LATIN AMERICA AND THE CARIBBEAN (LAKLEMS)

OVERVIEW OF METHODOLOGY AND DATABASE

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Summary

This technical note describes the LAKLEMS database and explains the methodology used to calculate the growth of Total Factor Productivity (TFP) and the contributions to the growth of production factors by type of input according to sector (http://laklems.net/).

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[1] This document was put together for LAKLEMS by Eduardo Fernández-Arias, André Hofman, and Tomás Gálvez (Universidad de Santiago de Chile, USACH) based on the initial work of Matilde Mas and Eva Benages 2020 (Instituto Valenciano de Investigación Económica, IVIE) with contributions from Robert Stehrer (The Vienna Institute for International Economic Studies, wiiw) to expand it consistently to all LAKLEMS countries (based on EUKLEMS standards, 2019). The comments from the Colombia technical team are appreciated.

CONTENTS

1. Introduction

The objective of the LAKLEMS project is to create a database on measures of economic growth, productivity, employment, capital formation, and intermediate inputs, broken down by sector of economic activity. In this version, the database includes time series for eight Latin American economies (Chile, Colombia, Costa Rica, El Salvador, Honduras, Mexico, Peru, and the Dominican Republic) between 1990 and 2018, with detailed information on indicators by industry for 9 sectors.[2] It estimates the contribution to growth of Total Factor Productivity (TFP) and the types of input according to sector.

This document describes the procedures followed to construct the statistics included in the LAKLEMS database and the methodology used to estimate the sources of growth. This work aims to support empirical and theoretical research on economic growth, as well as the implementation of policies that promote productivity in Latin America and the Caribbean, for which comprehensive measurement instruments are required for understanding and evaluating the progress made.

Input measurements are broken down into a number of different categories: capital (K), labor (L), energy (E), materials (M), and service inputs (S). The “growth accounting” technique applied in this report estimates how much of the observed rate of change in the output of an industry or sector can be explained by the rate of change of the combined inputs. Thus, the growth accounting methodology evaluates the growth of (TFP) as a residual. One of the main advantages of the growth accounting used by the KLEMS methodology is that it is embedded in a clear analytical framework based on production functions and economic growth theory. It therefore provides a conceptual framework in which the interaction between variables can be analyzed, which is of fundamental importance for policy evaluation.

The estimates made for the different Latin American countries follow the same logic as the estimates used in "sister" KLEMS databases in the United States, Canada, the European Union and Japan. It is hoped that building and updating the LAKLEMS database will facilitate the sustainable production of high-quality statistics using the methodologies of the national accounts and the input-output tables.

2 For the sector breakdown, see table A1 in the appendix. The level of sector detail in the LAKLEMS database varies by country and variable due to data limitations. In order to ensure a minimum level of detail for making comparisons between countries, a minimum list of nine industries was selected. However, LAKLEMS expects to be able to increase the degree of sector detail with future updates to the database. In the near future, the expectation is that the ISIC Rev.4 classification of activities will be adopted, as all countries expect to incorporate it into their National Accounts.

The document is structured as follows: In section 2, the general approach to GDP growth accounting (Value Added) is outlined, and details are provided on the calculation of capital and labor services (inputs of physical capital K and human capital L, respectively). Section 3 shows the methods for deriving growth from (TFP). Section 4 extends the GDP growth or value added accounting to gross output growth accounting, which includes intermediate inputs (energy E, materials M, and services S). Section 5 describes the architecture of the database and Section 6 discusses the data used and their sources, including country-specific issues.

2. GDP growth accounting approach (value added)

In this section, the basic variables for performing value-added growth accounting are introduced, then applied to build the factor growth accounts and TFP in the LAKLEMS database.[3] The starting point of the growth accounting framework is a value-added production function, given that

$$V_j = g_j(KS_j, LS_j, T_j)$$

where j indicates the industry,[4] V_j is the measurement of the added value (real), and the inputs are labor services LS_j and capital services KS_j. T_j indicates the level of productivity (not observed) (total factor productivity).

How growth in labor value added is accounted for is calculated and described below. It should be noted that the applied growth accounting framework is based on several standard assumptions (see Jorgenson *et al*., 2005, for more details); they are competitive factor and output markets (such that prices are equal to marginal costs and factor prices are equal to marginal output), full utilization of inputs (specifically for capital due to lack of data on utilization rates) and constant returns at scale. Assuming a translog functional form of the production function, the growth of total factor productivity of the value added of an industry can be derived as follows (see Jorgensen *et al.*, 2005):

$$\Delta \ln T_{VA,j} \equiv \Delta \ln V_j - \bar{v}_{K,j} \Delta \ln KS_j - \bar{v}_{L,j} \Delta \ln LS_j$$

where $\Delta \ln x_t = \ln x_t - \ln x_{t-1}$ indicates the logarithmic growth rate of each of the variables. The nominal proportion of production (costs) in the added value of labor and capital is indicated by $v_{L,j}$ and with $v_{K,j}$, respectively.[5] For later use, the variables $\bar{v}_{f,j} = 0.5(v_{f,j,t} + v_{f,j,t-1})$ will indicate the average proportions of the period (Divisia index). By definition, we have $\sum_f v_{f,j} = 1$ based on the assumption of constant returns at scale; this also implies $\sum_f \bar{v}_{f,j} = 1$.

By measuring value added and inputs (primary), as well as the respective nominal proportions of labor compensation and capital, TFP growth rates (based on value added) can be calculated as a residual—that is, the difference between the growth in value added and the growth rates of the primary input factors, labor and capital, weighted by their average nominal share in value added.

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3 This is obtained based on Stehrer *et al*. (2019); also see Timmer *et al.*, (2010), Chapter 3.

4 This also applies to the total economy, as this approach is used at each level of aggregation (see Table A1). Thus, in the current LAKLEMS approach, following the recent version of the 2019 edition of EU KLEMS, the growth accounts of the total economy are calculated at the level of the total economy and are not derived as a weighted average of all industries. However, this is a subject for future discussion. In the case of Colombia, for example, they are currently derived as a weighted aggregate of all industries.

5 The proportions correspond to the LAB and CAP variables derived below.

Therefore, the following sections analyze the steps for constructing labor and capital inputs, respectively. In the growth accounting methodology, the growth rates of primary inputs are measured by constructing capital and labor services rather than using measurements of people employed or hours worked or a total capital stock.

The following subsections analyze the calculation of the share of labor and capital income in value added, as well as the construction of the growth rates for labor and capital services.

2.1 Proportion of labor and capital income

For the growth accounting approach, one must first calculate the share of labor and capital income in value added in nominal terms for each industry. As the National Accounts data only documents and makes available the compensation of employees by industry, $\mathrm{COMP_j}$, this partial measurement should be adjusted to take into account the labor income of self-employed workers (including all workers not included formally as employees). Labor income (LAB) is calculated as:

$$\mathrm{LAB_j} = \frac{\mathrm{H\_EMP_j}}{\mathrm{H\_EMPE_j}} \mathrm{COMP_j}$$

where $\mathrm{H\_EMP_j}$ indicates the hours worked of all persons engaged and $\mathrm{H\_EMPE_j}$ is hours worked of employees. This calculation to obtain a rough indicator of labor income assumes that the hourly income of self-employed workers is equal to that of employees.[6] Capital income is then calculated as the difference between value added and labor income, that is:

$$\mathrm{CAP_j} = \mathrm{V_j} - \mathrm{LAB_j}$$

Using these approaches to labor and capital income, the proportions for labor and capital income are calculated as

6 For methodological consistency, this criterion—used by EUKLEMS (2019)—was applied: that the income of the self-employed or informal worker is identical to that of formal worker in all accounts, for the calculations of the basic file for both GO and VA. However, it is important to note that the SNA (2008) dealt with the topic of the informal economy in Chapter 25, recognizing the analytical importance—especially in developing countries—of the possibility of measuring the part of the economy reflecting the efforts people lacking formal jobs to participate in some type of monetary economic activity. That part of the economy has become known as the informal economy. In the labor accounts, it is assumed that informal workers have the same gender structure, age groups, and levels of education. In the capital factor, calculated by the difference between GO or VA and the labor contribution, EUKLEMS (2019) resolved that, when the employment contribution is greater than GO or VA, the capital contribution is set to zero. It is possible that in the case of Europe, the assumption of equality between employees and the self-employed or informal workers is reasonable. However, in the case of Latin America, this assumption is untenable and leads to gross errors in the growth accounting calculations. In several Latin American countries—for example, in Chile and Peru—there are data on real incomes in the informal sector that could be used to arrive at more realistic estimates of the importance of the informal sector in the economy, correctly reflected in growth accounting. In this version of the document, we have applied the criterion of EUKLEMS (2019). However, in future versions of the methodological document, more realistic methods of incorporating informal work in growth accounting exercises will be included.

