment prices, whenever available, and harmonized US ICT deflators for the other countries—is labelled as TCB original, while the version that uses alternative ICT prices as developed by Byrne and Corrado is labelled TCB adjusted. The original version ensures continuity with the previous TED vintages, except that it uses new and improved (official) data on ICT investment. Moreover, the current version uses official ICT prices whenever available, whereas in previous versions harmonized (official) US deflators (see equation 10) were used for all countries. This holds mainly for European economies and some other advanced economies, including Japan, South Korean and Australia.

Since ICT assets in the adjusted version of TED are deflated using prices that show faster declines compared to official data, the growth rate of ICT capital, and consequently aggregate capital, are generally higher in this version. As a consequence, the contribution of capital to GDP growth is higher and total factor productivity lower. Also note that GDP deflators are likewise adjusted for the difference between official and alternative prices of ICT goods, which is discussed in section 1.1.5.

2.2.2 From investment to capital stocks and capital services

Data on investment is used to generate measures of capital stock and capital services. Capital stocks are constructed for each asset category listed in Table 6, except that cultivated assets and intellectual property products (IPP) other than software are combined with other machinery, while residential and non-residential structures are considered as a single asset. The final estimates of capital stock and capital services are aggregated to ICT assets, which consists of hardware, software and communication equipment, and non-ICT assets, which consists of residential and non-residential structures (though they are treated as a single asset if the distinction between residential and non-residential is not available), transport equipment and all other non-ICT machinery categories.

Capital stocks are calculated using the perpetual inventory method (PIM), based on geometric depreciation rates that are common across countries and constant over time (see Table 7 for a list of depreciation rates used). It is debatable whether this assumption is appropriate (see Bu, 2006), but this approach is followed to ensure international comparability.

Table 7 – Depreciation rates by assets (percent)

Asset	Depreciation rate(%)
1. Machinery and Equipment	
Transport equipment	18.9
Machinery	
Computer Hardware	31.5
Communication equipment	11.5
Other machinery (including cultivated assets and intellectual property products)[17]	12.6
2. Construction	
Residential & non-residential construction	2.5
3. Other Products	
Intangible Assets	
Software	31.5

Given investment at current prices, investment deflators and depreciation rates, the capital stock of each asset is computed as:

$$A_{i,t} = A_{i,t-1}(1 - \partial_i) + I_{i,t} \qquad (11)$$

where $A_{i,t}$ is the capital stock in asset i in year t, ∂ is the geometric depreciation rate, and I is investment at constant prices.

The implementation of this equation requires an initial stock estimate, as the annual stream of investment is added to existing stock after allowing for depreciation. The typical approach in choosing an initial capital stock estimate is to assume a steady-state economy, which allows the capital stock to be derived from initial investment and assumed growth of investment in the preceding period (Harberger, 1978). However, this assumption can lead to problematic outcomes when an economy is not in a steady state, such as the formerly Communist countries in the early 1990s. An alternative is to assume a predetermined initial capital-output ratio. For instance Feenstra et al. (2015) suggests an economy-wide initial capital-output ratio of 2.6, divided between residential structures (1.1), non-residential structures (1.1), other machinery (0.3), and transport equipment (0.1). Given the different levels of development across 123 countries in our dataset, it is hard to argue that a common capital-output ratio is a better assumption. Therefore TED applies the steady-state assumption. Following Hargberger (1978), we derive the initial capital stock as:

$$A_0 = \frac{I_0}{gI} + \partial \qquad (12)$$

[17] Note that IPP and cultivated assets are combined with other machinery, and residential land non-residential structures into one single asset. In the Penn World Tables, where these assets are treated separately, the depreciation rate used for IPP is 15 percent, 1.1 percent for residential structures and 3.1 percent for non-residential structures.

where A_0 is the initial capital stock, I_0 is the real investment in the first year, gI is the average investment growth during the first 10 years of available data, and ∂ is the depreciation rate. These are calculated for each asset separately.[18]

Capital stock is in itself a useful indicator for policy analysis and other research purposes. However, the amount of capital used in the production process in any given year, also referred to as capital services, is more relevant for the analysis of the contribution of capital to economic growth. While it is hard to precisely measure the amount of services provided by each capital asset, following Jorgenson and Grilliches (1967), we assume a proportionality between capital stock and capital service growth rates at the individual asset level, but allow for differences in capital services growth rates across assets. Estimates of aggregate capital services are obtained as weighted growth rates of individual asset-wise capital stock, where the weights are derived as the rental share of individual assets in total capital compensation.[19] More specifically, capital services growth is calculated as

$$\Delta \ln K_t = \sum_{i=1}^{k} \bar{v}_{i,t} \Delta \ln A_{i,t} \tag{13}$$

where $\bar{v}_{i,t}$ is the two year average share of each individual asset in total capital compensation and where total capital compensation M is defined as value added net of labor compensation. Individual asset-wise capital compensations are obtained as products of individual capital stock, and the rental price of each asset is defined as:

$$c_{i,t} = r_t P_{i,t-1} + \partial_i P_{i,t} - \left(P_{i,t} - P_{i,t-1}\right) \tag{14}$$

where r is the internal rate of return, measured as:

$$r_t = M_t - \sum_{i=1}^{k} \left[\partial_i P_{i,t} A_{i,t} - A_{i,t}\left(P_{i,t} - P_{i,t-1}\right)\right] \tag{15}$$

where P is the investment price deflator. The difference between growth rates of capital services (equation 13) and growth rates of aggregate capital stock obtained by adding asset wise capital stock measured using equation 11 is the so-called capital composition effect (Erumban, 2008; Inklaar, 2010). This is a proxy measure of how fast a country is upgrading its capital by increasing the share of assets of high marginal productivity. The growth rate of capital composition ($\Delta lnKQ$) can be obtained by

[18] In the previous versions of the TED, initial capital output ratio was calculated as $a_0 = \frac{i}{g+\partial}$, where a_0 is the initial capital to output ratio, i is the average investment to output ratio for the first 10 years, and g is the average output growth rate for first 10 years. Then initial capital stock was obtained by multiplying a_0 with initial output. The new approach, explained in equation 12, improves the capital stock data in the initial years significantly. We are thankful to Dale Jorgenson and Khuong Vu for providing advice on the new approach.

