EUKLEMS & INTANProd: industry productivity accounts with intangibles

Sources of growth and productivity trends:
methods and main measurement challenges

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1. Introduction

EU KLEMS & INTANProd is a new database, funded by the Directorate General for Economic and Financial Affairs (DG-ECFIN) of the European Commission, for productivity analysis that updates previous editions of the EU KLEMS database and extends them with productivity estimates that incorporate measures of intangible investment from INTAN Invest.[1]

This report provides an overview of the database and summarizes the methods used to develop growth accounting variables and estimates of intangible investment.

EU KLEMS & INTANProd is the first cross-country productivity database including all intangible assets proposed by Corrado, Hulten and Sichel[2] in a harmonized framework coherent with national accounts, thus representing a significant advancement for productivity analysis and policymaking.

The database provides data for 27 European countries, United Kingdom, United States and Japan across 42 industries and 15 industry aggregates[3] for 1995-2020. The Japanese data are kindly supplied by RIETI institute and Hitotsubashi University[4] and data for Belgium are generated with the support from the Federal Planning Bureau. The Instituto Valenciano de Investigaciones Económicas (IVIE) has provided gross fixed capital formation (GFCF) and capital stocks data for Spain since the first EUKLEMS release to supplement the lack of official data and kindly contributed to both releases of EUKLEMS & INTANProd.

The EU KLEMS & INTANProd database is organized in two modules: a **statistical** module, a repository of all the key variables for industry-level productivity analysis sourced directly from the national accounts of individual countries; an **analytical** module that complements these data

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[1] The procurement procedure ECFIN/2020/OP/0001 – Provision of Industry level growth and productivity data with special focus on intangible assets – 2020/S 114-275561 provided funds for the new database. For information about past releases of EU KLEMS see www.euklems.net, van Ark, O'Mahony and Timmer (2008), and Timmer, Inklaar, O'Mahony and van Ark (2010) and https://euklems.eu/ by the Vienna Institute for International Economic Studies (wiiw). For more information about INTAN Invest see www.intaninvest.net.

[2] See Corrado, Hulten and Sichel (2005, 2009).

[3] Industry detail and coverage vary over time and across countries. Detailed information for each country is available on the website: https://euklems-intanprod-llee.luiss.it/

[4] Data and documentation about Japanese estimates of intangibles are available at: https://www.rieti.go.jp/en/database/JIP2021/index.html

with information on investment and capital stocks for intangible assets that are not included as gross fixed capital formation in official national accounts. The analytical module contains ongoing improvements on estimates of intangibles and growth accounting with intangibles. Some of the most recent developments include the following:

1. The harmonized estimates for intangible assets are now generated for 38 NACE industries versus 19 industries of the INTAN-Invest database. Measures of intangible assets are available for 12 manufacturing industries as well as for selected service sectors (wholesale and retail trade, transport, professional services, and health) now expanded to provide larger industry detail.
2. Intangible investment by asset covers purchased and own-account components for all asset types.
3. Real intangible investment incorporates price deflators based on closely aligned services output. A deflator for investment in brand and marketing research was developed from input price indexes for content development and production costs, internet advertising, and traditional media advertising. Information and communication technology (ICT) assets in volume terms reflect price deflators whose product quality change component is harmonized across countries, based on the methodology developed by Schreyer (2002) and widely used since then, including in the first EUKLEMS release.
4. The analytical module provides harmonized capital stocks for all tangible and intangible assets based on geometric depreciation.
5. The analytical growth accounting also incorporates bottom-up aggregations for the market sector excluding agriculture and for the total economy for a selected number of countries.

The report also addresses any major foreseeable gaps or breaks in the update of the database, or any major problem related to the availability of source or benchmark data, focusing on issues affecting a relevant number of countries or industries. Finally, alternative approaches to fill the data gaps are suggested resorting to country-specific data sources and indicators.

The report is organized as follows: section 2 illustrates the structure and content of the statistical module providing detailed information on the sources and methods adopted to compute labor and capital inputs and the growth accounting variables. Section 3 provides an overview of the analytical module, including the sources and methods for measuring non-national accounts intangibles and for expanded sources of growth model.

2. Statistical module

The statistical module collects existing official national accounts data, consistently with previous EU KLEMS releases, and organizes them for developing productivity analysis. Value added, gross output, employment and labour compensation data are included in the "national accounts" database, while capital stocks and investment (gross fixed capital formation, GFCF) are in the "capital accounts" database. In addition, the "labour accounts" database provides estimates of the shares of employment and labour compensations by type of workers in each industry needed to estimate the labour input in the growth accounts. The construction of national and capital accounts for the European countries [5] is organized around three main steps:

1) The collection of official national accounts data at current and previous year prices from Eurostat or national statistical offices for non-European countries at the maximum level of industry disaggregation.

2) The computation of the aggregates of interest at current and previous year prices for the total economy and all the desired intermediate levels of (dis-)aggregation adding up detailed industry-level data.

3) The calculation of chain-linked volumes and price indices individually for each level of industry aggregation considering 2015 as the reference year consistently with current practice in European official national accounts.

The main data sources for the statistical module for the European countries are annual national accounts from Eurostat (National accounts (ESA 2010) (na10)). Data for the US are from the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS); while UK data are generated resorting to the OECD annual national accounts database integrated with data from the UK Office for National Statistics (ONS).

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[5] The procedure of the US is different as chained-volume series for aggregate industries and asset classes are obtained using Fisher quantity indexes, consistently with the official national accounts methodology.

The coverage of the variables included in the national accounts database for EU countries is generally exhaustive for all variables but gross output in volume terms. For countries not reporting gross output in volume terms, corresponding deflators have been computed using price indexes gathered from the following sources:

- National Statistical Institutes;
- the OECD STructural ANalysis (STAN) industry database;
- Official Supply and Use Tables (SUT) from Eurostat to estimate gross output in volume terms for the time series starting in 2010. Data for the years 2000-2009 have been produced with the deflators provided by the latest release of the World Input-Output Database (WIOD).

Gross output at previous year prices has been calculated following the general method described above, whereas intermediate consumption at previous year prices has been derived as a residual.

The next sections describe methods and main sources used for computing labor and capital inputs for productivity accounts.

2.1. Labour accounts

The labour service input has two components: labour quantity and labour quality. The labour quantity is measured by employment variables included in national accounts: number of persons employed, number of employees, total hours worked by persons engaged and total hours worked by employees. Labor quality aims at capturing the different composition of the workforce considering workers' characteristics likely affecting their productivity contribution[6] and must be estimated. In particular, and consistently with prior EUKLEMS releases, the labour accounts include the shares of employment and labour compensation by type of worker cross-classified by gender, age, and educational attainment by industry. We distinguish eighteen worker types within each country, industry, and year. Worker types are also classified by gender categories (male, female), age categories (15-29 years; 30-49 years; 50 years and higher), and educational qualifications levels (high, medium, and low).

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[6] An hour worked by a young un-skilled person does not usually have the same economic value that an hour worked by a highly qualified highly experienced person.

Data sources

As a consequence, data on employment and wages are gathered cross-classified by industry, age, gender, and level of education. Such information is not available through public data sources and has to be estimated from micro data. The main source for European countries (including UK) are Eurostat Labour Force Survey (LFS) and Structure of Earnings Survey (SES).

The LFS provides detailed information on the number of hours worked by each person in the survey, along with their characteristics in terms of gender, age, educational attainment, and sector of economic activity (NACE rev.2). We use this information to compute employment shares which we then apply to national account's information on total hours worked and total number of people engaged as shown in our growth accounting procedure detailed below.

The SES provides information on the earnings of European workers as well as their gender, age, educational attainment, and sector of economic activity. The main variable of interest is the mean annual gross earnings including all payments workers receive on top of their monthly wage, such as bonuses and other benefits. The amount of such additional income is likely to vary across educational attainment, gender, age and economic sector. Thus, annual earning is considered a better measure of relative compensation levels across different worker types than weekly or monthly earning.[7] We also follow Eurostat's methodology[8] to account for part-time work and the varying number of working weeks across workers and double-check that our procedure generates publicly available estimates made available by Eurostat. We then compute total wages for each type of worker in each country and industry by multiplying the mean annual gross earning from the SES by the corresponding number of persons employed from the LFS. Finally, we transform wages by industry and type of worker in the wage shares included in the labor input database. In the growth accounting calculation, we use these shares to compute the share of each worker type in labor compensation.

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[7] Previous EUKLEMS releases based their calculation on weekly earnings, then EUKLEMS 2019 used wage shares from the previous EUKLEMS release. Older EUKLEMS editions, such as EUKLEMS 2017 used 2010 SES microdata plus aggregate Eurostat tabulations of 2014 SES.