$$v_{K,j} = \frac{CAP_j}{V_j} \qquad y \qquad v_{L,j} = \frac{LAB_j}{V_j}$$

However, it could be that LAB_j is higher than value added (for example, if the proportion of self-employed workers in a specific industry is very high and their average hourly pay is lower, or if the industry receives large subsidies to offset negative benefits), and therefore capital income CAP_j would be negative. In these cases, several adjustments have been suggested, including:

- First, it can be argued that capital inflow may be negative in certain years for reasons of the business cycle, in which case no adjustment would be applied. In these cases, the proportion of labor income would be greater than one and, consequently, the proportion of capital income would be negative.
- Second, the labor income ratio could be set at 1, and thus the capital income ratio at 0, as an *ad hoc* adjustment.
- Third, the observed proportions in these cases could be replaced by long-term averages or by interpolations to smooth them.
- Fourth and finally, previous option aside, the option could be considered that in Latin America, the hourly labor income of self-employed workers is lower than hourly wages, especially in activities such as agriculture and retail. This would make it possible to adjust the wage rates of the self-employed by factor $0 < \lambda_j \leq 1$, reducing the estimate of their labor income and, therefore, of the total labor income, thus preventing the proportion of labor income from being greater than one. In other words:

$$LAB_j = COMP_j + \lambda_j \frac{(H\_EMP_j - H\_EMPE_j)}{H\_EMPE_j} COMP_j$$

where $(H\_EMP_j - H\_EMPE_j)$ is the number of hours worked by self-employed workers and λ_j is a ratio of the hourly remuneration of these self-employed workers and that of employees. (Note that if $\lambda_j = 1$, then this formula reduces to the one given above.) To apply this alternative, data must be collected to adjust the income of the self-employed.

The specific adjustment that is ultimately chosen might depend on the specific reason for the negative shares of capital inflow. In this version, following the practice of EUKLEMS, option 2 is used when the abnormal situation occurs sporadically. However, in countries where labor ratios greater than 1 were consistently observed in a given industry (especially agriculture), option 4 was used by taking $\lambda_j = 0$.

2.2. Labor services

The next step is to calculate the growth of labor and capital services. In this subsection, we describe the calculation of the growth of labor services. For this, data on hours worked (alternatively, number of people employed) must be available broken down by various characteristics (age, sex, education). Taking these data, the labor input of type l (age, sex, education) in industry j measured in hours worked is indicated by $H_{l,j}$[7] In addition, data must be available on the hourly wages of these groups, indicated by $p_{L,l,j}$.

The measurement of the logarithmic growth rate of labor services in industry j, $\Delta \ln LS_j$, is then calculated as a Törnqvist volume index of the growth in hours worked by type l weighted by its nominal share in the cost of production (period average). Formally, this is expressed as

$$\boldsymbol{\Delta \ln LS_j = \sum_l \bar{v}_{L,l,j} \Delta \ln H_{l,j}}$$

where $\bar{v}_{L,l,j} = (v_{L,l,j,t} - v_{L,l,j,t-1})/2$ indicates the Divisia index of the proportions of the nominal value of the type of work l. For type of work l in industry j these are defined as

$$\boldsymbol{v_{L,l,j} = \frac{p_{L,l,j} H_{l,j}}{\sum_l p_{L,l,j} H_{l,j}} \frac{p_{L,l,j} H_{l,j}}{\sum_k p_{L,l,j} H_{l,j}}}$$

By definition, $\sum_l v_{L,l,j} = 1$ is obtained (and therefore $\sum_l \bar{v}_{L,l,j} = 1$)). The development of the Törnqvist volume index of labor services can finally be broken down into (i) a work composition effect, and (ii) a change effect in hours worked, as follows:

$$\begin{aligned}
\Delta \ln LS_j &= \sum_l \bar{v}_{L,l,j} \Delta \ln H_{l,j} - \Delta \ln H_j + \Delta \ln H_j \\
&= \left(\sum_l \bar{v}_{L,l,j} \Delta \ln H_{l,j} - \sum_l \bar{v}_{L,l,j} \Delta \ln H_j \right) + \Delta \ln H_j \\
&= \sum_l \bar{v}_{L,l,j} \Delta \ln \frac{H_{l,j}}{H_j} + \Delta \ln H_j
\end{aligned}$$

This gives us the equation

7 Alternatively, information on the number of people employed can be used if data on hours worked is not available.

$$\Delta \ln \mathbf{LS_j} = \Delta \ln \mathbf{LC_j} + \Delta \ln \mathbf{H_j}$$

The first term shows the work composition effect's contribution to the growth of labor services; the second term shows the contribution of changes in hours worked. Therefore, this expression can be interpreted directly: First, if the total hours worked did not change, that is $\Delta \ln H_j = 0$, only an increase in the hours worked of workers who obtain a relatively higher proportion of labor income in the industry would produce an increase in labor services. Second, if there are no changes in the composition of labor inputs measured in hours worked, that is, $\Delta \ln \frac{H_{l,j}}{H_j} = 0$ for all types of work, the growth of labor services would correspond to the overall growth rate of hours worked in industry j. Also, thirdly, the change in labor services is affected by the (relative) prices of the factors (that is, wages per hour worked) at each moment in time, since they weight changes in composition. [8]

The variables concerning labor services of the total economy are obtained by adding the corresponding variables of each sector, from which the growth of labor services for the total economy is obtained.

2.3. Capital services

The next step is to calculate the growth of capital services. To calculate capital services, data are needed (by industry and type of asset) on price deflators of gross fixed capital formation (GFCF), along with data on capital stocks in volumes (chained) broken down by industry and type of asset.[9]

2.3.1 Constructing the time series of capital stocks

As no data are available on capital stocks, they are estimated using the time series of gross fixed capital formation in volumes, applying the permanent inventory method. For this, it is necessary to first calculate an initial capital stock at time 1 for each type of asset *k* in each industry *j*, that is $K_{k,j,1}$. This is done by calculating the average GFCF (by industry and asset types) for the first five

8 This reflects the assumption that wage rates are equal to their marginal output (given prices). For example, if there is a composition shift towards women or immigrant workers who earn less due to discrimination, the approach would still indicate a negative productive effect on the composition of work. Similarly, (exogenous) changes in wage structures imply an effect on the growth rate of labor services.

9 For the list of asset types and their depreciation rates, see the table in Appendix A.2.

years, indicated by $\bar{J}_{k,j}$ and the long-term average logarithmic growth rate of GFCF (by industry), indicated by $\bar{g}_{J,l,j}$. The initial stock is therefore calculated as

$$K_{k,j,1} = \bar{J}_{k,j}/\left(\delta_{k,j} + \bar{g}_{J,k,j}\right)$$

where $\delta_{k,j}$ indicates the annual depreciation rate of asset type k in industry j. The capital stock time series is then calculated sequentially as

$$K_{k,j,t+1} = K_{k,j,t}\left(1 - \delta_{,j}\right) + J_{k,j,t}$$

The capital stock of the total economy by asset type is calculated as the sum of the industries.

2.3.2 Derivation of the use cost of capital

Calculating the use cost of capital then requires first of all calculating the *nominal rate of return* per industry, $i_{j,t}$, as follows:

$$i_{j,t} = \frac{p_{K,j,t}K_{j,t} + \sum_k \left(p_{I,k,j,t} - p_{I,k,j,t-1}\right)K_{k,j,t} - \sum_k \delta_{k,j} p_{I,k,j,t} K_{k,j,t}}{\sum_k p_{I,k,j,t-1} K_{k,j,t}}$$

where $p_{K,j,t}K_{j,t} = CAP_{j,t}$ (that is, capital input) and $K_{k,j,t}$ is the capital stock for asset types k in real volumes. The nominal rate of return can become negative, in which case it is set to zero (following EUKLEMS practice).

To calculate the *cost of use of capital* (price of capital services or "rental price") for each type of asset, the “cost of use of capital approach” is used. This is the price at which it makes no difference to an investor whether to buy the capital or rent it for one year. The equation for the *cost of use of capital*[10] is as follows:

$$p_{K,k,j,t} = p_{I,k,j,t-1} i_{j,t} + \delta_{k,j} p_{I,k,j,t} - (p_{I,k,j,t} - p_{I,k,j,t-1})$$

where $p_{I,k,j,t}$ is the price of investment in asset type k in industry *j* and δ_k is the depreciation rate (geometric).