[19] See Erumban (2008) for a detailed discussion.

subtracting the growth rate of aggregate capital stock from the growth rate of aggregate capital services, i.e:

$$\Delta lnKQ = \Delta lnK - \Delta ln\left(\sum A_i\right) \tag{16}$$

Once these growth rates are obtained, multiplying $\Delta ln(\sum A_i)$ and $\Delta lnKQ$ with the capital income share in GDP ($\bar{v}_K$ in equation 6), we can obtain the respective contributions of capital quantity and capital composition to GDP growth.

2.3 Labor quality

The contribution of labor input to GDP growth is distinguished between quantity and composition (or quality). The former is based on hours worked, whenever available, or employment otherwise. Data on hours worked or total employment as described in section 1.2 and 1.3. Measures of labor quality or labor composition are based on the skill composition of workers, proxied by educational attainment of workers. As described in the case of capital, the growth rate of labor composition can be calculated as the difference between labor input growth rates, measured as a labor composition weighted growth rate of individual skill categories of workers, and labor quantity growth rates, measured as the growth rate of aggregate hours or employment, i.e.:

$$\Delta \mathrm{lnLQ} = \Delta \mathrm{ln} \sum_{\mathrm{l}} \mathrm{L_l} - \sum_{\mathrm{l}} \bar{\mathrm{s}}_{\mathrm{l}} \Delta \mathrm{lnL_l} \tag{17}$$

in which $\Delta \mathrm{lnLQ}$ is the growth rate of labor quality, $\sum_{\mathrm{l}} \mathrm{L_l}$ is the total employment or total hours (sum across all types of workers), $\bar{\mathrm{s}}_{\mathrm{l,t}}$is the two-year average of compensation share of labor type l in total labor compensation. Alternatively, labor composition growth rates can be constructed using shares of employment or hours of different worker categories and their respective wage shares as:

$$\Delta lnLLQ = \sum_{l} \bar{\mathrm{s}}_{\mathrm{l}}\, \Delta lnh_l \tag{18}$$

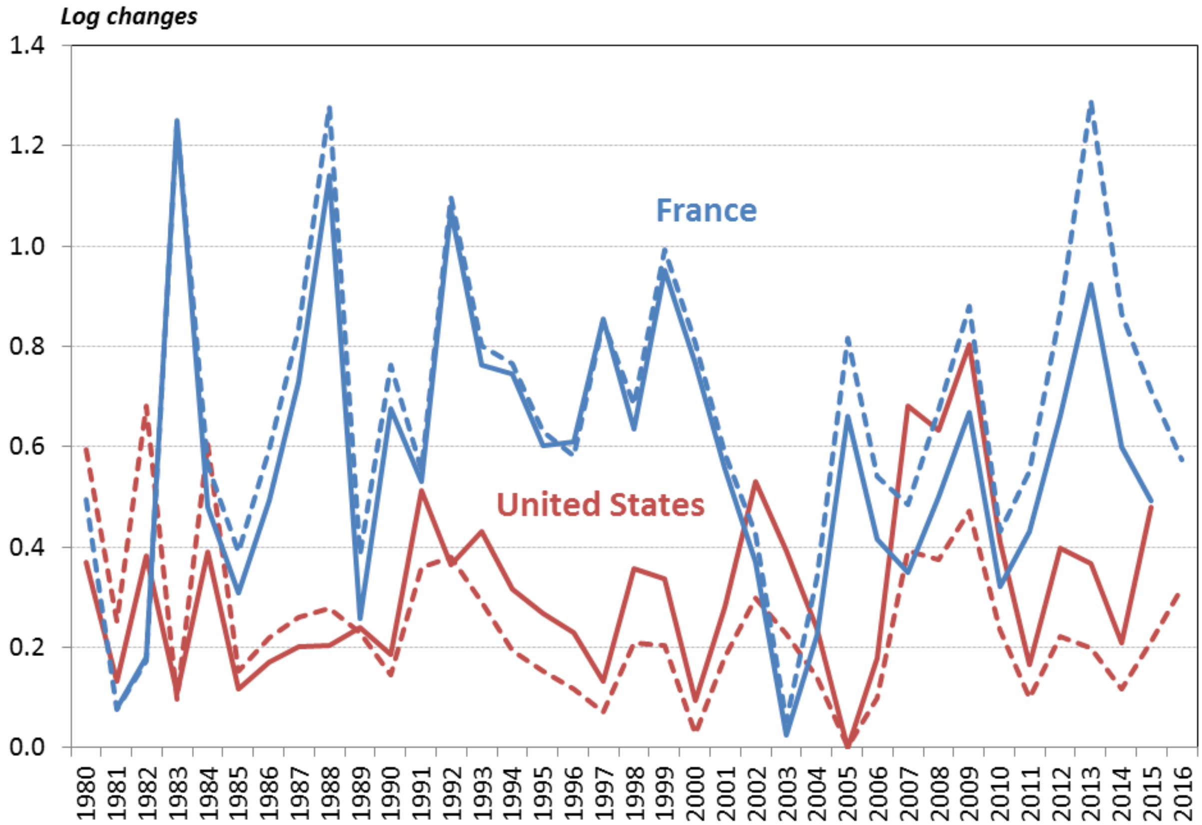
where $\Delta lnh_{l,t}$ is the growth rate of share of hours worked by labor type *l*.

Skill compositions of workers in the TED are proxied by educational attainment of workers. Data on the structure of employment by educational attainment is generally available for most countries, barring a number of (mostly) African and Middle Eastern countries. The data is sourced from international databases, such as Eurostat, OECD and the UN ILO, as well as databases mainly maintained by academic institutions such as the World Input Output Database and KLEMS (various countries). Furthermore, in some cases country specific data is sourced from national statistical offices. Population data on educational attainment are used to fill in the gaps, either using the trend or level data when there is no benchmark information at all. Data on the structure of labor compensation by educational attainment is less widely available, and is currently available only for 92 out of 123 countries in TED (for at least one year). A regression approach is used to fill in the data for missing countries and years, which is explained below.

While there are efforts underway to improve the coverage of the labor quality indicator in TED, currently only 96 out of 123 countries are covered. This means that TFP growth rates for the remaining 27 countries are generally somewhat higher relative to the other countries as they are inclusive of labor quality growth.