[8] Structure of Earnings Survey 2014, Eurostat's arrangements for implementing the Council Regulation 530/1999, the Commission Regulations 1916/2000 and 1738/2005

For the US, wage and employment shares for total economy have been provided by the BLS, Industry Productivity Studies.[9]

Dealing with missing data and outliers in labor accounts

The SES microdata with NACE Rev. 2 industry classification are available only for reference years 2010, 2014 and 2018. Therefore, we have produced wage shares time series from 2008 to 2020, interpolating missing years based on alternative indicators (depending on data availability): employment shares derived from the LFS, EUKLEMS 2019 wage shares or linear interpolation. We have imputed missing values in the employment shares using the same approach.

In order to deal with outliers, we have also smoothened employment and wage shares. Our assumption is that large jumps in the shares' growth rates are due to measurement errors, sampling problems, or lack of comparability across different waves of the surveys. We considered 2018 shares as our benchmark, and we applied a winsorisation-like procedure to smooth yearly variations higher than 1.4 or lower than 0.7.[10]

The issue of lack of comparability across different waves of the surveys is particularly acute for the years before 2011.[11] As a result, and to be consistent with previous EUKLEMS releases, we have used the growth rates from EUKLEMS 2019 as indicators to backcast 2011 to 2008.

Industry detail in the LFS and SES is restricted to one-digit NACE Rev. 2 and thus data in the labour input database are only disseminated at that level of industry detail. Then to generate growth accounting results at lower levels of aggregation, we assumed that labour characteristics do not vary widely across closely related industries, and we imputed one digit shares to two digits level.

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[9] Data have been kindly provided by Corby Garner.

[10] More precisely we edited growth rates of employment and wage shares as follows. Let $HS_{l,j,t}$ be the share for workers type l in industry j at time t and $varHS_{l,j,t} = HS_{l,j,t} / HS_{l,j,t-1}$. If $varHS_{l,j,t} > 1.4$ then $adj\_varHS_{l,j,t} = varHS_{l,j,t}*0.25 + 1.4*0.75$. If $varHS_{l,j,t} < 0.7$ then $adj\_varHS_{l,j,t} = varHS_{l,j,t}*0.25 + 0.7*0.75$.

[11] Data for 2008 are still in NACE Rev. 1 and in 2011 there was a change in the ISCED classification (from ISED 1997 to ISED 2011).

2.2 Capital accounts

The estimate of capital input is based on national account capital stock and investment (gross fixed capital formation, GFCF) cross-classified by industry and asset type. In the statistical module, net capital stocks are gathered directly from national accounts, and capital services are computed for growth accounting purposes, as illustrated in the section below.

Data sources

The main data source for measuring GFCF and capital stocks for the European countries is the database "Cross-classification of gross fixed capital formation by industry and by asset (flows) [nama_10_nfa_fl]" from Eurostat. However, the availability of disaggregated data coherent with the EUKLEMS industry and asset disaggregation is quite limited[12].

Data for the US are gathered from BEA, mainly from the database Detailed Data for Fixed Assets and Consumer Durable Goods for the private sector and from Fixed Assets Accounts Tables for Government.

Dealing with missing data in capital accounts

The asset coverage for GFCF data might be incomplete as many statistical institutes do not release disaggregated data by asset and by industry as required by EUKLEMS & -INTANProd classifications. The major gaps are for IT and CTassets, that are missing for several contries. Among them, there is Spain, for which the data with the required assets detail are provided by the IVIE. Additionally, also Germany and Denmark do not release data for information technology (IT) and communication technology (CT) by industry, and Denmark publishes only Intellectual Property Products (IPP) as an aggregate by industry. To fill these gaps, EUKLEMS & INTANProd generates estimates of assets not available by industry combining Eurostat data with previous EUKLEMS estimates while for Germany with country-specific data.[13] The basic rule of our approach is, to regularly update the matrix of GFCF in machinery and equipment cross-classified by industry and asset (IT, CT, Traeq and Omach) from the previous EUKLEMS release with an

[12] Only six countries report GFCF for all asset types for 64 industries (A64, which is the level of detail needed to cover all the industries of the EUKLEMS industry classification). Germany reports GFCF and capital stocks data to Eurostat only for 21 industries (corresponding to the A21 classification of national accounts) but disseminates highly disaggregated data by industry on the NSI's website (for machinery and equipment, construction and other assets, with no further asset detail). Only 15 countries provide some information at the A64 level; out of them, only nine provide GFCF for all or almost all asset types.

iterative bi-proportional fitting procedure using totals by industry and asset from the Eurostat database as rows and columns control totals.[14] For Denmark, we use the same approach also to get estimates of Soft_DB, RD and OIPP.

Among intellectual property products (IPP), the third category beyond computer software and databases (Soft_DB) and research and development (RD), labelled as OIPP (i.e. other intellectual property products), is obtained as a residual (IPP minus Soft_DB minus RD). There are cases where the calculation generates negative values, thus requiring some adjustment. Therefore for some countries-industries, the sum of (OIPP+Soft_DB+RD) does not exactly equal IPP from national accounts.

2.3 Theoretical framework: standard growth accounting

The theoretical framework underlying the growth accounting model has its roots in the seminal contributions of Jorgenson and Griliches (1967) and Jorgenson et al. (1987).[15] In the statistical module, the methodology follows closely the approach adopted since the first EUKLEMS release.[16]

General approach

In the standard growth accounting model, value-added growth in volume terms is decomposed into the contribution of capital, labor services and total factor productivity growth as:

$$\Delta \boldsymbol{lnV_j} = \overline{\boldsymbol{v}}_{\boldsymbol{L,j}} \Delta \boldsymbol{lnL_j} + \overline{\boldsymbol{v}}_{\boldsymbol{K,j}} \Delta \boldsymbol{lnK_j} + \Delta \boldsymbol{lnTfp_j} \qquad (\mathbf{1})$$

where j denotes the industry, Δln denotes logarithmic growth rate, V_j is value added in volume terms, Tfp_j is total factor productivity, L_j are labor services, K_j are capital services, and $\bar{v}_{L,j}$ and $\bar{v}_{K,j}$ are, respectively, year t and t-1 averages of the share of labour and capital compensation in value added at current prices.

From equation (1) we can rearrange and compute TFP growth as a residual as follows:

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[14] A detailed description of the imputation procedure is available from the authors on request.

[15] Extensive surveys of the growth accounting methodology include Jorgenson (2005) and Hulten (2010).

[16] For more detailed information on the EUKLEMS approach to growth accounting, see O'Mahony and Timmer (2009) and the literature cited therein. Consistently with the most recent EUKLEMS releases, we calculate value-added based productivity, while the first EUKLEMS releases adopted the full KLEMS approach, using gross output and all five major input factors (K-L-E-M-S).

$$\Delta lnTfp_j = \Delta lnV_j - \bar{v}_{L,j}\Delta lnL_j - \bar{v}_{K,j}\Delta lnK_j \qquad (2)$$

Labour and capital compensations

Labour compensation (the variable *LAB* in the database) is obtained as the sum of compensation of employees and an imputation for the compensation of self-employed. Compensation of employees is available from the national accounts module (*COMP*), while labour compensation of self-employed is computed assuming that their compensation per hour is equal to the compensation per hour of employees:

$$LAB_j = COMP_j + (COMP_j / HEMPE_j) * (HEMP_j - HEMPE_j) \qquad (3)$$

Where $HEMP_j$ and $HEMPE_j$ are, respectively, total hours worked by persons engaged and by employees.

Capital compensation (*CAP*) is then derived as value added minus labour compensation.

Capital services

Capital services, ΔlnK_j, are estimated with a two-stage method. First, we compute the volume of the services provided by each type of asset (i.e., its productive capital stock) and the corresponding asset price (i.e., its user cost); then, the second step entails the calculation of an aggregate measure of the productive contribution of the different types of assets (i.e., of the aggregate flow of capital services). Consistently with previous EUKLEMS releases, we adopt the standard neoclassical approach that provides a coherent and comprehensive framework for measuring capital services.

The flows of capital services provided by each asset type are not observable and must be estimated by a proxy. The standard practice assumes that the service flows in volume terms are proportional to the capital stock in volume terms. Then, the cost of using one unit of the services provided by that asset, its user cost, $p_{K,k,j,t}$,is obtained as:

$$p_{K,k,j,t} = p_{I,k,j,t-1} i_{j,t} + \partial_{k,j} p_{I,k,j,t} - (p_{I,k,j,t} - p_{I,k,j,t-1}) \qquad (4)$$

Where $p_{I,k,j}$ is the investment price index for asset type k in industry j, i_j is the nominal rate of return in industry j, and $\partial_{k,j}$ is the asset type k's geometric depreciation rate in industry j.