2.3.3 Growth of capital services

Analogously to labor services, capital services inflow is measured as a Törnqvist volume index of various types of assets:

$$\mathbf{\Delta \ln KS_j = \sum_k \bar{v}_{K,k,j} \Delta \ln K_{k,j}}$$

10 For an analysis, see Jorgenson *et al*. (2005) for detailed information. Specifically, a geometric pattern of economic depreciation is assumed.

where $K_{k,j}$ indicates real capital stock (in chained volumes) of the asset type k in industry j and $\bar{v}_{K,k,j}$ indicates the nominal proportions (Divisia) of the participation of this type of assets. These nominal proportions are defined as

$$v_{K,k,j} = \frac{p_{K,k,j}K_{k,j}}{\sum_k p_{K,k,j}K_{k,j}} = \frac{p_{K,k,j}K_{k,j}}{p_{K,j}K_j}$$

where $p_{K,k,j}$ is the cost of using capital asset k in industry j derived from the above. It is found (by definition) that $\sum_k v_{K,k,j} = 1$. The variables $\bar{v}_{K,k,j,t} = (v_{K,k,j,t} + v_{K,k,j,t-1})/2$ indicate the proportions of Divisia for which it is also verified that $\sum_k \bar{v}_{K,k,j} = 1$.

The growth rate of capital services, $\Delta \ln KS_j$, can also be divided into 2 groups. Specifically, it is grouped into growth of ICT-linked capital services and non-ICT-linked capital.[11] The growth rate of ICT-related capital services is found by:

$$\Delta \ln KS_{ICT,j} = \left(\bar{v}_{IT,j}\Delta \ln K_{IT,j} + \bar{v}_{CT,j}\Delta \ln K_{CT,j} + \bar{v}_{SoftDB,j}\Delta \ln K_{SoftDB,j}\right)/\left(\bar{v}_{IT,j} + \bar{v}_{CT,j} + \bar{v}_{SoftDB,j}\right)$$

that is, the growth rates of the three types of assets linked to ICT (information technology, communication technology, and software and databases). For further use, $\bar{v}_{ICT,j} = \left(\bar{v}_{IT,j} + \bar{v}_{CT,j} + \bar{v}_{SoftDB,j}\right)$.

Similarly, the growth of non-ICT capital services is calculated by

$$\begin{aligned}\Delta \ln KS_{NICT,j} = \big(&\bar{v}_{RStruc,j}\Delta \ln K_{RStruc,j} + \bar{v}_{OCon,j}\Delta \ln K_{OCon,j} + \bar{v}_{TraEq,j}\Delta \ln K_{TraEq,j} \\ &+ \bar{v}_{OMach,j}\Delta \ln K_{OMach,j} + \bar{v}_{Cult,j}\Delta \ln K_{Cult,j} + \bar{v}_{RD,j}\Delta \ln K_{RD,j} + \bar{v}_{OIPP,j}\Delta \ln K_{OIPP,j}\big) \\ &/\left(\bar{v}_{RStruc,j} + \bar{v}_{OCon,j} + \bar{v}_{TraEq,j} + \bar{v}_{OMach,j} + \bar{v}_{Cult,j} + \bar{v}_{RD,j} + \bar{v}_{OIPP,j}\right)\end{aligned}$$

Again, for further use:

$$\bar{v}_{NICT,j} = \left(\bar{v}_{RStruc,j} + \bar{v}_{OCon,j} + \bar{v}_{TraEq,j} + \bar{v}_{OMach,j} + \bar{v}_{Cult,j} + \bar{v}_{RD,j} + \bar{v}_{OIPP,j}\right)$$

Note that by definition $\bar{v}_{ICT,j} + \bar{v}_{NICT,j} = 1$.

The growth rate of capital services for the entire sector can then be written as

$$\mathbf{\Delta \ln KS_j = \bar{v}_{ICT,j}\, \Delta \ln KS_{ICT,j} + \bar{v}_{NICT,j} \Delta \ln KS_{NICT,j}}$$

The global growth of capital services is calculated in the same way using aggregated statistics.

11 Of course, other groups of asset types could also be constructed in a similar way. However, for this methodology, only two groups will be used.

2.4. Summary

In this section, we have documented how labor and capital income ratios are calculated, as well as growth rates for labor and capital services for LAKLEMS growth accounts. These variables are then used to calculate total factor productivity growth and contributions to growth.

3. TFP and the factor contributions to value added growth

In this section, we use the above-described variables to estimate TFP growth and thereby account for the growth of GDP (Value Added) and of labor productivity.

3.1. Contributions to GDP or value added growth

By definition, the growth of value added is:

$$\Delta \ln \mathrm{V_j} = \Delta \ln \mathrm{T_j} + \bar{v}_{K,j} \Delta \ln \mathrm{KS_j} + \bar{v}_{L,j} \Delta \ln \mathrm{LS_j}$$

that is, the TFP growth rate plus the growth rates of labor and capital services weighted by their share of value added. If expressions are inserted for labor and capital services, we have:

$$\Delta \ln \mathrm{V_j} = \Delta \ln \mathrm{T_j} + \bar{v}_{K,j}\left(\bar{v}_{ICT,j} \Delta \ln \mathrm{KS_{ICT,j}} + \bar{v}_{NICT,j} \Delta \ln \mathrm{KS_{NICT,j}}\right) + \bar{v}_{L,j}\left(\Delta \ln \mathrm{LC_j} + \Delta \ln \mathrm{H_j}\right)$$

where labor inputs are differentiated by the composition and effect of hours worked. In practice, this equation is used to calculate TFP growth, $\Delta \ln \mathrm{T_j}$, as a residual, that is,

$$\Delta \ln \mathrm{T_j} = \Delta \ln \mathrm{V_j} - \bar{v}_{K,j}\left(\bar{v}_{ICT,j} \Delta \ln \mathrm{KS_{ICT,j}} + \bar{v}_{NICT,j} \Delta \ln \mathrm{KS_{NICT,j}}\right) - \bar{v}_{L,j}\left(\Delta \ln \mathrm{LC_j} + \Delta \ln \mathrm{H_j}\right)$$

Furthermore, the expression can also be used to calculate the contributions to the growth of ICT-related capital services ($\bar{v}_{K,j}\bar{v}_{ICT,j} \Delta \ln \mathrm{KS_{ICT,j}}$), non-ICT capital services ($\bar{v}_{K,j}\bar{v}_{NICT,j} \Delta \ln \mathrm{KS_{NICT,j}}$), composition of work ($\bar{v}_{L,j} \Delta \ln \mathrm{LC_j}$), and contribution of hours worked ($\bar{v}_{L,j} \Delta \ln \mathrm{H_j}$).

3.2. Contributions to the growth of labor productivity per hour worked

The breakdown of growth into value added per hour worked (growth of labor productivity in hours worked) can be derived by dividing the labor term and subtracting the change in growth in hours worked from both sides of the equation. This gives us

$$\Delta \ln \mathrm{V_j} - \Delta \ln \mathrm{H_j} = \Delta \ln \mathrm{T_j} + \bar{v}_{K,j} \Delta \ln \mathrm{KS_j} + \bar{v}_{L,j} \Delta \ln \mathrm{LC_j} + \bar{v}_{L,j} \Delta \ln \mathrm{H_j} - \Delta \ln \mathrm{H_j}$$

Using $\left(\bar{v}_{K,j} + \bar{v}_{L,j}\right) = 1$, we get

$$\Delta \ln \mathrm{V_j} - \Delta \ln \mathrm{H_j} = \Delta \ln \mathrm{T_j} + \bar{v}_{K,j} \Delta \ln \mathrm{KS_j} + \bar{v}_{L,j} \Delta \ln \mathrm{LC_j} + \bar{v}_{L,j} \Delta \ln \mathrm{H_j} - \left(\bar{v}_{K,j} + \bar{v}_{L,j}\right) \Delta \ln \mathrm{H_j}$$

which then gives us

$$\Delta \ln \mathrm{V_j} - \Delta \ln \mathrm{H_j} = \Delta \ln \mathrm{T_j} + \bar{v}_{K,j}\left(\Delta \ln \mathrm{KS_j} - \Delta \ln \mathrm{H_j}\right) + \bar{v}_{L,j} \Delta \ln \mathrm{LC_j}$$

Analogously to the above, this can be rearranged to divide capital services into ICT-linked capital services and non-ICT-linked capital services (using $\bar{v}_{ICT,j} + \bar{v}_{NICT,j} = 1$),

$$\Delta \ln V_j - \Delta \ln H_j = \Delta \ln T_j + \bar{v}_{K,j}\left(\bar{v}_{ICT,j}\left(\Delta \ln KS_{ICT,j} - \Delta \ln H_j\right) + \bar{v}_{NICT,j}\left(\Delta \ln KS_{NICT,j} - \Delta \ln H_j\right)\right) + \bar{v}_{L,j}\Delta \ln LC_j$$

This breaks down the growth in value added per hour worked into the growth of ICT-linked capital services and non-ICT capital services per hour worked, the effect of the composition of work and TFP growth. Again, in practice, TFP growth is calculated as a residual. However, it must be taken into account that the contribution of TFP growth and of the composition of work to the growth of labor productivity is the same as that of the growth of value added. The contributions of the different factors to the growth of the value added per hour worked can be derived similar to the above.