The underlying assumption used in the regression to estimate labor compensation by educational attainment is that the returns to education are broadly similar across countries in a given region for a given educational category. Data on average years of schooling by educational attainment (primary, secondary and tertiary) from Barro and Lee are combined with the available data on the structure of labor compensation by educational attainment. To allow for country-specific circumstances the panel regression includes inflation as well as time and regional dummies. Figure 5 presents two sets of growth rates of labor quality for France and the United States over the period 1980-2016. Both are based on actual data on the educational distribution of the workforce, but differ in terms of data on labor compensation. The solid lines are based on actual data on the educational distribution of labor income and the dotted lines are estimates based on the regression approach outlined in annex 4. As can be seen from the chart, the difference for these two countries between the two sets of data is relatively small.

Figure 5 – Labor quality growth rates, actual and estimated, United States and France, 1980-2016



Notes: The dotted line represents estimated labor quality growth rates based on modelled compensation data.
Source: France based on EUKLEMS (various editions) and Eurostat; United States based on BLS, BEA and WorldKLEMS.

2.4 Labor income share

In order to calculate the contributions of labor and capital to GDP growth, as described in equation (7), weights need to be assigned to the different factor inputs. These weights are determined by the share of total income accrued by either labor or capital. Since the share of capital and labor in total income equal one under constant returns to scale assumption as explained in section 2.1, data on the the capital income share is derived indirectly as a residual after labor income is subtracted from GDP.

Labor income of employees is derived from the national accounts (whenever available), while the labor income of the self-employed is proxied using mixed income. Mixed income from the national accounts reports the self-employed income accrued to both capital and labor. However, TED assumes that the income earned by self-employed persons is by and large accrued to labor as these type of workers generally rely mostly on labor in the production process. The labor income share is then calculated as:

$$s_L = \frac{CL + MI}{Y} \tag{19}$$

where s_L is the nominal income share of labor in GDP, CL compensation of employees, MI mixed income and Y nominal GDP.

Whenever data on employee compensation and mixed income is available, the above approach is followed. However, this data is not available for some countries, or longer historical series are not always available. In such cases, we assume a common wage rate to hold for the total economy, a method often used in international growth accounting datasets such as KLEMS or ILC.[20] Assuming that the observed wage rate of employees applies to self-employed as well, the labor share is calculated as:

$$s_L = w_e . L/Y \tag{20}$$

where w_e is the wage rate earned by employees ($w_e = w_s$, with w_s being the self-employed wage rate), L is the total hours worked by all employed including self-employed. When there is no data available on hours worked, L is replaced by E where E denotes the number of employed persons.

For the remaining countries TED relies on data from the Penn World Table (PWT)—which uses a number of different estimation methods—and the Asian Development Bank Productivity Database. There is a difference in the concept of labor share used in the TED (as explained above) and the PWT. While the PWT obtains the share of labor income in total value added (or GDP at basic prices), the labor income shares in equation (19) and (20) are obtained in GDP at market prices. The implication is that in the TED net taxes on products (taxes minus subsidies) are attributed to capital income, whereas in the PWT they are proportionally distributed between capital and labor. The former is more appropriate when GDP is used as the output concept in the growth accounting. To keep consistency with the TED definition, the PWT labor income share estimates are adjusted to include net taxes on products.

For countries with no data at all a 50 percent labor income share is assumed, and for years with missing data, the last latest available labor income share is kept constant. Table 8 summarizes the sources and methods used to construct the labor income share time series data in TED.

[20] Data on the Conference Board International Labor Comparisons Program can be obtained from: https://www.conference-board.org/ilcprogram/index.cfm?

Table 8 – Sources and methods used to construct the labor share time series

Method	*#*	*Sources*
1. Compensation of employees + mixed income	56	Eurostat; OECD; UN National Accounts; country-specific
2. Average wage rate	5	Eurostat; OECD; country-specific
3. PWT	22	Groningen Growth and Development Center
4. APO Productivity Database	20	Asian Productivity Organization
5. 50% assumed	20	
	123	

3 – Aggregation of growth rates

This section outlines the method of aggregation used to obtain regional growth rates, as available from the file ‘Regional Aggregates’. Growth rate of any given indicator for individual countries are aggregated to relevant regions using nominal GDP or employment weights as:

$$\Delta \ln X_{region} = \sum_{i} \overline{w_i}\, \Delta \ln X_i \qquad (21)$$

where X_i denotes the indicator (growth in GDP, employment, labor productivity or TFP) for country i, and, depending on X_i, $\overline{w}_i$ denotes either the country share in PPP adjusted nominal GDP in the case of growth in GDP, labor productivity and TFP of the region for each year, or the share in total employment in the case of employment growth, while the bar denotes the use of a two-period average. This means that the sum of regional labor productivity and employment growth may not add up to GDP growth because of the different weighting schemes used.

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ANNEX 1 – Frequently Asked Questions on Alternative China GDP series

Version: November 2015

Note: Parts of this FAQ were previously published as part of the Global Economic Outlook 2016.

Why did TCB change its China GDP series?

1. Why is TCB so concerned about China's GDP numbers?

Throughout its near one-century presence, The Conference Board has conducted and commissioned studies in the areas of productivity measurement and GDP growth in many countries, including (since 2000) China. While we do rely heavily on government statistics, we do not subscribe to unquestionably adopting the official figures for any economy. But we also do not believe that reliance on judgmental, ad-hoc measures is a robust and credible methodology. In the case of China, we have therefore endeavored to reconstruct the Chinese GDP series bottom-up on a sector-by-sector basis, partly relying on official measures where we find those to be relatively unbiased, and partly constructing new estimates where we have concerns about the methodology of the published estimates.

We feel the alternative GDP series provides a better description of China's growth performance historically, and provides a better basis for projecting its growth going forward. We have discussed our alternative estimates at length with representatives from the academic and policy worlds in China and globally.

Over the past decade, we have worked closely with Professor Harry X. Wu (Japan's Hitotsubashi University) – to develop alternative growth and productivity estimates for China. Based on his latest work, as well as earlier studies he conducted in collaboration with the late Professor Angus Maddison (University of Groningen in the Netherlands), we have fully integrated Professor's Wu alternative estimates into this year's annual Global Economic Outlook.[21]

[21] Van Ark, B et al. (2015), The global economy in a holding pattern, The Conference Board Global Economic Outlook 2016. See also Global Economic Outlook 2016.