In EUKLEMS & INTANProd the nominal rate of return is measured as an endogenous (or internal) rate adopting the assumption that the remuneration of capital services exhausts total non-labor income measured from national accounts (gross operating surplus plus an imputation for the component of gross mixed income attributed to capital). If this equality holds, given the estimates of total income and productive capital stock and the other components of user-cost for each asset, the rate of return can be computed residually. Depreciation rates for national accounts assets are the same as in previous EU KLEMS releases except for R&D, which are based on depreciation rates used by the BEA, while for non-national accounts assets the rates are the same as in INTAN-Invest database (see Table A1 in the appendix). Finally, the capital gains-losses are computed on the basis of the implicit GFCF deflator for each asset. To reduce negative user costs, the capital gains-losses are smoothed by means of a moving average of the growth rate of investment deflator at t-1, t and t+1.

Then, the flows of capital services provided by different types of assets are aggregated to get a volume index of total capital services, ΔlnK_j.[17] The aggregation procedure uses the Tornqvist index, and the weights are the average shares of each asset in the value of capital compensation:

$$\Delta lnK_j = \sum_k \bar{v}_{K,k,j} \Delta lnK_{k,j} \qquad (5)$$

where $K_{k,j}$ denotes the capital stock in volume terms of asset type k in industry j and $\bar{v}_{K,k,j}$ represents the (average of year t and t-1) share of asset type 'k's compensation in capital compensation. For each asset k, capital compensation is calculated as its productive capital stock times the corresponding user cost, where the asset share is defined as:

$$v_{K,k,j} = \frac{p_{K,k,j} K_{k,j}}{\sum_k p_{K,k,j} K_{k,j}} \qquad (6)$$

where $p_{K,k,j}$ is the user cost of asset k in industry j.

[17] In the EUKLEMS & INTANProd database the volume index of capital services is published as index equal to 100 in 2015 (*CAP_QI*).

Labor services
As for capital services, labor services aim at capturing the changes in the quantity and quality of labor input over time. Consistently with previous EUKLEMS releases, we assume that the labor force is divided into different worker types based on age, gender, and educational attainment, as described above. We further assume that each worker type's flow of labor services is proportional to the number of hours worked, and workers are paid their marginal productivity. On this basis, the flow of labor services is computed by aggregating volume indexes of individual categories using a Tornqvist index and weighting them with the average shares of each type in labor compensation:

$$\Delta lnL_j = \sum_l \bar{v}_{L,l,j} \Delta lnH_{l,j} \qquad (7)$$

where $H_{l,j}$ is type l labour input in industry j measured as hours worked and $\bar{v}_{L,l,j}$ is the corresponding (average of year t and t-1) share in industry 'j's labour compensation.[18] For each worker's type l, labor compensation is calculated as its worked hours times the corresponding hourly wage rate, and the share in labour compensation is:

$$v_{L,l,j} = \frac{p_{L,l,j} H_{l,j}}{\sum_l p_{L,l,j} H_{l,j}} \qquad (8)$$

where $p_{L,l,j}$ is the hourly wage of workers type l in industry j.

Labor services breakdown
The flow of labor services can be split into two components: hours worked and labour composition. Data on hours worked are available from the national accounts module (*H_EMP*), so that (delta log of) labour composition (*LC*) in industry j can be calculated as:

$$\Delta lnLC_j = \Delta lnL_j - \Delta lnH_{EMP\,j} \dots\dots\dots..(9)$$

The contribution of labor input to value added growth can thus be decomposed into the contribution from changes in hours worked (*VAConH*) and changes in the composition of hours worked (*VAConLC*) by multiplying the delta log of hours worked and labour composition components for the share of labour compensation in value added as:

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[18] In the EUKLEMS & INTANProd database the volume index of labour services is published as an index equal to 100 in 2015 (*LAB_QI*).

$$VAConH_j = \bar{v}_{L,j} \Delta lnH\_EMP_j \qquad (10)$$

$$VAConLC_j = \bar{v}_{L,j} \Delta lnLC_j \qquad (11)$$

Capital services breakdown

The additive structure of the Tornqvist index allows calculating the breakdown of total capital contribution into the contributions from different asset groups. In EUKLEMS & INTANProd statistical module, the contributions of capital services are distinguished between tangible non-ICT (*VAConTangNICT*), tangible ICT (*VAConTangICT*), and intangibles (*VAConIntang*) contributions to value added growth.[19]

In the statistical module, capital services are broken down as listed in Table 1 below:

Table 1 - Capital services breakdown in the statistical module

TangICT	IT - Computer hardware
	CT - Telecommunications equipment
TangNonICT	Rstruc - Dwellings
	Ocon - Other buildings and structures
	Traeq - Transport equipment
	Omach - Other machinery and equip. &weapons
	Cult - Cultivated biological resources
Intang	RD - Research and development
	Soft_DB - Computer software and databases
	OIPP - Entertain.& Artistic Originals

The volume index of the flow of capital services from each asset group is computed by aggregating across productive stocks of the assets included in that group using the Tornqvist index with weights equal to the share of each asset in the value of total cost capital services from that asset group.

[19] Capital services are published in the database as indexes equal to 100 in 2015 (*CAPNICT_QI*, *CAPICT_QI* and *CAPIntang_QI*). Total capital contribution to value added growth can be easily calculated as the sum of *VAConTangNICT*, *VAConTangICT* and *VAConIntang*.

As an example, the (delta log of) volume index of the flow of capital services from intangible capital (CAPIntang) is obtained as:

$$\Delta lnCAPIntang_j = \sum_{kint} \bar{v}_j^{kint} \Delta lnK_j^{kint} \quad \dots\dots\dots (12)$$

where K_j^{kint} is capital stock in volume terms of intangible asset type *kint* in industry j, $\bar{v}_j^{kint}$ is the (average of year t and t-1) share of intangible asset type *'kint's* compensation in intangible capital compensation and *kint* = Soft_DB, RD and OIPP. For each intangible asset in *kint*, the capital compensation is calculated as its productive capital stock times the corresponding user cost, and the asset share in intangible capital compensation is:

$$\bar{v}_j^{kint} = \frac{p_j^{kint} \Delta lnK_j^{kint}}{\sum_{kint} p_j^{kint} \Delta lnK_j^{kint}} \qquad (13)$$

where p_j^{kint} is the user costs of intangible asset *kint* in industry j.

Each asset 'group's contribution to value added growth is calculated as the logarithmic growth rate of that 'group's capital services multiplied by the value-added share. For instance, the intangible capital contribution to value added growth is

$$VAConIntang_j = \bar{v}_j^{kint} \Delta lnCAPIntang_j \qquad (14)$$

where $\bar{v}_j^{kint}$ is the year t and t-1 average of the share of intangibles capital compensation in value added.

The growth accounting equations

EUKLEMS & INTANProd provides a full decomposition of value added growth into six elements as follows (using the above formulas and notations):

$$\Delta lnV_j = \bar{v}_{L,j} \Delta lnH_j + \bar{v}_{L,j} \Delta lnLC_j + \bar{v}_j^{ktang} \Delta lnKTangICT_j + \bar{v}_j^{ktangNICT} \Delta lnKTangNICT_j + \bar{v}_j^{kint} \Delta lnKIntang_j + \Delta lnTfp_j \qquad (15)$$

Subtracting the growth rate of hours worked from both sides of equation (15) we get a decomposition of labour productivity (measured as value added in volume terms per hour worked) growth into the contributions from capital services per hour worked, the labor composition effect, and TFP growth (calculated as a residual and equivalent to the estimate obtained from the growth accounting decomposition of value added growth).

By referring to the variable labels in the database, the growth accounting equation for value added growth for industry j can be written as:

$$VA\_G_j = VAConH_j + VAConLC_j + VAConTangICT_j + VAConTangNICT_j + VAConIntang_j + VAConTFP_j \quad (16)$$

The growth accounting equation for labour productivity[20] growth is instead:

$$LP1\_G_j = LP1ConLC_j + LP1ConTangICT_j + LP1ConTangNICT_j + LP1ConIntang_j + LP1ConTFP_j \quad (17)$$

Implementation issues

To guarantee continuity with the most recent EUKLEMS releases, in the statistical module we use capital stocks data provided by national statistical institutes (NSIs). However, this creates some inconsistencies across growth accounting variables. Depreciation rates assumed by the NSIs can be different from the depreciation rates we use in our calculations to derive capital services. Therefore, capital stock measures are not entirely consistent with our measures of return rates, user costs, and capital services. Besides, capital stocks available from national accounts are net stocks (a measure of wealth), while productivity calculations should use productive stocks (a measure of productive capacity). Net and productive stocks, although related to each other, are generally different, and they coincide only if calculated according to the geometric depreciation model.

Although smoothing the capital gains component reduces their occurrence, the standard user cost calculation described above might generate some negative values. If these negative user costs do occur, they are replaced with a value close to zero, and the capital compensation for the corresponding assets based on the new user cost is recalculated. Then capital compensation of all assets is rescaled to guarantee that the sum is equal to total capital compensation.

Another issue is the occurrence of negative values of capital compensation when the estimated labour compensation is higher than value added. This is more likely to happen in highly subsidized industries or where self-employed are a very large share of employment. If negative values of *CAP*

[20] Measures of labor productivity are computed both in terms of hours worked (LP1) and number of employees (LP2).