3.3. Contributions to the growth of labor productivity per person employed

To derive the contributions to the growth of value added per person employed (growth of labor productivity in terms of persons employed), it is necessary to subtract the variation in the growth of persons employed from both sides, as follows:

$$\Delta \ln V_j - \Delta \ln L_j = \Delta \ln T_j + \bar{v}_{K,j}\Delta \ln KS_j + \bar{v}_{L,j}\Delta \ln LC_j + \bar{v}_{L,j}\Delta \ln H_j - \Delta \ln L_j$$

This expression can be manipulated similar to the previous one to get

$$\Delta \ln V_j - \Delta \ln L_j = \Delta \ln T_j + \bar{v}_{K,j}\left(\Delta \ln KS_j - \Delta \ln L_j\right) + \bar{v}_{L,j}\Delta \ln LC_j + \bar{v}_{L,j}\left(\Delta \ln H_j - \Delta \ln L_j\right)$$

Again, capital services can be divided into its two components to arrive at

$$\Delta \ln V_j - \Delta \ln L_j = \Delta \ln T_j + \bar{v}_{K,j}\left(\left(\Delta \ln KS_{ICT,j} - \Delta \ln L_j\right) + \bar{v}_{NICT,j}\left(\Delta \ln KS_{NICT,j} - \Delta \ln L_j\right)\right) + \bar{v}_{L,j}\Delta \ln LC_j + \bar{v}_{L,j}\left(\Delta \ln H_j - \Delta \ln L_j\right)$$

which expresses the growth rate of labor productivity per person employed as a function of employment growth. Note the additional term that reflects the growth differential between hours worked and persons employed, that is, the growth rate of hours of work per person employed $\Delta \ln H_j - \Delta \ln L_j$, or, expressed another way, the growth rate of average hours worked, weighted by labor participation (for example, hours worked per person employed increase faster than the number of people employed, which has a positive impact on labor productivity per person employed.)[12]

Also, note that, again, the contribution of TFP growth and the composition of work is also the same as that of hourly labor productivity growth (and value-added growth). However, the growth contribution of capital services (by asset type) differs because it is now measured in relation to people employed rather than hours worked.

12 This is consistent with the approach applied in the 2019 edition of EUKLEMS; see Stehrer *et al*. (2019).

4. Gross output growth accounting

As in the case of value-added growth accounting, the growth of gross output can also be broken down taking into account the growth of intermediate inputs (energy, materials, and services). The output function would then be

$$Y_j = f_j\left(E_j, M_j, S_j, KS_j, LS_j, T_{GO,j}\right)$$

where Y_j indicates gross output, E_j energy inputs, E_j materials, S_j services and $T_{GO,j}$ is the TFP of gross output. Labor and capital income and labor and capital services are calculated as in the approach explained above. From now on $\bar{v}_{k,j}$ indicates the Divisia proportions of the proportions of the nominal cost of the factors of production of energy (IIE), materials (IIM), services (IIS) and labor (LAB) and capital (CAP) in gross output.

4.1. Gross output growth

Using these definitions, the growth of gross output can be broken down as follows:

$$\begin{aligned}\Delta \ln Y_j = \Delta \ln T_{GO,j} + \bar{v}_{K,j}\left(\bar{v}_{ICT,j}\Delta \ln KS_{ICT,j} + \bar{v}_{NICT,j}\Delta \ln KS_{NICT,j}\right) + \bar{v}_{L,j}\left(\Delta \ln LC_j + \Delta \ln H_j\right) \\ + \bar{v}_{E,j}\Delta \ln E_j + \bar{v}_{M,j}\Delta \ln M_j + \bar{v}_{S,j}\Delta \ln S_j\end{aligned}$$

where $\Delta \ln T_{GO,j}$ indicates the growth rate of TFP of gross output.

4.2. Growth in gross output per hour worked

Similar to the foregoing, if the growth in hours worked is subtracted from both sides of the equation, we get

$$\begin{aligned}\Delta \ln Y_j - \Delta \ln H_j = \Delta \ln T_{GO,j} + \bar{v}_{K,j}\left(\bar{v}_{ICT,j}\Delta \ln KS_{ICT,j} + \bar{v}_{NICT,j}\Delta \ln KS_{NICT,j}\right) + \bar{v}_{L,j}\left(\Delta \ln LC_j + \Delta \ln H_j\right) \\ + \bar{v}_{E,j}\Delta \ln E_j + \bar{v}_{M,j}\Delta \ln M_j + \bar{v}_{S,j}\Delta \ln S_j - \Delta \ln H_j\end{aligned}$$

Rearranging the term work and using $\left(\bar{v}_{E,j} + \bar{v}_{M,j} + \bar{v}_{S,j} + \bar{v}_{K,j} + \bar{v}_{L,j}\right) = 1$ we get

$$\begin{aligned}\Delta \ln Y_j - \Delta \ln H_j = \Delta \ln T_{GO,j} + \bar{v}_{K,j}\left(\bar{v}_{ICT,j}\Delta \ln KS_{ICT,j} + \bar{v}_{NICT,j}\Delta \ln KS_{NICT,j}\right) + \bar{v}_{L,j}\Delta \ln LC_j \\ + \bar{v}_{L,j}\Delta \ln H_j \;\; \bar{v}_{E,j}\Delta \ln E_j + \bar{v}_{M,j}\Delta \ln M_j + \bar{v}_{S,j}\Delta \ln S_j \\ - \left(\bar{v}_{E,j} + \bar{v}_{M,j} + \bar{v}_{S,j} + \bar{v}_{K,j} + \bar{v}_{L,j}\right)\Delta \ln H_j\end{aligned}$$

which can be rearranged to break down ICT-linked and non-ICT-linked capital services (using $\bar{v}_{ICT,j} + \bar{v}_{NICT,j} = 1$) as follows

$$\Delta \ln Y_j - \Delta \ln H_j = \Delta \ln T_{GO,j} + \bar{v}_{K,j}\left(\bar{v}_{ICT,j}\left(\Delta \ln KS_{ICT,j} - \Delta \ln H_j\right) + \bar{v}_{NICT,j}\left(\Delta \ln KS_{NICT,j} - \Delta \ln H_j\right)\right) + \bar{v}_{L,j}\Delta \ln LC_j + \bar{v}_{E,j}\left(\Delta \ln E_j - \Delta \ln H_j\right) + \bar{v}_{M,j}\Delta\left(\ln M_j - \Delta \ln H_j\right) + \bar{v}_{S,j}\left(\Delta \ln S_j - \Delta \ln H_j\right)$$

4.3. Growth of gross output per person employed

And finally, by subtracting the growth in the number of people employed from both sides of the equation, we get

$$\Delta \ln Y_j - \Delta \ln L_j = \Delta \ln T_{GO,j} + \bar{v}_{K,j}\left(\bar{v}_{ICT,j}\Delta \ln KS_{ICT,j} + \bar{v}_{NICT,j}\Delta \ln KS_{NICT,j}\right) + \bar{v}_{L,j}\left(\Delta \ln LC_j + \Delta \ln H_j\right) + \bar{v}_{E,j}\Delta \ln E_j + \bar{v}_{M,j}\Delta \ln M_j + \bar{v}_{S,j}\Delta \ln S_j - \Delta \ln L_j$$