While the new series suggests an upward bias in the previously published GDP growth series of, on average, 2.6 percentage points per year since the start of Deng Xiaoping's so-called "reform era" that began in 1978, this percentage has not been constant over time. In fact, our alternative series indicates much larger volatility in the year-on-year estimates (sometimes even showing faster growth rates than the official estimates), suggesting that the impacts of external and internal shocks on the Chinese economy are much more pronounced than the official statistics convey.

Our analytics provide a different perspective on the stability of the Chinese economy and the features of volatility that shape the business environment. This helps to better inform companies how to appraise and react especially in times of economic stress in China.

2. Why are China's GDP numbers important for business?

China's macro growth performance is a key measure of the "temperature" of the economy and business environment. Whereas in other countries GDP serves primarily as an ex-post performance measure, China's government has traditionally been strongly focused on targeting aggregate GDP growth via industrial policies and central planning. As a result, understanding the implications of either not reaching or overshooting the GDP target is of considerable significance to the business and policy community in China. This will necessarily remain true until the significance of GDP as a national target diminishes for China – a notion that some in the policy community, both domestically and internationally, have argued will be forthcoming.

By identifying possible pitfalls in the existing GDP measure in China, as well as contributing to the improvement of the measurement framework, The Conference Board aims to provide business with a more accurate compass on the basis of which business decisions can be taken. For example, the perceptions about the progress (or lack thereof) of China's strategy to rebalance the economy from industry- and investment-driven growth to services- and consumption-driven growth hinge on adequate measures of output and expenditures. Better measures also help to identify how large (or small) the returns on investment are in an arguably overinvested economy. Or, they provide an answer to how large China's consumption potential really is.

When the Chinese economy is genuinely in a high-growth mode, an overstated growth rate by one or two percentage points may not be a problem for business planning. Opportunity cost is, after all, not a direct loss to business. However, when, in reality, the economy is slowing down markedly, the impacts of overstated growth measures are farther reaching and more risky in that they potentially undermine efficacy in business, policy, and household planning, both inside and outside of China. For business, growth projections that fail to depict downward trends or low-growth levels necessarily undermine the responsiveness businesses need to appropriately adjust planning, budgeting, and operations to assure competitiveness and sustainability through difficult times. This scenario is now clearly playing out in China.

3. What are the biases in data collection and how much do they affect the GDP numbers?

Despite significant changes to and improvements in the Chinese statistical program, including a gradual transition from the former Material Product System (MPS), which was adopted from the former Soviet Union in the earlier period of central planning, to the internationally harmonized System of National Accounts (SNA), China's official economic statistics still suffer from many deficiencies. These range from inconsistencies in definition, classification and coverage, to errors caused by inappropriate statistical approaches to data collection and reporting inaccuracies attributable to institutional deficiencies.

Unlike most advanced economies, China's measurement of GDP is traditionally and primarily based on an output method - i.e. measuring production by sector - rather than an expenditure method which measures investment and consumption. The latter is more commonly used in advanced economies and requires a more sophisticated data generation framework comprising well-developed surveys of consumer spending and business investment. Such expenditure-based metrics are often not available, nor of sufficient quality, in developing economies. China's recent efforts to improve measurements on the expenditure-side are important, but are still under development and not transparent in methodology.

Output measures have their own drawbacks. They are largely based on regular data collection and reporting via administrative channels from the bottom up involving records of firms, local governments and state agencies. Those official records are inevitably affected by various political incentives. We argue that the upward bias in the published GDP numbers in China is attributable to two sources: (1) a "misreporting effect" which accounts for about two-thirds of the upward bias; and (2) a "price effect" which accounts for the remaining one third. While originating from the old MPS system, both bias-causing problems have basically prevailed since the beginning of the so-called "reform period" which began in 1978.[22]

The misreporting effect

The "misreporting effect" refers to inconsistencies in the data collection process, methodological problems in data processing, as well data reporting inaccuracies that occur at any level of the data-generation process, from the localities on up to the central authorities. The misreporting effect includes the tendency of firms and local and provincial officials to exaggerate their output achievements to the central authorities relative to their respective plans or growth targets. This dynamic has caused significant overstatements in both levels and growth rates of output. For example, it has been reported that the value added of so-called "above size" industrial enterprise (which until 2011 used to cover all firms with annual sales of more than 5 million yuan) as reported through the statistical system was 10 percent higher than the reported industrial GDP in the national accounts. Even the growth rates of provincial GDPs, in aggregate, suggest faster growth than the national account-level GDP, and this growth gap has increased over time. For example, from 2001 to 2013, aggregate GDP growth at a provincial level was 2.4 percent faster than the national accounts growth rate. Hence, while statistical adjustments were made to account for over-reporting, it stands to reason that such adjustments were kept to a minimum.

An additional misreporting effect relates to the possibility of adjustments at the central level under the influence of political intervention from the political entities that set the growth targets, and from which the National Bureau of Statistics is not institutionally independent. Deliberate data manipulation at the central level is a cause of the unlikely smoothness of China's GDP series, but less so on the upward bias in the growth rates. The latter is more likely due to the systematic, skewed-data problems that emanate from the manual data corrections that occur throughout the data generation process at all levels.

The price effect

A rather retrograde approach to price measurement is deeply engrained in China's political-economic system; and specifically, there is a potentially deleterious lack of clarity on how the deflation of nominal GDP is carried out. In short, the concern is that prices are significantly understated in the statistical data. An understatement of prices is in part a legacy of the central planning period (1952 to 1977) when output was typically valued at "comparable prices", which are institutionally determined "constant prices" over long time intervals (typically 10 to 13 years). In 2002 this system was abandoned, but there

[22] Wu, Harry X. (2014a) *Re-Estimating Chinese Growth: How fast has China's economy really grown?* Special Briefing Paper, The Conference Board China Center for Economics and Business, June. Wu, Harry X. (2014b), *China's Growth and Productivity Performance Debate Revisited*, The Conference Board Economics Working Papers, February.

is still a near total lack of clarity around how the new GDP deflator was designed and implemented, and there still seems to be a significant downward bias in price measurement. For example, while the (implicit) GDP deflator for the industrial sector – obtained by dividing nominal output growth by real output growth – has increased faster since 2002 than before, its growth rate remains significantly lower than the officially reported producer price index. Our adjusted (lower) productivity assumptions for so-called “non-material services” (see below) also show much higher inflation than that suggested by the implicit national accounts deflators, for example in healthcare and education.