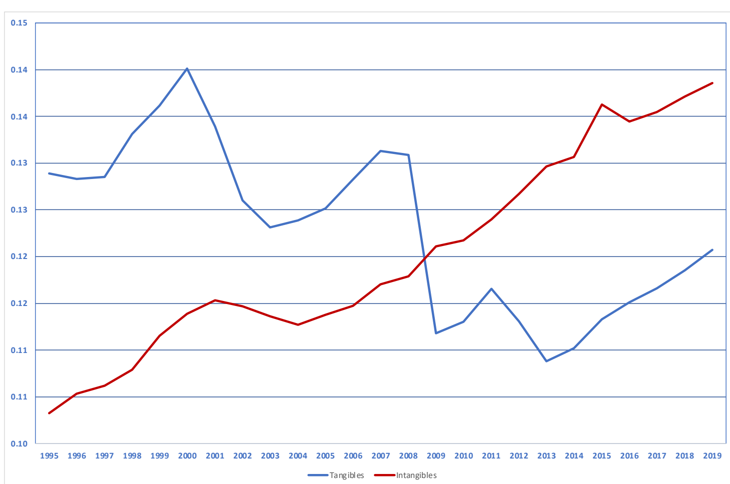
occur, we simply assume that capital and labour compensation are equal to five percent and 95 percent of value added, respectively.

3. Analytical module

The analytical module complements the statistical module with information on investment and capital stocks for the intangible assets not included in the National Accounts, notably industrial design, brand, organisational capital, training, and new financial products (Corrado et al 2022). The main goal of the analytical module is to provide data for productivity research looking beyond the boundaries of GDP. In this respect, EUKLEMS & INTANProd is the first database consistently integrating EUKLEMS standard variables with all categories of CHS intangibles, making a relevant advancement in productivity analysis. The capitalization of intangible assets not classified as investment in national accounts makes total fixed investment, capital stocks and value added at current prices increase thus affecting the sources of growth (Corrado et al 2005, 2009).

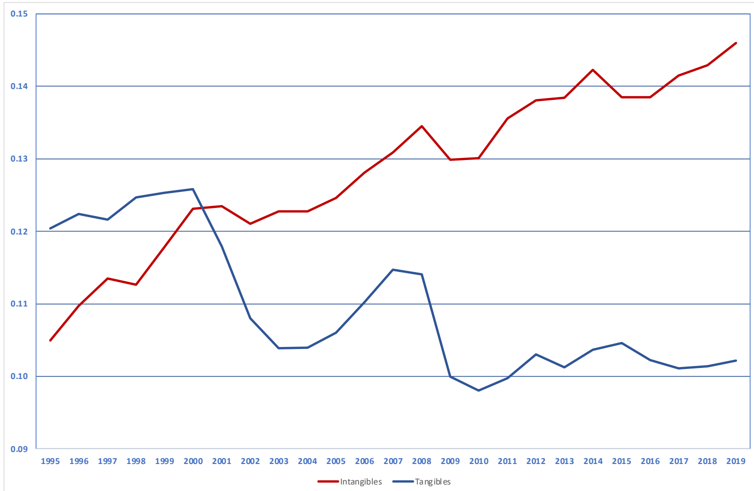
Consequently, the investment slowdown experienced by advanced economies and highly debated since the onset of the global financial crisis in 2008, can be analyzed adding intangibles not included in the asset boundaries of GDP into the picture (Corrado et al., 2016; European Investment Bank, 2018).

Figure 1 - Tangible and Intangible shares of GVA – EU



Source: EUKLEMS-INTANProd

Figure 2 - Tangible and Intangible shares of GVA – US



Source: EUKLEMS-INTANProd

Figures 1a and 1b show data on the intangible and tangible investment shares of aggregate gross value added (GVA) in Europe and the United States up to 2019. The European aggregate refers to 11 EU economies (AT, BE, DE, DK, ES, FI, FR, IT , NL, SE, UK). The charts cover up to 2019 to get the complete coverage of EU11 countries as for some of them (DK and ES) investment data by asset will be released by National Statistical Institutes after the publication of this report. Intangible investment overtook tangible investment after the global financial crisis, during which intangible investment fell comparatively less than tangible investment. The U.S. intangibles share is higher and more variable than the aggregate share for the 11 European (EU) countries. The dip in the U.S. share in 2015 and 2016 is due to sharp contractions in mineral exploration in those years; excluding this component (not shown), the U.S. share continues to rise. In the EU countries, the intangible investment share follows a steadily increasing trend over the years. The tangible share declines, on balance, in both geographies suggesting a substitution process between physical and intangible assets is going on.

3.1 Measuring Nominal Intangible Investment: Methods and sources

Procedures used to estimate nominal intangible investment flows for assets not currently classified as investment in national accounts follow the general approach adopted for software by official statistics. The approach involves the estimation of two components, o*wn-account* and *purchased* investment.

The method is summarized as follows:

- Purchases of noncapitalized intangibles usually may be found among the detailed product categories in supply-use tables, which are consistent with national accounts and reflect a reconciliation of comprehensive data from economic censuses and annual surveys, administrative sources, and international transactions.
- A *sum-of-costs* approach is used to estimate most own-account components of intangibles reported in EUKLEMS & INTANProd.

The methods used for the European economies and the United States are similar, but there are some departures and differences in data availability.

Table 2 summarizes the data sources used to measure intangible assets currently not classified as investment in national accounts, distinguishing between purchased and own account components. The main source for the purchased components is the Supply and Use Tables (SUTs) from national accounts. Own-account components are developed from survey data on employment and compensation by occupation and industry. Although details of specific procedures used to estimate nominal investment flows for the assets on lines 1 to 4 of Table 2 differ for European countries and the United States, the general approach is the same.

The methods and sources used to estimate both purchased and own-account intangible investment in assets listed on lines 1 to 4 are described in more detail below, and an example for each (i.e., purchased and own-account) are set out in Box 1 and Box 2.

Table 2 - Data sources for expanded components of intangible investment

Intangible Asset	Purchased	Own-account (O-A)	Total
1. Attributed designs	Supply-use tables	Employment and wages by occupation & industry	Purchased + O-A
2. New financial products	n.a.	Employment and wages by occupation & industry	O-A
3. Market research and brand	Supply-use tables	Employment and wages by occupation & industry	Purchased + O-A
4. Operating models	Supply-use tables	Employment and wages by occupation & industry	Purchased + O-A
5. Firm-specific human capital	Supply-use tables (US only)	Employment and wages by occupation & industry (US only)	Survey data (EU) Purchased + O-A + employer opportunity cost (US)

The estimation procedures for investment in firm-specific human capital for European countries and the United States, which, as may be seen on line 5 of the table, differ, are reviewed in a separate section below.

Purchased components

Measures for the purchased components of market research and brand, attributed design and operating models for *Europe* are obtained directly at the industry level (NACE Rev.2/CPA 2008) using data on intermediate costs gathered from the Use Tables (UT) for the following products: advertising and market research services (CPA M73), architectural and engineering services, technical testing and analysis services (CPA M71) and legal and accounting services, services of head offices and management consulting services (CPA M69 and M70).

The products classified as advertising and market research services (CPA M73) and architectural and engineering services, technical testing, and analysis services (CPA M71) are considered good proxies of expenditures for "Market research and brand" and "Attributed design", respectively. Thus they do not need to be integrated with additional information from other sources.

As for legal and accounting services, services of head offices and management consulting services the CPA M69_M70 is a broad category including expenditures beyond consulting services. Therefore, to get a better proxy of management consulting services, the expenditure corresponding to CPA M69_M70 is adjusted with the share of turnover of NACE M702 (consulting services) in total turnover of NACE M69_M70 from Structural Business Statistics. The share is kept constant across industries in each country.

Finally, a capitalization factor (CF) is applied to total expenditure by market producers to obtain the value of total expenditure to be capitalized (i.e., to be treated as fixed investment). The capitalization factors are asset specific and are as follows: Operating models (0.8), Brand (0.6) and Attributed Design (0.5). Capitalization factors do not vary across industries, except for the industry producing the corresponding asset, where capitalization factors are reduced to reflect estimates of the industry own use, i.e., subcontracting activity within the industry.

Box 1

Example: Calculating purchased investment in market research and brand

As previously indicated, the main source for measuring purchased investment in market research and brand in is the USE table from National Accounts reporting expenditures on advertising and market research services by industry. Official national accounts record these expenditures as intermediate consumption.

The approach for capitalizing this expenditure is as follows.