Rearranging the term work and using $\left(\bar{v}_{E,j} + \bar{v}_{M,j} + \bar{v}_{S,j} + \bar{v}_{K,j} + \bar{v}_{L,j}\right) = 1$ we get

$$\Delta \ln Y_j - \Delta \ln L_j = \Delta \ln T_{GO,j} + \bar{v}_{K,j}\left(\bar{v}_{ICT,j}\Delta \ln KS_{ICT,j} + \bar{v}_{NICT,j}\Delta \ln KS_{NICT,j}\right) + \bar{v}_{L,j}\Delta \ln LC_j + \bar{v}_{L,j}\Delta \ln H_j + \bar{v}_{E,j}\Delta \ln E_j + \bar{v}_{M,j}\Delta \ln M_j + \bar{v}_{S,j}\Delta \ln S_j - \left(\bar{v}_{E,j} + \bar{v}_{M,j} + \bar{v}_{S,j} + \bar{v}_{K,j} + \bar{v}_{L,j}\right)\Delta \ln L_j$$

which ultimately results in

$$\Delta \ln Y_j - \Delta \ln L_j = \Delta \ln T_{GO,j} + \bar{v}_{K,j}\left(\bar{v}_{ICT,j}\left(\Delta \ln KS_{ICT,j} - \Delta \ln L_j\right) + \bar{v}_{NICT,j}\left(\Delta \ln KS_{NICT,j} - \Delta \ln L_j\right)\right) + \bar{v}_{E,j}\left(\Delta \ln E_j - \Delta \ln L_j\right) + \bar{v}_{M,j}\Delta\left(\ln M_j - \Delta \ln L_j\right) + \bar{v}_{S,j}\left(\Delta \ln S_j - \Delta \ln L_j\right) + \bar{v}_{L,j}\Delta \ln LC_j + \bar{v}_{L,j}\left(\Delta \ln H_j - \Delta \ln L_j\right)$$

5. Architecture of the LAKLEMS database

Databases produced with the KLEMS methodology have a number of distinctive characteristics. One of the most important is disaggregation of the data by sector and the growth accounting analysis performed. Effectively, LAKLEMS seeks to examine the productive output of the different industries and their contribution to aggregate growth in Latin American countries. Several studies have shown that there is enormous heterogeneity in the growth of production and productivity across all industries, so analysis in this area must be conducted at the sector level to understand the origins of countries' growth processes. To this end, the LAKLEMS database has been created from the data provided by the countries participating in the initiative and has been processed in accordance with internationally-established procedures, in particular the EUKLEMS (2019) standards, which guarantee harmonization of basic data and allow for growth accounting to be applied in a consistent and uniform manner. It is important to highlight that this database is based on National Accounts statistics and conforms as much as possible to the framework of the System of National Accounts. This also ensures comparability of the data from the different countries, as well as with data from other international databases with similar characteristics.

The standardization of basic data from LAKLEMS countries has focused on a number of areas:

- Levels of aggregation: the level of detail of the sectors of economic activity or industries in the National Accounts statistics varies considerably between countries, variables, and periods. LAKLEMS has produced a shared industrial breakdown for all countries, made up of nine economic activities and the total aggregate.13
- Reference year for volume measurements: The countries differ when it comes to setting the base year for the volume measurements of their basic variables in the National Accounts, so standardization work has been necessary in this area. In this version of the database, all series have been built using 2011 as the reference year.
- Strategies to address breaks in series: Given the long time period covered by the database, it has been necessary to link various National Accounts series with different base years in order to build series that are consistent throughout all the years included in the database. Although standardized methodologies have been used, this task has been carried out by the working groups of each of the countries that are part of the database.

13 The number of industries available is expected to increase in the future.

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- Labor input: The database includes various types of labor input (employees, total persons engaged, hours worked, etc.).
- Labor services input: The labor services input has been measured in a standardized way, distinguishing different types of labor according to gender, age, and educational level. For these series, it has been necessary to collect additional material, since this information is not part of the System of National Accounts (SNA). In most countries, data has been used from different national surveys (most are employment or household surveys).
- Asset breakdown: Although gross fixed capital formation is part of the System of National Accounts, it does not always provide an asset classification that is detailed enough to meet LAKLEMS objectives. Despite this, an attempt has been made to ensure that the information for all the countries is as similar as possible. If this is not possible, a note for users has been added to the data files.
- Capital services input: The capital services input has been measured in a standardized way, using harmonized depreciation rates and commonly-accepted international rules. Specifically, an attempt has been made to follow whenever possible the methodology used for preparing the European KLEMS database (EU KLEMS). It is important to note that capital input is measured by capital services, not by capital stocks, although both are included in the database as independent variables.
- Total factor productivity measurements: Total factor productivity (TFP) has been generated from value added using a standard methodology developed by Jorgenson, Gollop, and Fraumeni (1987) and followed by the rest of the KLEMS databases.
- Measurements of intermediate inputs: The series on intermediate inputs are broken down into energy, materials, and services, following the typical standardized classification of KLEMS databases at the international level.
-

This section describes the coverage of the LAKLEMS database in terms of countries, industries, and the variables included in this version of it. In principle, the period covered is from 1990 to 2018, although due to data limitations, it varies from country to country and sometimes from variable to variable, as indicated below.

5.1. LAKLEMS variables and connection to National Accounts

The following five tables give an overview of all the series included in the LAKLEMS database, ordered by the worksheets they contain. The variables covered can be divided into five main groups: basic variables (production accounts and intermediate inputs), capital variables, labor input variables, and growth accounting (for Value Added and Gross Output). Each of these five groups of variables is collected in an separate file, so that five data files are prepared for each country: the basic file (***BF***) for the basic macro indicators (gross output, intermediate inputs, and added value), the capital inputs file (***CIF***) for the variables related to gross fixed capital formation and capital stock; the labor input file (***LIF***) for the variables related to employment and its structure by sector, sex, age, and educational levels; and two growth accounting files (***GAF***) for the growth accounting estimates, one for the value added or GDP (***GAFva***) and another for gross value of production (***GAFgo***).

The basic series contain all the data necessary to make individual productivity measurements, such as value added per hour worked. They include nominal, volume, and price series corresponding to production and intermediate inputs, value added, and employment. All these series are part of the current System of National Accounts and can be found in all countries' National Accounts, at least in the most recent period.[14]

The capital and labor files provide additional series that have been used to produce growth accounting: measurements of capital linked to ICT, and other assets and measurements of the various types of labor and their remuneration within the LAKLEMS classification.

The growth accounting variables in the fourth and fifth files, unlike the aforementioned, are analytical in nature and cannot be derived from published data from the National Accounts without additional assumptions. These variables include the series for capital services, labor services (quantity and composition), and total factor productivity (TFP), which are the focus and main objective of the LAKLEMS project. Assembly of these series is based on a theoretical model of production and requires additional assumptions.

14 The ISIC rev.3 classification has been used for this phase of the LAKLEMS project. However, it is important to note that in some countries the information from the national accounts was already measured in the ISIC rev.4 classification, and the information was re-estimated in ISIC rev.3. In the next stage of the project, ISIC rev. 4 will be used for all countries.

Table 1: Basic File (BF) variables

Current values (national currency)	
GO	Gross output at current basic prices
II	Intermediate inputs at current purchaser’s prices
II_E	Intermediate energy inputs, at purchaser's prices
II_M	Intermediate materials inputs, at purchaser's prices
II_S	Intermediate services inputs, at purchaser's prices
VA	Gross value added at current basic prices
COMP	Compensation
EMP	Number of persons engaged
EMPE	Number of employees
H_EMP	Total hours worked by persons engaged
H_EMPE	Total hours worked by employees
Price Index	
GO_P	Gross output, at basic prices, price indices
II_P	Intermediate inputs, at purchaser's prices, price indices
II_E_P	Intermediate energy inputs, at purchaser's prices, price indices
II_M_P	Intermediate materials inputs, at purchaser's prices, price indices
II_S_P	Intermediate services inputs, at purchaser's prices, price indices
VA_P	Gross value added at basic prices, price indices
Volume Index	
GO_QI	Gross output, at basic prices, volume indexes
II_QI	Intermediate inputs, at purchaser's prices, volume indices
II_E_QI	Intermediate energy inputs, at purchaser's prices, volume indices
II_M_QI	Intermediate materials inputs, at purchaser's prices, volume indices
II_S_QI	Intermediate services inputs, at purchaser's prices, volume indices
VA_QI	Gross value added at basic prices, volume indices

Table 2: Capital Input File (CIF) variables

Gross fixed capital formation at current prices (in national currency) [15]	
I_IT	Computing equipment
I_CT	Communications equipment
I_Soft_DB	Software
I_TraEq	Transport equipment
I_OMach	Other machinery and equipment
I_OCon	Non-residential construction
I_RStruc	Residential structures
I_Cult	Cultivated assets
I_RD	Research and development
I_OIPP	Other intellectual property products
I_GFCF	Total assets

15 Although an attempt has been made to ensure disaggregation of capital variables is the same for all countries, this has not been achieved in this edition of the database, in which two countries (the Dominican Republic and El Salvador) have not yet incorporated investment in intangible assets into their National Accounts.