4. **Have the frequent adjustments in GDP series by the NBS taken care of the problems in the output data?**

Statistical agencies need to regularly refresh and revise their measurement framework to record output from hitherto unobserved (and often new) enterprises. Especially if the economy changes rapidly, the historical series understate growth if new economic activities remain unmeasured for substantive lengths of time. In five-year intervals since 2004 the National Bureau of Statistics (NBS) has adjusted the GDP data series several times when economic census data become available always leading to significant increases in the level and growth rates of China’s GDP. There were few if any downward adjustments most likely because of political constraints. For example, the 2004 economic census generated a substantial GDP adjustment from 1993 through 2003 but it left the relatively high 1998 growth rate untouched even though it was questioned internally and internationally as China was badly hit by the Asian Financial Crisis. Also the deteriorating manufacturing performance since 2011, after the effect of the unprecedented fiscal injection in previous years died out, was not reflected in the newly released 2013 census-based adjustment, which instead confirmed the original growth rate estimate for 2013. Also, despite the needed revisions to reflect genuinely new economic activities, the latest censuses also reflect better measurement of already existing activities that had simply remained uncounted until then. To treat all undercounting as new economic activity therefore creates an upward bias in the growth rate of historical economic activity.

How did TCB produce its new GDP series?

5. **What are the most important changes in the TCB series compared to the official series?**

The Maddison-Wu approach, which The Conference Board has adopted, reconstructs aggregate real GDP growth from the bottom-up on a sector-by-sector basis. The biggest adjustments are for the industrial sector and the so-called “non-material services” sector, which includes banking and financing, real estate, professional services, education, healthcare, culture and entertainment services, and government services.[23]

China’s Industrial Sector[24]

The biggest data adjustment is for China’s industrial sector, which focuses on correcting the misreported annual output values and price series. The estimates are based on a consistently built volume series of commodities and commodity groups, with multi-level and multi-year pricing and weighting using input-output table weights. In a nutshell the following steps were taken:

[23] Maddison, Angus (1998), *Chinese Economic Performance in the Long Run*, OECD Development Centre, Paris; Maddison, Angus and Harry X. Wu (2008), “Measuring China’s Economic Performance”, *World Economics*, Vol. 9 (2), April-June; Wu, Harry X. (2014b) *Re-Estimating Chinese Growth: How fast has China’s economy really grown?* Special Briefing Paper, The Conference Board China Center for Economics and Business, June.

[24] See Wu, Harry X. (2013), “How fast has Chinese industry grown? – The upward bias hypothesis revisited”, *China Economic Journal*, Vol. 6 (2-3): 80-102.

- The first step aggregates 165 available series of commodities or commodity groups from the China Industrial Economy Statistical Yearbook into (larger) groups that could be matched to 83 basic (3-digit) industries in a specific year's Chinese input-output table (CIOT). Each basic CIOT industry may contain several commodity groups. Benchmark-year price data are first used in intra-group weighting and then in aggregating the groups to produce indices that match the basic CIOT industries.
- The second step is to use the gross value of output of the 83 basic (3-digit) CIOT industries to weight and aggregate these commodity groups to match 25 major (2-digit) CIOT industries (or branches).
- The third step is to construct a quantity index for each of the major CIOT industries by assuming the unidentified part of the output value in an industry moves together with the identified part of the output value within each industry.
- The final step is to estimate gross value added at the major industry level, using a time series of the ratio of gross value added to gross value of output by industry based on Chinese input-output tables for 1987, 1992, 1997, 2002 and 2007.

As a result of these adjustments, the growth rate of real value added in industry (including energy, primary inputs, and semi-finished and finished products) was on average 7 percent per year from 1977 to 2014, compared to the average 11.3 percent stated in the official estimates from the NBS. However, there are substantial differences in the growth gap between our estimates and the NBS series for sub-periods. For example, for the period from 2001 to 2007, our index growth was faster, at an average 12.3 percent per year, than the NBS series which increased at 11.8 percent on average. However, for the period since 2007, real industry value added has increased at 4.8 percent per year on average according to our alternative series, compared to 9.8 percent per year average according to the NBS data. We also observe, in our series, a much higher variation in the annual growth rates of industry value added than does the NBS.

China's Non-Material Services[25]

The estimates for the so-called "non-material services" which include, for example: banking and financing, real estate, professional services, education, healthcare, culture and entertainment services, and government services (but exclude "material" services such as transportation, telecommunications and postal services, trade, and hotel and catering services), are based on changes in the number of people employed in each of those sectors, and assuming average labor productivity improvements of 1 percent per year from 1982 to 1991 and 2 percent from 1992 onward. These labor productivity growth estimates in non-material services are much lower than the implicit measures in the official accounts, which show output per worker (deducting employment growth from output growth) at 6 per cent per year, on average.

The labor productivity adjustments are judgmental in that they are based on the empirical experience of other, precursor, emerging and mature markets. For example, in other East Asian economies, productivity growth rates in non-material services sectors typically range at between 0 to at most 2 percent per year, depending on the relative level of economic development. In all cases, productivity in East Asian economies is less than half of the implied 6 percent labor productivity growth rates in non-material services in China according to the official data.

The exaggeration of labor productivity growth for non-material services in the published GDP figures is likely caused by deficient measures of price changes for the output of the non-material services – i.e. the Chinese official measurements didn't sufficiently deflate for price increases, and thus

[25] See Wu, Harry X. (2014c), "The growth of "non-material services" in China – Maddison's "zero-labor-productivity-growth" hypothesis revisited", *The Economic Review*, Institute of Economic Research, Hitotsubashi University, Vol. 65 (3).

exaggerated output growth in real terms. Inaccuracies may also have been caused by considerably underestimated initial-level growth contributions of those services due to price distortions.

6. If official price statistics in China are deficient, can you use those weights for commodity groups in your alternative series?