Denote I_i^{Bp} the purchased component of brand investment for industry i, γ_i^b the corresponding capitalization factor and IC_i^{M73} the intermediate consumption expenditure for Advertising and Market Research Services (CPA M73). Thus, investment in brand (purchased component) is measured as:

$$I_i^{Bp} = IC_i^{M73} * \gamma_i^b$$

The same calculation can be applied to any country with due consideration for the specific-country classification product codes, e.g., for the United States the intermediate consumption expenditure is measured as

$$I_i^{Bp} = \lambda_i^b * IC_i^{BEA5412OP} * \gamma_i^b$$

where λ_i^b is a time-varying factor that represents the portion of relevant purchases in BEA's annual intermediate use series 5412OP that includes brand investment. The time-varying factor is developed from benchmark-year values for intermediate purchases of advertising, public relations, and related services (BEA/NAICS 5418) and marketing research and public opinion polling services (NAICS 54191). Because benchmark year values for intermediate purchases of NAICS 54191 not available (they are included in "all other professional, scientific, and technical services, BEA industry code 5419AO), information on industry revenues of NAICS 54191 relative to the other industries included in 5419AO (NAICS 54193 and 54199) is also used to the develop the annual factor λ_i^b applied to $IC_i^{BEA5412OP}$.

Estimates for the United States follow a similar approach, though the U.S. industry data follow the North American Industry Classification System (NAICS). The main source for the purchased components of expanded investment is BEA's Annual UT and Input-Output Accounts (IO), which are available for 71 commodities defined according to NAICS from 1997 on; these data are linked to earlier formats (with slightly fewer industries) from 1977 to 1997. Management and technical consulting services (NAICS 5416), advertising and market research (NAICS 5418 and 54191), and architectural and engineering design services (5413) are not separate commodity codes in BEA's annual system; they are included along with selected other services in "Miscellaneous professional, scientific and technical services (BEA 5412OP).[21] Detailed annual gross output statistics and information from benchmark SU/IO tables available at five-year intervals from 1987 to 2012 (covering 405 industry groups for 2007 and 2012, with slightly fewer in earlier years) are used to determine individual times series for the relevant components of this aggregate.

Another complication is that, in the underlying NAICS data, strategic consulting services are not limited to the management consulting industry; rather strategic IT consulting expenditures are part of intermediate purchases from the computer design industry (NAICS 541512) and headquarter provision of strategic services to separately located establishments are included in purchases from management of companies (NAICS 55). Fractions that represent the relevant long-lived service flows are estimated using a combination of benchmark SUTs and detailed product-level revenue data from the US Census Bureau; the resulting time series are included in the purchased component of investment in organization structure.

As with the estimates for Europe, noting that the sum-of-costs approach to estimating co-production requires separating firms that produce the intangible asset as a line of business from those with hypothetical factories that produce for own use, e.g., workers at firms that sell software products or training services would not be included as workers producing software or training services on own account. For the United States, the benchmark SUTs provide the information needed to estimate this exclusion. The capitalization factors for design, management consulting and advertising are the same as used for European economies.

[21] The grouping also covers NAICS 5412 (Accounting, tax preparation, bookkeeping and payroll services), NAICS 5414 (Specialized design services), NAICS 5417 (Scientific research and development services) and NAICS 54192, 3, 4 and 9 (Photographic, veterinary, and other miscellaneous professional, scientific, and technical services).

Own-account components.

Estimates for the own-account component of market research and brand, attributed design, operating models, and new financial products are obtained using a sum-of-cost approach, consistent with the national accounts method for estimating own account software and databases.

The approach develops estimates using data on employment and compensation by type of occupation and by industry. For European countries the main sources are: 1) the Structural of Earning Survey (SES), which provides information on the annual earnings and number of employees by occupation (at the three-digit level of the 2008 International Standard Classification of Occupations, ISCO) and 2) the Labor Force Survey (LFS). For the United States, the main sources are 1) employment and earnings data by occupation from the Current Population Survey (CPS) and 2) industry-level compensation and employment data from national industry accounts. Information from Occupation and Earnings Survey (OES) of the Bureau of Labor Statistics (BLS), which provides wages and employment by occupation by detailed NAICS industries, is used to provide starting values for time series estimates developed via bi-proportional balancing of (1) and (2).

The main steps for generating own account intangible investment measures consistent with national accounts are summarized below in Box 2.

Box 2

Example: Estimating own-account investment in market research and brand for a European country

The application of the general approach to the generation of estimates of own-account investment in market research and brand for industry i in a country proceeds according to the following steps:

Step1. Identify the relevant occupations: Sales, marketing and development managers (ISCO 122) and Sales, marketing and public relations professionals (ISCO 243).

Step 2. Assume that sales, marketing and development managers spend 15 percent of their time producing long-lived services to be used internally by the (same) firm and that sales, marketing and public relations professionals spend 50 percent of their time. Thus, indicating with τ_j the time share spent by each type of occupation (j) in producing the asset, the time assumptions for ISCO 122 and ISCO 243 occupations are as follows:

$$\tau_{122} = 0.15$$
$$\tau_{243} = 0.50$$

Step 3. The total wage cost of employees corresponding to the production of market research and brand asset, $W_{i,j}^{Br}$,for own-account use generated in each industry (i) by each type of occupation (j) is then computed as:

$$W_{i,j=122}^{Br} = W_{i,j=122} * \tau_{122}$$

$$W_{i,j=243}^{Br} = W_{i,j=243} * \tau_{243}$$

where $W_{i,j=122}$ and $W_{i,J=243}$ are the wages earned by j=ISCO_122 and ISCO_243 occupations in each industry (i) gathered from the SES survey.

Step 4. Once $W_{i,j}^{Br}$ is computed it is necessary to make it consistent with national accounts' estimates of labor costs. To do so, first it is necessary to calculate the share of the wage cost for market research and brand assets production in each industry (i):

$$W_i^{Br} = (W_{i,j=122}^{Br} + W_{i,j=243}^{Br})/W_i$$

where W_i is the total wage in industry (i), also from the SES survey.

Step 5. Then, for each industry (i), labor costs related to the production of own-account market research and brand assets consistent with national accounts are calculated multiplying the wage shares from step 4 by compensation of employees by industry from national accounts C_i:

The ISCO occupations and time use assumptions used for estimating own-account investment components for European countries are included in the appendix. The example provided in Box 2 illustrates assumptions to estimate own-account investment in market research and brand for a European country. For the United States, the identification of relevant occupation codes used for the own account component of brand are found in Corrado and Hao (2014, page 85), for new financial products in Corrado et al. (2012, pages 29-31), and for organizational capital Corrado (2021, Box 2).

Measuring Firm-Specific Human Capital

Availability of information for measuring firm specific human capital differ noticeably between Europe and the United States but the conceptual basis of the EU KLEMS & INTANProd estimates for European economies and the United States, like the INTANInvest estimates that preceded them, is the same.

Note first there is no ongoing, official source of data covering private sector spending on employer-provided training for the United States. The US intangible investment estimates are benchmarked to a one-time BLS survey of employer-provided training (SEPT) conducted in 1995 that has been extended using information from multiply sources: Surveys reported annually in *Training Magazine*; intermediate purchases other education services (NAICS 6114-7) from annual USE tables; and estimates of the annual payroll of workers assigned to the training function within private organizations developed from CPS data.

This approach to measuring U.S. investment in firm-specific capital follows the conceptual framework of the SEPT, in which the cost of *formal* employer-provided training is captured by the sum of (a) purchases of training services, (b) the in-house cost of providing training services (wages of training personnel and materials used), and (c) the opportunity cost in terms of hourly wages paid for employee time spent in training functions. The industry distribution of (a) and (b) is implicit in the source data used for the extrapolators for these components (Use tables and CPS survey data). The industry distribution for the opportunity cost component is benchmarked to the SEPT, extended by information on hours and spending by industry (broad groups only) in the annual industry report in *Training Magazine.*

For European countries, investment in firm specific human capital (training) is obtained as the sum of investment in vocational training and apprenticeships. Estimates are based on data from the EU

Continuing Vocational Training Survey (CVTS) integrated with data from the EU Labour Cost Survey (LCS) to generate investment by industry. The CVTS collects information on enterprises' investment in the continuing vocational training of their staff and is available for the years 2005, 2010, and 2015. Continuing vocational training (CVT) refers to education or training courses that are financed in total or at least partly by the enterprise (directly or indirectly).

Estimates of training costs based on the CVTS include both the purchased and the own account component. Both internal and external CVT courses are identified, and courses' costs include the labour costs of internal trainers. In addition, CVTS costs also cover the opportunity cost for employees attending courses, as they include the labour cost of participants for vocational training courses that take place during paid working time.

The country coverage of the CVTS is almost complete, but the industry detail is very coarse, so the information gathered from the CVTs is complemented with data on investment in training from LCS. The approach used for Europe can be described as follows. Define E_i^{CVT} the cost of CVT courses and compute the share over total labor cost W_i as:

$$T_i^{CVT} = E_i^{CVT} / W_i \qquad (18)$$

As CVT is available only for a limited number of years, a time series for T_i^{CVT} is generated via linear interpolation. To guarantee consistency with national accounts, the share of CVT expenditure is multiplied by compensation of employees C_i as:

$$C_i^{CVT} = T_i^{CVT} * C_i \qquad (19)$$

The apprenticeships component is calculated using the same approach as vocational training: the share of apprentice costs in total labor cost from the LCS is multiplied by compensation of employees from national accounts.