Gross fixed capital formation at constant prices	
Iq_IT	Computing equipment
Iq_CT	Communications equipment
Iq_Soft_DB	Software
Iq_TraEq	Transport equipment
Iq_OMach	Other machinery and equipment
Iq_OCon	Non-residential construction
Iq_RStruc	Residential structures
Iq_Cult	Cultivated assets
Iq_RD	Research and development
Iq_OIPP	Other intellectual property products
Iq_GFCF	Total assets

Gross fixed capital formation price index	
Ip_IT	Computing equipment
Ip_CT	Communications equipment
Ip_Soft_DB	Software
Ip_TraEq	Transport equipment
Ip_OMach	Other machinery and equipment
Ip_OCon	Non-residential construction
Ip_RStruc	Residential structures
Ip_Cult	Cultivated assets
Ip_RD	Research and development
Ip_OIPP	Other intellectual property products
Ip_GFCF	Total assets

Nominal fixed capital stock, in millions of national currency	
K_IT	Computing equipment
K_CT	Communications equipment
K_Soft	Software
K_TraEq	Transport equipment
K_OMach	Other machinery and equipment
K_OCon	Non-residential construction
K_RStruc	Residential structures
K_Cult	Cultivated assets
K_RD	Research and development
K_OIPP	Other intellectual property products
K_GFCF	Total assets

Real fixed capital stock	
Kq_IT	Computing equipment
Kq_CT	Communications equipment
Kq_Soft	Software
Kq_TraEq	Transport equipment
Kq_OMach	Other machinery and equipment
Kq_OCon	Non-residential construction
Kq_RStruc	Residential structures
Kq_Cult	Cultivated assets
Kq_RD	Research and development
Kq_OIPP	Other intellectual property products
Kq_GFCF	Total assets

Additional variables	
Deprate	EUKLEMS geometric depreciation rates by asset

Table 3: Labor Input File (LIF) variables

Variables (men/women, 3 age groups, and 3 levels of education.)	
H_shares	Share of hours worked by type of job in total for each economic activity (18 types of employment)
W_shares	Share of labor compensation by type of job in total for each economic activity (18 types of employment)

Table 4: Growth Accounting File, value added variables (GAFva)

Growth of labor and capital services.	
LAB	Labor compensation (in millions of national currency)
CAP	Capital compensation (in millions of national currency)
LAB_QI	Labor services, volume, 2011=100
CAP_QI	Capital services, volume, 2011=100
Contributions to value added growth (percentage points)	
VA_Q	Growth rate of value added volume
VAConH	Contribution of hours worked to value added growth
VAConLC	Contribution of labor composition change to value added growth
VAConKIT	Contribution of ICT capital services to value added growth
VAConKNIT	Contributions to value added growth, Non-ICT capital services
VAConTFP	Contribution of the TFP to value added growth
TFPva_I	Contributions to value added growth, TFP Index, 2011=100
Contributions to value added growth, hour worked	
LP1ConLC	Contribution of labor composition change to value added growth
LP1ConKIT	Contribution of ICT capital services to value added growth
LP1ConKNIT	Contributions to value added growth, Non-ICT capital services
LP1ConTFP	Contribution of the TFP to value added growth
LP1TFP_I	Contributions to value added growth, TFP Index, 2011=100
Contributions to value added per person employed growth	
LP2ConLC	Contribution of labor composition change to value added growth
LP2ConKIT	Contribution of ICT capital services to value added growth
LP2ConKNIT	Contributions to value added growth, Non-ICT capital services
LP2ConTFP	Contribution of the TFP to value added growth
LP2TFP_I	Contributions to value added growth, TFP Index, 2011=100

Table 5: Growth Accounting File, gross output (GAFgo) variables

Contributions to Gross Output growth (percentage points)	
GOConH	Contribution to gross output (GO) growth, hours worked
GOConLC	Contributions to gross output growth, labor composition change
GOConII_E	Contributions to GO growth, energy composition change
GOConII_M	Contributions to GO growth, materials composition change
GOConII_S	Contributions to GO growth, services composition change
GOConKIT	Contributions to gross output growth, ICT capital services
GOConKNIT	Contributions to gross output growth, non-ICT capital services
GOConTFP	Contributions to Gross output growth, TFP
TFPgo_I	Contributions to Gross output growth, TFP Index (2011=100)

5.2. LAKLEMS countries

Table 6 lists the countries included in this edition of the database. The period for which each one has information is also indicated. In general, for this edition of the LAKLEMS database, the objective is to have data for the period 1990-2018.

Table 6: Countries covered by the LAKLEMS database

Country	*Period*
Chile	1990-2017
Colombia	1990-2019
Costa Rica	1991-2016
El Salvador	1990-2018
Honduras	1990-2016
Mexico	1990-2018
Peru	1990-2018
Dominican Republic	1990-2016

5.3. Industry classification and coverage

For this edition of the database, and in order to achieve a degree of homogeneity between the data from the different countries, sector information has been compiled under nine industries.[16] The industries are classified using the International Standard Industrial Classification of All Economic Activities Rev.3. Table A.1 in the Appendix provides a list of the industries.

16 The level of sector detail in the LAKLEMS database varies by country and variable due to data limitations. This minimum list of nine industries has been selected to ensure a minimum level of detail for making comparisons between countries. However, future updates to the database are expected to increase the degree of sector detail. Likewise, in the near future, the expectation is that the ISIC Rev.4 new classification of activities will be adopted as all countries incorporate it into their National Accounts.

6. Available data and compiling the statistics[17]

6.1. Output and intermediate inputs account

Panel "a" of table 1 lists all the variables considered in the LAKLEMS output and intermediate inputs account. All basic monetary variables are presented both in current values (in millions of the national currency of each country) and in constants, using volume indices, with 2011 as the base year. The indices have been obtained from the rates of annual change of variables expressed in constant terms (money chain or volumes at prices of a fixed base year) provided by the institutions responsible in each country. The price indices are derived from the nominal and volume series provided by the institutions responsible in each country, which, for the sake of convenience, were adjusted so that all countries share the same base year, 2011.

The intermediate inputs of the LAKLEMS database are divided into three groups: energy (E), materials (M) and services (S). This breakdown of intermediate inputs can be used to extend growth accounting exercises, but it also provides information of interest on the development of intermediate input patterns (see, for example, Jorgenson, Ho and Stiroh (2005), chapter 4).

Compiling the series

To obtain these series, the LAKLEMS project follows a two-step process. First, it starts from the most recent series published in the framework of the National Accounts of each country on gross output (GO), total intermediate inputs (II) and value added (VA). These series are expanded and broken down with a higher level of sector detail if necessary, using additional or complementary information. Likewise, the temporal coverage of these more recent series, which are taken as a point of reference, is also expanded by linking previous National Accounts series (with different bases, and sometimes following older SNAs). In these cases, the usual procedure is to apply the growth rates of the oldest National Accounts series to the variables of the new series in a specific link year.

For missing data, different procedures are used, as determined by the those responsible or the points of contact for each of the countries included in the LAKLEMS database. The different

[17] The sources and the treatment of the specific information on each country are presented more fully in the country-specific files, included in the database, called metadata. The information available in the countries has been detailed in the specific sections of this chapter.

procedures applied are described in the metadata files, along with the sources of information used in each case.

Aggregation of volume indices

In the case of the volume indices of the basic variables for growth accounting, for industry aggregation, we use the Törnqvist quantity index, which is a discrete temporal approximation of a Divisia index. This aggregation method uses annual moving weights based on averages from adjacent points in time. The advantage of the Törnqvist index is twofold. First, it is one of a preferred class of superlative indices (Diewert 1976). More precisely, it precisely reproduces a translog model, which is very reliable—that is, a model in which the aggregate is a linear and quadratic function of the components and of time. This is in contrast to the Laspeyres chained index, which is currently used in many National Accounts and is prone to substitution biases. In practice, however, when applied as an annual chain, the Laspeyres index is not far from the Törnqvist index as long as the growth rates are modest.[18] Second, the Törnqvist index is relatively easy to apply.[19]

Volume measurements for added value

In this database, we have chosen to use the volume indices for value added at the industry level for each country from the National Accounts of that particular country, so the methodology may differ between the different countries.

6.2. Capital account

Table 5.1 panel b presented the variables of the capital account included in the LAKLEMS database: gross fixed capital formation (GFCF) in current, constant terms, deflators of gross fixed capital formation, and capital stock in current terms and also in real or constant terms. All variables are presented broken down by asset.

In this section, we analyze three relevant issues when measuring capital services inputs: the types of assets identified, the depreciation rate used, and the treatment of negative prices for capital services.

18 Considerable differences can arise in industries or in the total that are experiencing rapid growth caused by the very nature of the industry or by extreme or unexpected events in the economy.