While the prices that are implicit in the Input-Output (IO) tables, and which are used for weighting the commodity volume indexes by value added, have the same problematic characteristics as the implicit deflator for GDP, we are less concerned about their impact on the alternative growth estimates. Those prices are only used for weighting rather than for deflating nominal output. In other words, while we think the official price deflators cannot be used in time series, the biases in a cross-section are less of a concern.

A detailed analysis was also carried out to determine whether subsequent weights in the IO tables for 1987, 1992, 1997, 2002 and 2007 reflected substitution of more expensive items for cheaper items. This is what one would normally expect if at least some market forces are in play. This effect was confirmed by the analysis, and suggests that the use of multiple IO weights for commodity series is economically and statistically sensible to reduce the substitution bias. All in all, despite the limited use of prices, this weighting method is to be preferred over directly using prices for deflation.

7. Does the "commodity method" for industrial production pick up quality improvements?

The quality of many products in the commodity groups will certainly have improved over the years. If this were to create a systematic bias we may of course understate the real output growth in manufacturing due to those unmeasured quality improvements. On the other hand, as the implicit price deflator in the national accounts has grown very slowly, the official method seems to assume that all quality improvements are being reflected in real output rather than in price increases – an unlikely possibility given the lack of sophistication in price measurements in China.

While it is not possible to come up with adequate quality measures for individual commodity groups, we were able to test whether the use of the commodity method would cause a systematic bias at the aggregate level. Assuming that the quality problem in our estimates would have increased over time, we would have had to find an increasing bias in our estimates relative to the official measures. However, correcting for external shocks and filtering out statistical noise, we didn't find such a systematic bias, leading us to conclude that, at least at aggregate level, quality issues are not a major concern in our index for industry.

8. Will TCB make further changes to the alternative China GDP series?

While we will continue to look for ways to improve the measures of China GDP, and hope to benefit from better data coming along in the future, we believe that the two important adjustments for the industrial sector and non-material services account for the lion's share of the upward bias in the real GDP series for China. There is, of course, room for further improvement of our series, such as a better measurement of quality improvements in industry and a more solid measurement of labor productivity in services. There may also be scope for improving the estimates of construction, for which we have adopted the official estimates so far. Professor Maddison's earlier work showed that agriculture only required level adjustment rather than price adjustment, but this may have to be revisited again. However, various tests suggest those adjustments cause relatively small revisions in the aggregate, and often in opposite directions between sectors, creating offsetting effects at the aggregate level.

The bigger issue is to come up with a better measure of nominal GDP, which essentially requires not only a re-estimating of volume growth (real GDP) but also of prices and the absolute level effect from underreporting on an annual basis. This will be a much more complex undertaking and is seriously constrained by the inability to reconstruct better price data historically.

How do TCB's new series compare to other alternative measures of economic performance?

9. Why not use the Li Keqiang index as an alternative?

The so-called Li Keqiang index, named after China's current premier, and which is based on electricity consumption, bank lending, and rail cargo volume, has also shown weaker growth performance in recent months.[26] However, there are several reasons while we eschewed using this index. The three underlying indicators are much more sensitive to shocks in industrial and commodity sectors than aggregate economic activity. Moreover, the Li Keqiang Index fails to take the growing services sector into account while it overstates the contribution from bank lending to the overall economy. Our research indicates that the index does not move in tandem with current economic activity. For example, The Conference Board Coincident Economic Index® (CEI) for China, which measures current economic activity and is based on measures from a broader range of sectors: electricity production (capturing demand from both manufacturing and consumer sectors), passenger transport (a service-sector indicator), value added of industrial production (industrial sector), retail sales of consumer goods (a service-sector indicator), and manufacturing employment, is also showing a slowdown but not as intense and volatile as the Li Keqiang index.[27] In fact, two of the three indicators in the Li Keqiang index, namely, bank loans and rail cargo volume, are more likely to lead the current state of the economy.

10. How does your analysis compare to the latest growth numbers as released by the NBS showing the growth of services is still proceeding well?

On October 19th 2015 the National Bureau of Statistics released its official third quarter real GDP growth number, which came in at 6.9 percent year over year for the three month period, only slightly below the 7 percent real GDP growth that was reported for the first two quarters of the year. Only four days after this GDP release, the People's Bank of China enacted the sixth benchmark interest rate cut of this easing cycle and the fourth cut to banks' reserve requirements. This seems to indicate that the slight reduction in officially reported real GDP growth does not reflect the true amount of downward pressure that the economy is facing.

The notion that the reported GDP growth rate is too high is further underscored by the component parts of output. In Q3 financial intermediation accounted for a full quarter of nominal GDP growth and 16 percent of real GDP growth – despite the fact that the sector accounts for only 8.7 percent of total GDP. This suggests that the economy seems to be "financializing" at an extraordinary pace. The second and third largest contributions to nominal growth in Q3 came from low-value-added service industries such as real estate services and wholesale and retail trade at 10 percent and 9.6 of GDP growth, respectively. These sectors are typically characterized by slow productivity growth. Hence the much-touted rebalancing of the economy towards high-value added services driven by innovation-driven activities with fast productivity growth seems unlikely. Instead it is quite natural to expect the growth slowdown to happen as a result of the rebalancing of the economy, as lower-productivity services are an important part of a more advanced economy.

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[26] This metric became a known entity after a leaked memo through WikiLeaks from U.S. Ambassador Randt in 2007, who reported that the Li Keqiang who was then head of Liaoning province had employing this index as an alternative to what he dubbed to the unreliable aggregate GDP numbers.

[27] For an earlier review of the TCB Coincident Index for China, see Guo Feng, Ataman Ozyildirim, and Victor Zarnowitz, "On the measurement and analysis of aggregate economic activity for China: the coincident economic indicators approach," *China Economic Journal* Vol. 2, No. 2, July 2009, 159–186. See also here.

11. **As the Chinese economy is supposedly rebalancing towards more consumption, does your methodological adjustment to output-based estimates really matter that much?**

Some scholars, both in China and abroad have been arguing that the biggest statistical problem in China is not overstated output measures, but understated expenditure measures, especially measures for consumption that are too low.[28] The proponents of the understatement of household consumption argue that better surveys of consumption would significantly raise the share of consumption in GDP, which is indeed quite low by international standards. We do not disagree with the viewpoint that the growth rate of consumption has been quite strong in the past two decades, and that the true share of consumption in China's economy may be understated especially when taking into account higher prices than previously assumed.[29] Indeed the upward adjustments in the output levels of services in the re-benchmarking of China's GDP would argue in favor of a larger share of consumption in the economy than the official statistics suggest. Unfortunately statistical surveys based on consumer spending are still very unreliable in China, and likely to remain so for a while. Even in the United States, which has one of the most well-established statistical systems in the world, consumer spending surveys are still quite problematic.