Estimates of training are based on the assumption all expenditures increase the value of the stock and therefore should be considered as investment (i.e. the capitalisation factor is equal to one).

3.2 Measuring Real Intangible Investment: Method and sources

Real investment for each asset listed in table 2 above is obtained by dividing its nominal investment flow by an appropriate price index. Specific investment deflators for table 2 assets are not available from official statistics, thus EUKLEMS & INTANProd uses closely aligned services output deflators from national accounts. The data sources used as listed in table 3. The services output price indexes listed as sources for assets listed on lines 1, 2, 4 and 5 are directly used as price indexes for the corresponding assets.

Table 3 - Sources for price deflators for expanded components of intangible investment

Intangible Asset	United States		European Countries	
	Indicator	Data sources	Indicator	Data sources
1. Attributed designs	Gross output price deflator NAICS 5413	BEA	Gross output price deflator NACE M71	OECD STAN, EUROSTAT Service producer prices, EUROSTAT National accounts
2. New financial products	R&D investment deflator in the financial, insurance, and real estate services	BEA	R&D investment deflator in the financial and insurance activities industry (NACE K)	EUROSTAT National accounts
3. Market research and brand (see text for further explanation)	Gross output price deflator NAICS 5418, input price indexes for internet and traditional paid media costs	BEA, BLS	Gross output price deflator NACE M73	OECD STAN, EUROSTAT Service producer prices, EUROSTAT National accounts
4. Operating models	Gross output price deflator NAICS 541512, NAICS 54161	BEA	Gross output price deflator NACE M69_70	OECD STAN, EUROSTAT Service producer prices, EUROSTAT National accounts
5. Firm-specific human capital	Gross output price deflator NAICS 6114-7	BEA	Gross output price deflator NACE M	OECD STAN, EUROSTAT Service producer prices, EUROSTAT National accounts

A price index for investments in market research and brand has been specifically constructed for the analytical module in EU KLEMS & INTANProd. The price index is calculated as a weighted average of production/content development costs and media dissemination costs. The former is proxied by a related gross output price deflator—the deflator for the advertising and related services industry (NAICS 5418) in the United States and the advertising and market research industry in European countries (M73). Media costs for the United States are constructed from BLS producer *input* price indexes for internet and traditional media (newspapers, periodicals, television, and radio). BLS estimates that the cost of internet advertising declined 5 percent per year from 2009 to 2020. Comparable internet media cost price indexes are not available for European countries, however, and changes in the US input price index are used to develop the prices indexes for investments in market research and brand used for European countries.

Aggregated (by industry and asset) real investment is obtained using annual chain-linked measures (i.e., quantity indexes are based on the linking (chaining) of indexes for consecutive periods to form time series). Annual chain-linked measures are recommended by the *2008 System of National Accounts* and used to compile official national accounts both in the US and in European countries. However, in the US annual changes in the quantities are calculated using a Fisher index formula (which incorporates weights from 2 adjacent years) to construct the chain-type indexes, while European countries use Laspeyres quantity indexes (which incorporate weights derived from the previous year). To maintain consistency with national accounts, in EUKLEMS & INTANProd we use Fisher for the US intangibles and Laspeyres for European countries.

Measuring Real Intangible Capital Stocks

Capital stock estimates in real terms are derived using the perpetual inventory method (PIM), which involves aggregating real investment over time but allowing for declines in efficiency and value until assets reach the end of their service lives and are retired. Intangibles are not subject to wear and tear like most fixed assets, such as machinery and buildings, but their value declines over time because they are subject to obsolescence.

In particular, we use the so-called geometric model, which defines the real stock of intangible asset j in industry i at the end of year t ($Kq_{i,t}^{j}$) as:

$$Kq_{i,t}^{j} = Kq_{i,t-1}^{j} * (1-\delta^{j}) + Iq_{i,t}^{j} \qquad (20)$$

where $Kq_{i,t-1}^{j}$ is the real stock of intangible asset j in industry i at the end of year t-1, δ^{j} is the annual depreciation rate for asset j and $Iq_{i,t}^{j}$ is real investment for asset j in industry i during year t. Note that depreciation rates are asset-specific and are assumed to not vary across industries and over time.

Our calculation of intangible capital stocks is based on specific assumptions on depreciation rates. Annual depreciation rates equal to 0.4 for operating models and firm-specific human capital, 0.2 for attributed design and new financial products, and 0.55 for market research and brand are used to develop stocks for market sector industries.

3.3. Extended Growth accounting

This section rests on the theoretical model described in (Corrado et al 2016) and describes how adding intangibles to the standard growth accounting framework deepens our understanding of productivity and economic growth. The standard growth accounting equation (1) modified to include intangible assets can be written as:

$$\Delta lnQ_j = \bar{v}_{L,j}\Delta lnL_j + \bar{v}_{K,j}\Delta lnK_j + \bar{v}_{R,j}\Delta lnK^{NNAInatang}{}_j + \Delta lnTfp_j \qquad (21)$$

Where Q is value added adjusted to consider the capitalization of intangibles currently excluded from the asset boundaries of GDP, $K^{NNAInatang}$ are capital services from intangible assets not included in national accounts, and $\bar{v}_{R,j}$ is year t and t-1 average of the share of capital compensation of non-national accounts intangibles in adjusted value added; the remaining variables are the same as in equation (1) in section 2.3 above .

The growth accounting results based on the extended asset boundary differ from those based on official national accounts for three reasons. First, the capitalization of intangible assets directly affects capital services and capital compensations, as additional assets are included in the calculation. Second, the capitalization of new intangibles increases the level of value added and changes its growth rate, as the expenditure to purchase them is no longer accounted for as intermediate consumption and the cost for own-account production is added to gross output. Third, because of the different level of value added, capital and labour shares are modified (even if the value of labour compensation is not affected).

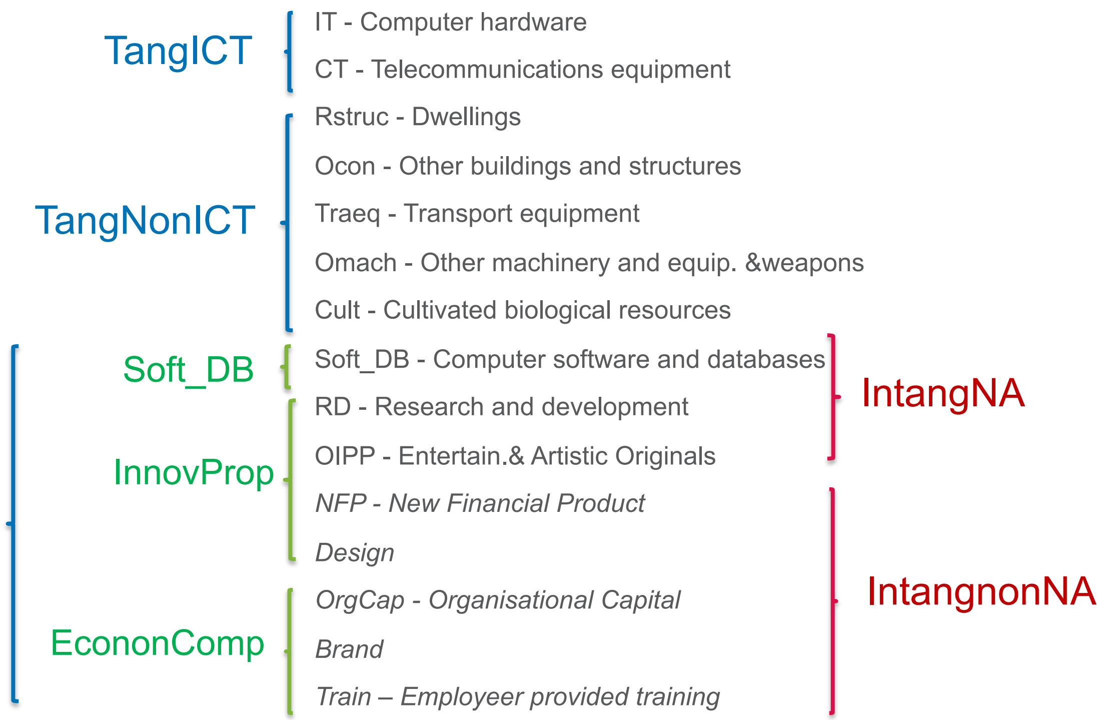
Besides a different assent boundary, growth accounting in the analytical module also uses different measures of national accounts assets. First, ICT assets in volume term reflect price deflators whose product quality change component is harmonized across countries, based on the methodology developed by Schreyer (2002) and widely used since then, including in the first EUKLEMS release. Second, capital stocks have been generated using the geometric method, consistently with non-national accounts intangibles, instead of using official national accounts estimates. Depreciation rates are the same as previous EUKLEMS releases except for R&D stocks, that are computed by applying industry-specific depreciation rates based on those used by the BEA for the US (see Table A1). The initial level of capital stock is estimated with the same method used for non-national accounts intangibles for IT, CT and Soft_DB, and set equal to the value of capital stock in the statistical module for the other assets.