19 The volume data of the different industries considered are taken directly from countries' National Accounts.

Asset types

Ideally, capital inputs should be broken down into a large number of different asset types. However, while some countries (such as the US or some European countries) have detailed GFCF matrices, in Latin America, most only provide a limited array of assets, usually the one proposed by the current SNA. Therefore, and due to this problem, a minimum number of asset types has been set to which more or less all the databases of the LAKLEMS countries adhere. The minimum list includes ten types of assets (see Table A.2 in the Appendix), of which three are ICT (information and communication technology) assets: computer equipment, communication equipment, and software. Information on intangible assets (R&D and other intellectual property assets), which have recently been included as investment by the 2008 SNA, is not yet available for all Latin American countries, since in many cases, their statistics agencies are still in a period prior to full adoption of the new SNA standards, or the information on these assets is only available for the most recent years. Such is the case for Chile, El Salvador, Honduras, and the Dominican Republic in the current edition of the database, since they do not contain information on these two assets.[20]

It should be noted that only produced fixed assets are included in LAKLEMS. However, in order for the capital account to be complete, land and inventories should also be taken into consideration, since the return on capital in the National Accounts also includes the cost of using these elements. However, measurements of variations in land use and inventory quantities at the industry level are practically non-existent in most countries, and their exclusion is common practice internationally. It could be argued that changes in inventories are short-lived, with no longer-lasting trends, so their exclusion will not skew the results of the growth accounting.[21] As far as land is concerned, this is probably not true. Although it could be argued that at the level of the entire economy, the amount of land used does not change much, at the industrial level, this assumption does not hold. Furthermore, the exclusion of land can also affect estimates of the rates of return. However, in view of the current availability of data at the industry level, this problem does not seem

20 This fact must be taken into account when comparing the capital data and also the growth accounting figures for Chile, El Salvador, Honduras, and the Dominican Republic with the rest of the countries, since their database is not completely homogeneous. A note has been added to the data files highlighting this fact, so that the database users take it into account when doing their analysis.

21 Although it is easy to think that inventories were reduced, thanks to storage and orders made with the help of ICT.

like it will be easily solved in the near future. In fact, the other KLEMS databases do not include land in their capital estimates and do not plan to do so at this time.

Depreciation patterns

The LAKLEMS database takes a harmonized approach to capital measurement and uses the same asset depreciation rates for all countries. These depreciation rates differ by asset type and industry, but not by country or by time. They are based on EU KLEMS industry depreciation rates by asset type, which in turn come from the US Bureau of Economic Analysis (BEA) and are described in Fraumeni (1997). The advantage of using BEA rates is that they are based on empirical research, and not on *ad hoc* assumptions based, for example, on tax law.

Table A.2 also presents the depreciation rates used to calculate the capital stock in the framework of the LAKLEMS project.[22] The information is provided by asset and by industry.

Negative prices of capital services

As indicated above, the KLEMS methodology uses an internal (*ex post*) rate of return. This option is justified if the following assumptions are met: 1. the markets are perfectly competitive; 2. the productive function provides constant returns at scale; 3. companies pursue profit maximization; 4. the asset list is complete (in particular, land and inventories are included), and 5. the nominal rate of return is the same for all assets in an industry. Under these conditions, it is true that the factors of production earn returns based on their marginal productivity and that the sum of the costs of all assets is equal to their total return.

Using these assumptions, and using data on return on assets in each industry, the rate of return in each industry can theoretically be determined. This rate is, in turn, used to calculate the price of capital services. In practice, however, the implicit prices of capital services can be negative. In theory, these negative user costs are not necessarily incoherent (see, for example, Berndt and Fuss 1986), but they can also be an indication of empirical problems in estimating the shares represented by the return on labor and capital over the profit generated, or in the investment deflator. Most negative usage costs are the result of large fluctuations in investment deflators—for example, in residential or non-residential buildings. Others are due to very low or even negative

22 In the case of Mexico, there is no separate information on R&D assets (RD) or other intellectual property products (OIPP). To make the necessary calculations related to the capital account, the average depreciation rate of these two assets by industry has been used.

returns on capital, related to negative value added, or an excessive adjustment of the return on labor for the self-employed (for example, in the agriculture industry).[23]

Negative capital prices do not allow the aggregation method described above to be applied and therefore must be dealt with by an *ad hoc* procedure. In the LAKLEMS database, a simple heuristic rule is used and we force the cost of use to be non-negative.

Estimates of capital services growth and TFP result from the assumptions made, and it should be expected that under other assumptions they will change considerably for some industries, particularly industries with a large proportion of self-employed workers, a large proportion of real estate assets in the capital stock, and little or negative added value.

Negative capital stocks

In some exceptional cases, the capital stock may become negative due to the existence of negative investments (for example, in the case of reallocation of capital to another productive sector). In those cases, the capital stock has been set to zero.

Stock at the end of the year

In the current database, we assume that all investment made in year *t* takes place at the beginning of the year. It could also be assumed that investment is distributed throughout the year and the flow of capital services is proportional to the average stock available at the end of the current period and the previous one, as in Jorgenson, Ho, and Stiroh (2005).

Return on capital by industry

As already noted in section 4.2.2, the return on labor for self-employed workers is not usually recorded in the National Accounts. Therefore, an imputation is made assuming that the hourly compensation of the self-employed is equal to the hourly compensation of employees. This assumption is made at the industry level and may be inappropriate for some industries if the

23 **This last argument applies to many Latin American countries, and a more precise adjustment for these countries will be included in a future version of the database.**

earnings of the self-employed and employees vary considerably. Consequently, the labor compensation is sometimes higher than the value added, such that the return on capital, which is obtained as a remainder, becomes negative. In these cases, the allocation of returns between capital and labor has been reviewed with *ad hoc* procedures to avoid excessive fluctuations in this distribution from one year to the next. Normally, the return on capital is obtained by interpolation, while the return on labor is obtained from the remainder.

6.3. Labor account

This section provides information on obtaining the labor services series for the LAKLEMS database. Among the LAKLEMS basic variables (basic file, BF) are the series of the number of salaried and total employees, as well as the number of hours worked by both groups (see table 5.1). The difference between the two groups is self-employed workers and domestic labor. In addition, in the database, the labor inputs file (LIF) also offers the percentages of different types of labor in the total return on labor and in the total hours worked. Specifically, 18 groups are identified within each industry based on sex (male or female), age (16-29 years, 30-49 years and 50 or more years) and educational level (high, medium, and low). These weights are what make it possible to estimate labor services, considering both the evolution of the number of hours worked and their composition.

Comparability with National Accounts

For all countries, data from the National Accounts have been used as the main starting point to construct series on employment and hours worked. However, the National Accounts do not provide sufficient information to disaggregate the data into a large number of detailed industries, and, in some cases, they do not distinguish between employees and self-employed workers.[24]

As in the case of the basic variables, from the National Accounts, it has also been necessary to use additional data or previous base series to splice the data and extend the series backwards. In these cases, the institutions responsible for statistical data in each country have applied the most appropriate methods according to their needs and the availability of additional information. The different procedures are described in the metadata files for each country.

24 This is the case in Mexico for employment and hours worked and in Chile and the Dominican Republic for hours worked.

Hours worked versus hours paid

One of the main problems encountered when estimating hours worked is that hours vary by data source. The most reliable data is contract hours or hours paid, as this data usually comes from the employer's payroll records or other similar source. However, the measurement of hours that is of interest to measure productivity is that of hours actually worked. This measurement also includes unpaid hours and excludes hours paid but not worked. National Accounts often provides actual hours worked, and this is the definition of hours appropriate for LAKLEMS.

Data on hours worked by self-employed workers

Data on hours worked by self-employed workers are usually more difficult to obtain and not always published in the National Accounts, so this variable is not available for all the countries in the database (Chile, the Dominican Republic, and Mexico do not keep track of this information). However, to carry out some of the calculations associated with the growth accounting methodology, it has been necessary to estimate them.

Workforce composition

To calculate the series on labor services inputs, data on hours worked and compensation by type of labor are needed. In most countries, the basic source for this type of data is national employment or household surveys (see the metadata files for each country). However, these surveys often have a limited sample size and are not sufficiently representative in the case of some industries, especially the smaller ones, so the weights may present significant interannual variations, and the results should be viewed with caution. The possibility of obtaining a greater degree of detail in the future will depend to a large extent on the evolution of the size of the survey samples.

Self-employed workers vs. employees

For almost all countries, data by type of workforce is only available for employees, not for the self-employed. In this version, it is assumed that the job characteristics of the self-employed and employees are the same within an industry. For most industries, deviations outside this assumption will have a negligible effect. However, for industries with a large number of self-employed workers, such as agriculture or retail, this assumption could pose more problems. In a future version of the project database, this assumption will be adjusted.