It is not clear, however, why a greater share of consumption should necessarily lead to a faster GDP growth rate than our new GDP measures suggest. While China's slower growth rate in recent years is largely the result of less efficient investment and slower productivity growth in the industrial sector, the transition to a services- and consumption-driven growth, also implies a larger role for sectors that have inherently slower productivity growth characteristics relative to industry. As indicated earlier, the implicit measures of productivity growth in the services sector, especially in "non-material services", in China's national accounts is arguably too high. This implies an increased bias if consumption advances more rapidly than in the past. For now, the output-based measures are the better way to go to gauge the growth performance of China's economy, provided the necessary adjustments are made as described in our alternative estimates.

Resources

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[28] See, for example, Yukon Huang, "China's Misleading Economic Indicators", Carnegie Endowment, August 2014.

[29] See also Louise Keely and Brian Anderson, Sold in China. Transitioning to a Consumer-Led Economy, The Demand Institute, 2015.

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ANNEX 2 – Commodity flow approach

To allow for a more comprehensive coverage of investment by asset data than possible based purely on national accounts data, we rely on the commodity flow method (CFM). This approach is commonly used to incorporate a greater level of asset detail in investment. It is used, for instance, in some early studies on the role of information and communication technologies (ICT) for economic growth in Europe (Timmer and van Ark, 2005) or in broader international comparisons (Caselli and Wilson, 2004). The CFM method relies on information on the supply (S) of investment goods:

$$S_i = M_i - X_i + Y_i \qquad (22)$$

where supply of asset i is computed as imports M minus exports X plus production Y. Note that for construction projects only production will be relevant as these are non-traded products. Economy-wide supply equals the total use of these goods, which includes investment in fixed assets by firms but also consumer purchases, and the ratio of investment-to-total use varies. This means it is important to have at least one benchmark observation on the asset composition of investment to serve as an anchor for the investment-to-total use ratio. We follow the approach also applied in Feenstra, Inklaar and Timmer (2015) for estimating investment by asset for the Penn World Table, versions 8.0 and 8.1. In this approach, national accounts data are used first and only when these are unavailable, we use CFM series to extrapolate growth in each asset. In the final step, investment is normalized to add up to total investment from the national accounts. Data on imports and exports are drawn from the UN Comtrade database, industrial production is from the UNIDO INDSTAT database and value added in construction is from the UN National Accounts Main Aggregates Database.[30]

[30] Practical complications arise from imperfect coverage of trade and production data, which requires the use of long-run trends and smoothing to avoid unrealistic swings in asset shares.

ANNEX 3 – WITSA ICT data

Since WITSA provides data on total ICT spending—both consumer spending and investment spending—it is necessary to disentangle business investment from consumer spending. To construct a consistent series of investment from total spending data, Jorgenson and Vu (2013) apply the average investment-to-spending ratio from the United States—a country for which both official national accounts data on ICT investment, and WITSA ICT spending data are available—to all other countries, i.e.:

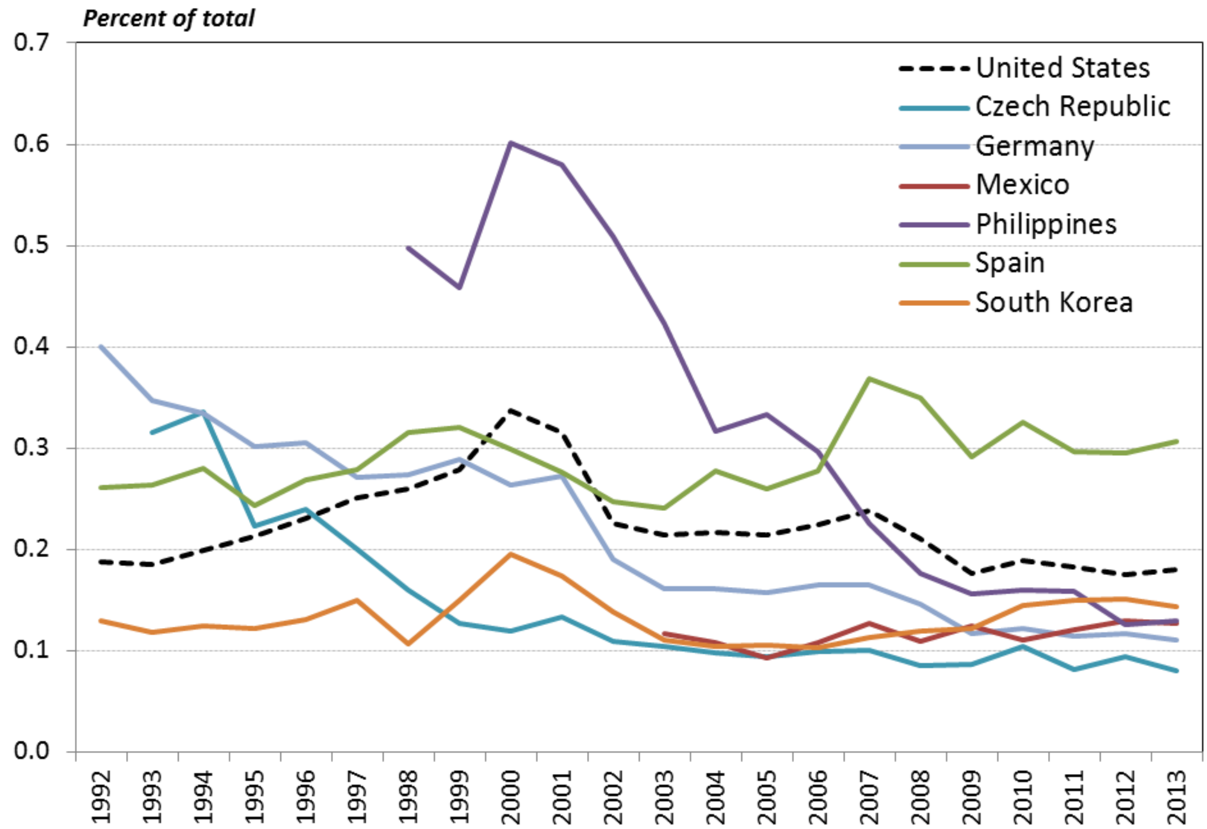
$$I_{i,t}^{j} = \emptyset_{i}^{US} S_{i,t}^{j,w} \tag{23}$$