Re computing capital stocks for national accounts assets allows: i) to get harmonized measures across countries and across assets; ii) to use a measure of productive stock in productivity measures (and not a measure of wealth, as the net capital stock from national account); iii) to obtain consistent measures of user costs and capital stocks based on the same depreciation rates.

Extended capital services breakdown

In the analytical module, in addition to tangible non-ICT, tangible ICT and intangibles, as shown in Table 4 below, we provide additional breakdowns of intangible capital services into national accounts (*IntangNA*) and non-national accounts (*IntangnonNA*) and into Software and databases (*Soft_DB*), innovative property (*Innovprop*) and economic competences (*EconComp*) .

Table 4 - Capital services breakdown in the analytical module



Thus, the analytical module provides three different decompositions of adjusted value added growth ($VAadj\_G$):

$$VAadj_{G_j} = VAConH_j + VAConLC_j + VAConTangICT_j + VAConTangNICT_j + \boldsymbol{VAConIntang_j} + VAConTFP_j \quad (21a)$$

$$VAadj_{G_j} = VAConH_j + VAConLC_j + VAConTangICT_j + VAConTangNICT_j + \boldsymbol{VAConIntangNA_j} + \boldsymbol{VAConIntangnonNA_j} + VAConTFP_j \quad (22b)$$

$$VAadj_{G_j} = VAConH_j + VAConLC_j + VAConTangICT_j + VAConTangNICT_j + \boldsymbol{VAConSoft\_DB_j} + \boldsymbol{VAConInnovprop_j} + \boldsymbol{VAConEconComp_j} + VAConTFP_j \quad (22c)$$

Note that:

$$VAConIntang_j = VAConIntangNA_j + VAConIntangnonNA_j = VAConSoft\_DB_j + VAConInnovprop_j + VAConEconComp_j.$$

Analogous decompositions are provided for labour productivity growth.

Aggregation of industry-level results

The standard approach adopted in the statistical and the analytical modules to conduct growth accounting at the aggregate level involves aggregating the quantities of labor (hours worked/number of employed) and capital (capital stocks) first, and then directly compute capital and labor inputs at the aggregate level. The "direct calculation" approach implicitly assumes perfect mobility of inputs across industries, that labor and capital earn the same compensation in all industries, and that all industries have the same value-added function. In an economy with these characteristics, the reallocation of capital and labor across industries does not contribute to aggregate growth. This is why, the assumptions underlying the "direct calculation" approach are considered as rather restrictive.

Against this background, in the analytical module growth accounting results are generated also adopting a bottom-up approach for the total economy and non-agricultural market sector. The bottom-up approach involves the aggregation of value added, capital input and labor input across industries to derive the corresponding aggregate measures. For capital inputs the weights are the industry shares of nominal capital income in total capital income. For labour, the weights are the shares of labour income. For value-added, the weights are the shares of nominal value-added. The aggregate TFP calculated with this approach reflects the value added weighted contribution of industry-level TFPs.

The aggregation procedure uses the Tornqvist index, and, for instance, the bottom-up calculation of capital input for the total economy, ΔlnK_{TOT}^{BU}, is:

$$\Delta lnK_{TOT}^{BU} = \sum_j \overline{w}_{K,j} \Delta lnK_j \qquad (23)$$

Where ΔlnK_j is the flow of capital services in industry j and $\overline{w}_{K,j}$ denotes the (average of year t and t-1) share of industry j in total capital compensation. Similar industry aggregations are used for labour and value added. In practice, our bottom-up estimates are obtained by aggregating capital and labor input calculated at the section level of the NACE Rev. 2 classification.

This method is similar to the "direct aggregation across industries" approach as developed by Jorgenson et al. (1987).[22] It assumes that value-added functions exist for each industry but does not impose identical value-added functions, mobility of inputs across industries, and equal factor prices for all industries. The difference between bottom-up and direct measures of labor and capital input depends on the extent of reallocation of labor and capital across industries.

3.4. Empirical results

As an example, below we report estimates of total factor productivity that cover the 11 European countries included in the empirical analysis of the data value chain and the United States from 1998 to 2019. The results for Europe are aggregated using production-side purchasing power parities (PPPs) to facilitate comparative analysis with the United States.[23] It should be noted that EUKLEMS & INTANProd includes estimates of intangible investment for all 27 EU countries (though histories are short for some); but only for a limited number of countries it is possible to compute growth accounting variables by industry over time because of data availabilities for GFCF.

For international comparability, the intangible capital estimates reflect the incorporation of price deflators for brand and marketing that are harmonized to include the drop in advertising media marketing costs. (Similarly, the deflators for computer, and communications equipment and software are harmonized).

Growth decompositions

The growth accounting reported below is in per hour terms, i.e., it decomposes the growth in output per hour for both the European aggregate and the United States. The accounting for the European aggregate is developed at the country-industry level, where industries are aggregated to "market" sector aggregates for each country and then weighted accordingly to generate the European aggregate.

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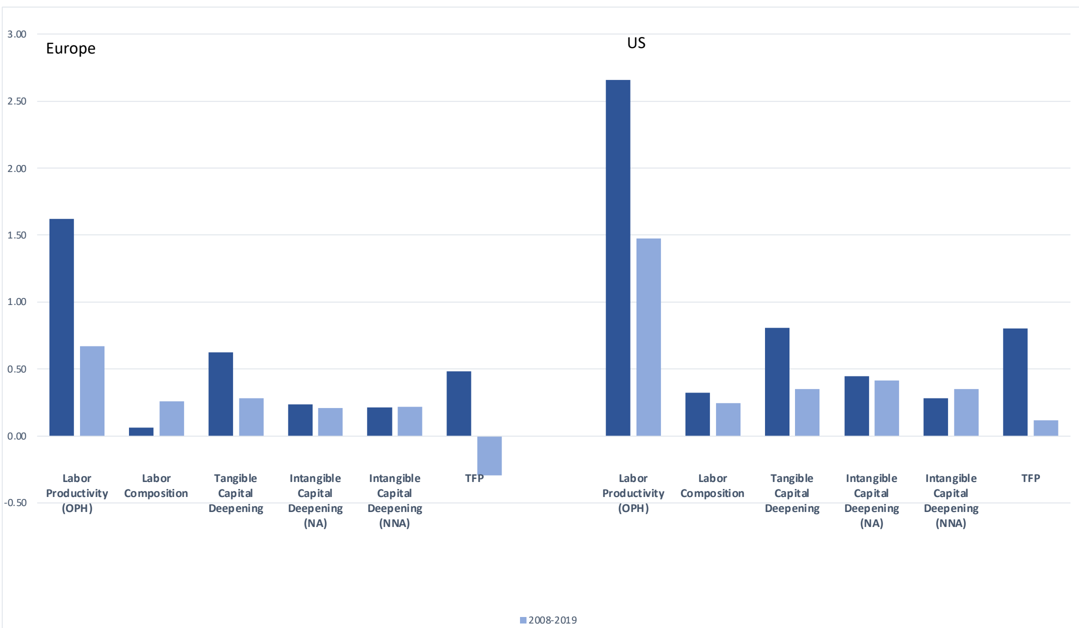
[22] The the weighting scheme developed by Jorgenson at al. (1987) is different than ours because they measure industry-level output in terms of gross output.

[23] Productivity comparisons at the industry level should use PPPs that adjust for differences in industry product output and input prices across countries rather than overall prices derived from expenditure component of final demand. Methods for obtaining production side PPP estimates from unit value production statistics and adjusted expenditure PPPs are set out in van Ark and Timmer (2009) and Inklaar and Timmer (2008). Updated production-side PPPs will be produced as part of the EUKLEMS & INTANProd project and released during Spring 2023.

Market sector aggregates exclude the public sector and the majority of public (or heavily subsidized) industries, thus being rather similar, though not identical, to the nonfarm business sector used for headline productivity statistics in the United States.[24]

Figure 3 sets out the decompositions of the within-industry change in labor productivity. Comparing the first set of columns in figure 3 for each region with the last set, the drop in growth of output per hour (OPH) is seen to be mainly accounted for by a substantial slowdown in total factor productivity (TFP) growth is 0.9 percentage point less per year in the period after 2007 compared with prior years in Europe and .7 percentage point less in the United States.