Compensation data

Data on compensation by age, sex, and education level are often available from the same national surveys mentioned for the labor force, and at the same level of detail. In some cases, the time series for compensation is shorter than for the number of people employed. In such cases, it has been assumed that the relative levels of compensation did not vary over time.[25]

Income of the self-employed

To apply the methodology set out at the beginning of this section, data must be available on the income of self-employed workers, since this is the only way to obtain the total compensation corresponding to the labor factor. Currently, labor compensation (the LAB variable in the database) is derived by applying the relationship between the hours worked by the total number of engaged persons and those worked by employees to the compensation of employees. Therefore, the assumption that is being used in most of the KLEMS projects is that the compensation of the self-employed is equal to the compensation received by employees.[26] This is also the assumption applied to estimate the total compensation for work in the LAKLEMS database.

In the case of Chile and the Dominican Republic, the hours worked by employees are not available, so the estimate is made based on the ratio of the number of total persons engaged to the number of payroll employees. In the case of Mexico, there is no information on employees, neither in number nor in hours, so it is not possible to use an estimate based on information from that country. For Mexico, the factor for correcting employee compensation is estimated using the sector information of Costa Rica, the country most similar to Mexico in this regard, and an

25 This is the case for the Dominican Republic in the years between 1990 and 1999.

26 A preliminary analysis carried out for European countries within the framework of the EU KLEMS project indicates that the compensation of a self-employed person is lower in industries such as agriculture and retail, but is at least as high in other sectors such as business services.

estimate[27] provided by the INEGI (National Institute of Statistics and Geography of Mexico) for the total economy.[28]

Comparability of educational level between countries

The definitions of high, medium and low level of education[29] are consistent over time for each country, but may vary slightly from one country to another, depending on the differences in education systems in Latin America. Consequently, care must be taken when comparing proportions of educational attainment across countries.

6.4. Growth accounting accounts

As explained, for all of our output and input aggregations across industries, we use the Törnqvist quantity index, which is a discrete temporal approximation of a Divisia index. This approach is similar to that of Jorgenson, Gollop, and Fraumeni (1987, Chapter 2). Additionally, all individual growth rates are measured in natural log differences.

Input proportions

The input weights for the labor and capital factors of production should reflect the marginal cost of using labor and capital, respectively. These can be based on components of the added value that appear in the National Accounts. The following definition is used in the National Accounts: The value added at basic prices is equal to the labor compensation of employees (the COMP variable in the database) plus the operating surplus and mixed income[30] plus other taxes on production: $\boldsymbol{P_j^V V_j = LC_j^E + OS_j + T_j^O}$, with $\boldsymbol{LC_j^E}$ being the compensation of employees, $\boldsymbol{OS_j}$ the gross operating surplus together with mixed income, and $\boldsymbol{T_j^O}$ being taxes. The sum of the operating surplus and mixed income must be separated into the compensation of self-employed workers ($\boldsymbol{LC_j^S}$)—which

27 The results of this work were presented at the fifth WORLD KLEMS Conference, held in June 2018. See https://scholar.harvard.edu/jorgenson/world-klems-2018 for more information on this.

28 This estimate assumes a differential factor with respect to the KLEMS accounts published by INEGI on its website for Mexico. See https://www.inegi.org.mx/programas/ptf/2013/ for more information on this.

29 The educational levels contemplated are defined as follows: high level of education includes university/higher technical education; medium level of education refers to secondary school; and low level of education refers to primary or lower education.

30 *Mixed income refers to income earned by self-employed workers. One part of it corresponds to the return on the labor factor, while another corresponds to the return on capital used in carrying out the productive activity.*

is part of return on labor—and the remainder, which must be assigned to the return on capital. Similarly, the other taxes on production should be assigned to capital and labor inputs: ($\boldsymbol{T_j^O} = \boldsymbol{T_j^K} + \boldsymbol{T_j^L}$). Thus, labor costs (LAB variable in the database) and capital costs (CAP) are defined as follows:

$$LAB = P_j^L L_j = T_j^L + LC_j^E + LC_j^S$$

$$CAP = P_j^K K_j = T_j^K + OS_j - LC_j^S$$

The allocation of the other taxes on production to labor and capital is not straightforward, since they consist of a series of taxes on property and land use, taxes on the use of fixed assets, taxes on total payroll, license taxes, pollution taxes, etc. In the absence of detailed knowledge on the different types of taxes and their frequency, the default option is to assign taxes on production to the return on capital, that is, $\boldsymbol{T_j^O} = \boldsymbol{T_j^K}$.

As already noted previously, the return on labor for self-employed workers is not always recorded in the National Accounts. Therefore, an imputation is made assuming that the hourly compensation of the self-employed is equal to the hourly compensation of employees. This assumption is made at the industry level, although as was noted, it may be inappropriate for some industries where the characteristics of the self-employed vary considerably from those of employees. This assumption will be analyzed in a future version of the LAKLEMS database.

Caveats for some industry-level productivity measures

In the LAKLEMS database, measurements of Total Factor Productivity (TFP) growth are provided for all industries spanning the total economy. However, the user should be aware of some specific limitations related to the interpretation of the results of some industries. In particular, the following must be taken into account:

- Land assets and natural resources are not included. TFP measurements for industries such as agriculture (AtB) and mining (C) must be interpreted from this perspective. Also, surely for this reason, the return on capital in these industries is often negative, indicating that capital assets do not contribute to growth, which is unlikely for long periods of time.

- A special element of the System of National Accounts is the imputation of owner-occupied dwellings. They are normally imputed to the leasing production activities of the real estate industry. From a productivity point of view, this is improper. First, it poses problems for making international comparisons, because the methods for imputing rents vary from country to country. Second, this output is measured as input (owner-occupied residential building services) and, therefore, productivity growth is zero by definition. Third, it is not clear to what extent the residential housing investment series distinguish between owner-occupied and rented housing, and how these flows are recorded between industries and private households. The most appropriate thing would be to handle the production derived from the allocated rents separately, taking into account only the services inputs from the buildings occupied by their owners. This would require a breakdown of investment in residential buildings by institutional sector (or at least the household sector versus others), which, unfortunately, very few countries have adequately available in their statistics. Consequently, and as in other KLEMS databases, in LAKLEMS these rents have been allocated to the real estate industry. Thus, comparisons of the productivity of this industry must be interpreted with caution and, precisely for this reason, this sector is frequently omitted in productivity calculations and analyses.

7. References

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8. Appendix Tables

Table A.1 - List of sectors (ISIC rev3)

code	desc
TOT	Total Industries
AtB	Agriculture, Hunting, Forestry, and Fishing
C	Mining and Extraction
D	Total Manufacturing
E	Electricity, Gas, and Water
F	Construction
GtH	Retail, Hotels, and Restaurants
I	Transportation, Storage, and Communications
JtK	Finance, Insurance, Real Estate, and Business Services
LtQ	Social Community and Personal Services

Source: LAKLEMS.

Table A.2 - Types of assets and depreciation rates

Assets included in the LAKLEMS database

code	desc
IT	Computing equipment
CT	Communications equipment
Soft	Software
TraEq	Transport equipment
OMach	Other machinery and equipment
OCon	Non-residential construction
RStruc	Residential structure
Cult	Cultivated assets
DR	Research and development
OIPP	Other intellectual property products
GFCF	Total assets

Source: LAKLEMS.

Depreciation rates

	Rstruc	Ocon	TraEq	Omach	IT	CT	Cult	Soft	DR	OIPP
TOT	0.011	0.032	0.189	0.131	0.315	0.115	0.200	0.315	0.200	0.131
AtB	0.011	0.024	0.170	0.129	0.315	0.115	0.179	0.315	0.200	0.129
C	0.011	0.033	0.174	0.108	0.315	0.115	0.207	0.315	0.200	0.108
D	0.011	0.023	0.191	0.094	0.315	0.115	0.207	0.315	0.200	0.094
E	0.011	0.023	0.191	0.094	0.315	0.115	0.207	0.315	0.200	0.094
F	0.011	0.034	0.195	0.139	0.315	0.115	0.195	0.315	0.200	0.139
GtH	0.011	0.029	0.165	0.124	0.315	0.115	0.188	0.315	0.200	0.124
I	0.011	0.028	0.203	0.140	0.315	0.115	0.188	0.315	0.200	0.140
JtK	0.011	0.040	0.182	0.132	0.315	0.115	0.187	0.315	0.200	0.132
LtQ	0.011	0.035	0.195	0.145	0.315	0.115	0.210	0.315	0.200	0.145

Source: EUKLEMS.