where $I_{i,t}^{j}$ is the current price investment in asset i (with $i = 1,..,3$; hardware, software and communication equipment) and $S_{i,t}^{j,w}$ is WITSA ICT spending data – both for year t and country j. $\emptyset_{i}^{US}$ is the average investment-to-spending ratio for ICT good i across all years: $\emptyset_{i}^{US} = \sum_{t=1}^{T} \left(\frac{I_{i,t}^{US,na}}{S_{i,t}^{US,w}} \right) / T$ where $I_{i,t}^{US,na}$ and , $S_{i,t}^{US,w}$ are respectively US ICT investment from the national accounts andUS ICT spending from WITSA . The approach of Jorgenson and Vu (2013) has been criticized by de Vries et al. (2010) and Erumban and Das (2016) as it will lead to biased estimates of investment if the true ratio $\emptyset_{i}$ differs across countries and over time.

We build on Jorgenson and Vu (2013, 2016), but seek to improve it by relaxing some of the underlying assumptions. Using the rich base of official and semi-official data, as described above, it is now possible to compare official data with WITSA total spending data for more countries than just the United States. Figure 6 compares the US investment to spending ratio with that of several developing and developed economies for communication equipment. We find that the investment to spending ratios differ widely over time and across countries.[31] For instance, it is clear that consumer expenditure on telecommunication equipment gradually outpaced business investment over the course of the last decade, coinciding with the increased consumer adoption of mobile phones and smartphones. This is the case in Germany, Czech Republic and is even more pronounced in the Philippines. In contrast, the US data suggest a relatively stable rate throughout, apart from a surge around the turn of the century at the time of the dotcom bubble when business investment temporarily increased relative to consumer spending before settling at the pre-bubble rate.

[31] A similar picture is observed in the case of software and hardware.

Figure 6 – Investment over total expenditure (communication eq.), selected countries, 1992-2013



Sources: Bureau of Economic Analysis (United States), Eurostat (Czech Republic), EU-KLEMS and DESTATIS (Germany), OECD National Accounts at a Glance and Mexico KLEMS (Mexico); Philippine Statistics Authority (Philippines); Fundación BBVA (Spain); World-KLEMS (South Korea); and WITSA, Digital Reports (various issues) for total spending.

The investment-to-spending ratio is not constant across countries and over time, but assumptions about this ratio are still required to estimate ICT investment for the full set of countries and years. We suggest using a regional moving average of investment to total spending ratio. In terms of equation (13), we replace $\emptyset_i^{US}$ by $\emptyset_{i,T}^{J}$, defined as:

$$\emptyset_{i,T}^{J} = \sum_{T=t-4}^{t} \left(\frac{I_{i,t}^{na}}{S_{i,t}^{w}}\right)^{J} \Big/ 5\,, \text{for } j \in J \qquad (24)$$

where J denotes the region. As official (or semi-official) data on ICT investment is missing for nearly all Middle Eastern and African countries we apply a global moving average investment-to-spending ratio for these countries.

ANNEX 4 – Estimation of Labor Compensation Shares

As is evident from equation (17) in section 2.3, we require distribution of employment and labor compensation by educational categories to accomplish the labor quality estimates. These data are not available for many countries, and even for countries for which they are available, there are often missing years. For countries and years for which the data is not available, we estimate it using a regression approach. We estimate distribution of wages by educational groups using a random effect panel regression.[32] The model we estimate is

$$lnW_{i,t} = \alpha + \beta_1 lnYS_{i,t} + \beta_2 lnCPI_{i,t} + \beta_3 D_i + \eta_i + \varepsilon_{i,t} \qquad (25)$$

where $\ln W_{i,t}$ is the log of wage rate for country i in year t, expressed in purchasing power parity (PPP), for any given educational category, YS is the average years of schooling, CPI is the relative level of consumer prices (prices of each country are taken as a ratio of the consumer prices in the United States, as wage rates are expressed in PPP), and D is a regional dummy[33]. η_i and $\varepsilon_{i,t}$ are respectively the country fixed effects and the error term. The equation is estimated separately for each educational category *l* (*l= low-skilled, medium-skilled and high-skilled*), so that we have three set of wage estimates. Since it is a log-log function, the coefficient of average years of schooling can be interpreted as the returns to schooling.

Once wages are estimated using equation (25), we compute the distribution of wages across different educational groups as:

$$\bar{\mathrm{s}}_{\mathrm{l,i,t}} = W_{l,i,t} / \sum_{l=1}^{L} W_{l,i,t} \qquad (26)$$

where $\bar{\mathrm{s}}_{\mathrm{l,i,t}}$ is the share of educational group *l* in total labor compensation, $W_{l,i,t}$ is the estimated compensation for educational group *l,* both for country i and year t. Whenever the actual data is available, we use the actual wage shares to calculate the labor quality. In the absence of such data, we apply the trend in the estimated wage shares using equations (25) and (26) to the available benchmark estimates. In case, no benchmark estimates available for a country, then the entire wage distribution is based on the estimated wages.

Recall that we also need employment shares to estimate the labor quality. We take the available estimates employment from various sources as explained in the main text. For missing years, these are extrapolated using the trend in the distribution of population by educational attainment in Wittgenstein Centre (2015) data. If there are still missing cases, we extrapolate it using the trend in updates of population distribution data from Barro and Lee (2012).

[32] The Hausman test favors the choice of a random effect model over a fixed effect model.

[33] The regional dummies used are Euro Area, Other Western Europe and Nordic, Eastern Europe, North America, Other Mature economies, Latin America, Developing Asia, Gulf Corporation Council and Iran, BRICS (Brazil, Russia, India, China and South Africa), and Middle East and North Africa, with one of them being excluded from the estimation.