Figure 3 – Sources of growth –EU vs US (1999-2007 vs 2008-2019)



[24] The market sector aggregates are formed using 25 individual industries that cover 10 NACE letter-level industry sectors: B (Mining), C (Manufacturing), F (Construction, G (Wholesale and retail Trade; repair of motor vehicles), H (Transportation and storage), I (Accommodation and food S=services), J (Information and Communication activities), K (Finance and insurance activities), M (Professional, scientific, and technical activities), N (Administration and support activities). NACE is an international system for industry classification used in Europe; for a concordance to the NAICS system used in North America, see the Bontadini et al. (2022) documentation on the EUKLEMS & INTANProd project portal.

The contribution of the second set of bars (labor composition) reflects the per hour contribution of increases in (employed) human capital, i.e., the contribution to the change in OPH of changes in the proportion of high-skilled/high wage jobs in an economy. Though this effect works in opposite directions in Europe vs the United States, its contribution to explaining developments in productivity growth in these regions during the past 20 years is relatively small.

The terms in capital deepening are part of the slowdown story, directly and indirectly. A drop in tangible capital deepening directly explains 22 percent of the drop in OPH in Europe and whopping 44 percent of the drop in the United States. The rate at which workers in both regions were equipped with intangible capital was maintained, or edged up a tad, over the entire period, however. That resources continued to be invested in innovation in both regions during the period of the slowdown in productivity suggests that the slowdown story must be about, at least in part, changes in the costless diffusion of innovations across firms and industries in these economies.

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Appendix

Appendix Table A1 - Depreciation rates

Code	IT	CT	Soft_DB	TraEq	OMach	OCon	RStruc	Cult	RD	OIPP	Brand	Design	NFP	Train
TOT	0.315	0.115	0.315	0.189	0.131	0.032	0.011	0.200	0.221	0.131	0.550	0.200	0.200	0.400
TOT_IND	0.315	0.115	0.315	0.191	0.129	0.031	0.011	0.201	0.221	0.129	0.550	0.200	0.200	0.400
MARKT	0.315	0.115	0.315	0.185	0.126	0.034	0.011	0.193	0.230	0.126	0.550	0.200	0.200	0.400
A	0.315	0.115	0.315	0.170	0.129	0.024	0.011	0.151	0.160	0.129	0.550	0.200	0.200	0.400
B	0.315	0.115	0.315	0.170	0.129	0.024	0.011	0.207	0.160	0.129	0.550	0.200	0.200	0.400
C	0.315	0.115	0.315	0.174	0.108	0.033	0.011	0.207	0.178	0.108	0.550	0.200	0.200	0.400
C10-C12	0.315	0.115	0.315	0.168	0.109	0.033	0.011	0.207	0.160	0.109	0.550	0.200	0.200	0.400
C13-C15	0.315	0.115	0.315	0.184	0.109	0.033	0.011	0.207	0.160	0.109	0.550	0.200	0.200	0.400
C16-C18	0.315	0.115	0.315	0.173	0.106	0.033	0.011	0.207	0.160	0.106	0.550	0.200	0.200	0.400
C19	0.315	0.115	0.315	0.154	0.110	0.032	0.011	0.207	0.160	0.110	0.550	0.200	0.200	0.400
C20	0.315	0.115	0.315	0.181	0.104	0.033	0.011	0.207	0.160	0.104	0.550	0.200	0.200	0.400
C21	0.315	0.115	0.315	0.181	0.104	0.033	0.011	0.207	0.100	0.104	0.550	0.200	0.200	0.400
C22_C23	0.315	0.115	0.315	0.191	0.112	0.033	0.011	0.207	0.160	0.112	0.550	0.200	0.200	0.400
C24_C25	0.315	0.115	0.315	0.166	0.108	0.033	0.011	0.207	0.160	0.108	0.550	0.200	0.200	0.400
C26	0.315	0.115	0.315	0.166	0.108	0.033	0.011	0.207	0.303	0.108	0.550	0.200	0.200	0.400
C27	0.315	0.115	0.315	0.166	0.108	0.033	0.011	0.207	0.160	0.108	0.550	0.200	0.200	0.400
C28	0.315	0.115	0.315	0.170	0.107	0.033	0.011	0.207	0.160	0.107	0.550	0.200	0.200	0.400
C29_C30	0.315	0.115	0.315	0.167	0.109	0.033	0.011	0.207	0.310	0.109	0.550	0.200	0.200	0.400
C31-C33	0.315	0.115	0.315	0.193	0.113	0.033	0.011	0.207	0.160	0.113	0.550	0.200	0.200	0.400
D	0.315	0.115	0.315	0.191	0.094	0.023	0.011	0.207	0.935	0.094	0.550	0.200	0.200	0.400
E	0.315	0.115	0.315	0.191	0.094	0.023	0.011	0.207	0.935	0.094	0.550	0.200	0.200	0.400
F	0.315	0.115	0.315	0.195	0.139	0.034	0.011	0.195	0.160	0.139	0.550	0.200	0.200	0.400
G	0.315	0.115	0.315	0.216	0.134	0.030	0.011	0.188	0.160	0.134	0.550	0.200	0.200	0.400
G45	0.315	0.115	0.315	0.229	0.121	0.031	0.011	0.188	0.160	0.121	0.550	0.200	0.200	0.400
G46	0.315	0.115	0.315	0.204	0.143	0.031	0.011	0.188	0.160	0.143	0.550	0.200	0.200	0.400
G47	0.315	0.115	0.315	0.215	0.137	0.027	0.011	0.188	0.160	0.137	0.550	0.200	0.200	0.400

H	0.315	0.115	0.315	0.114	0.114	0.028	0.011	0.188	0.160	0.114	0.550	0.200	0.200	0.400
H49	0.315	0.115	0.315	0.092	0.118	0.028	0.011	0.188	0.160	0.118	0.550	0.200	0.200	0.400
H50	0.315	0.115	0.315	0.092	0.118	0.028	0.011	0.188	0.160	0.118	0.550	0.200	0.200	0.400
H51	0.315	0.115	0.315	0.092	0.118	0.028	0.011	0.188	0.160	0.118	0.550	0.200	0.200	0.400
H52	0.315	0.115	0.315	0.092	0.118	0.028	0.011	0.188	0.160	0.118	0.550	0.200	0.200	0.400
H53	0.315	0.115	0.315	0.201	0.096	0.027	0.011	0.188	0.160	0.096	0.550	0.200	0.200	0.400
I	0.315	0.115	0.315	0.203	0.140	0.028	0.011	0.188	0.160	0.140	0.550	0.200	0.200	0.400
J	0.315	0.115	0.315	0.176	0.115	0.035	0.011	0.214	0.247	0.115	0.550	0.200	0.200	0.400
J58-J60	0.315	0.115	0.315	0.173	0.106	0.033	0.011	0.214	0.220	0.106	0.550	0.200	0.200	0.400
J61	0.315	0.115	0.315	0.201	0.096	0.027	0.011	0.214	0.160	0.096	0.550	0.200	0.200	0.400
J62_J63	0.315	0.115	0.315	0.155	0.144	0.044	0.011	0.214	0.360	0.144	0.550	0.200	0.200	0.400
K	0.315	0.115	0.315	0.187	0.149	0.044	0.011	0.160	0.160	0.149	0.550	0.200	0.200	0.400
L	0.315	0.115	0.315	0.227	0.147	0.027	0.011	0.218	0.160	0.147	0.550	0.200	0.200	0.400
M_N	0.315	0.115	0.315	0.155	0.144	0.044	0.011	0.215	0.160	0.144	0.550	0.200	0.200	0.400
M	0.315	0.115	0.315	0.155	0.144	0.044	0.011	0.215	0.160	0.144	0.550	0.200	0.200	0.400
N	0.315	0.115	0.315	0.155	0.144	0.044	0.011	0.215	0.160	0.144	0.550	0.200	0.200	0.400
O-Q	0.315	0.115	0.315	0.202	0.140	0.035	0.011	0.207	0.154	0.140	0.550	0.200	0.200	0.400
O	0.315	0.115	0.315	0.173	0.138	0.025	0.011	0.235	0.160	0.138	0.550	0.200	0.200	0.400
P	0.315	0.115	0.315	0.173	0.138	0.025	0.011	0.235	0.160	0.138	0.550	0.200	0.200	0.400
Q	0.315	0.115	0.315	0.225	0.149	0.027	0.011	0.235	0.143	0.149	0.550	0.200	0.200	0.400
R_S	0.315	0.115	0.315	0.223	0.136	0.051	0.011	0.186	0.160	0.136	0.550	0.200	0.200	0.400
R	0.315	0.115	0.315	0.223	0.136	0.051	0.011	0.186	0.160	0.136	0.550	0.200	0.200	0.400
S	0.315	0.115	0.315	0.223	0.136	0.051	0.011	0.186	0.160	0.136	0.550	0.200	0.200	0.400
T	0.315	0.115	0.315	0.198	0.140	0.032	0.011	0.186	0.160	0.140	0.550	0.200	0.200	0.400
U	0.315	0.115	0.315	0.198	0.140	0.032	0.011	0.186	0.160	0.140	0.550	0.200	0.200	0.400