Regional capital stock estimates – Methodological note

Introduction

As part of a wider project to make regional data with a long history (1980->) freely available through the EC data portal, Cambridge Econometrics have produced NUTS2 GFCF data and subsequently updated their estimates of regional capital stocks, originally produced as part of a feasibility study[1] and then published as a journal article[2]. This note provides details of the methodology adopted.

The aim of this exercise is to derive regional (NUTS2, 2013 version) net capital stocks starting from known country totals for the EU28 Member States, by broad sector of activity for as long a time series as is possible. In summary the method:

- uses the Perpetual Inventory Method (PIM), as the most straightforward way of producing capital stock estimates.
- is based on reliable country-level estimates from EU-KLEMS, AMECO and the OECD, as well as using regional GFCF estimates produced by Cambridge Econometrics.
- does not produce estimates by investment asset, but instead focuses on disaggregation by broad sector, i.e. Agriculture, Industry, Construction, Financial Business Services, Other Private Services, and Non-Market Services.
- is able to go back to 1995 for all Member States and regions, and then annually to 2016.
- is constructed in such a manner that it should be updateable and revisable by European Commission Services in future years, so that it can remain up-to-date and relevant for future research on Europe's regions by policy-makers, academics and other interested parties.

The next sections describe the method in more detail.

The Perpetual Inventory Method

The most widely used method to compute capital stocks is the so-called Perpetual Inventory Method (PIM), based on the following equation:

$$K_t = (1 - \delta)K_{t-1} + GFCF_t \qquad (1)$$

[1] See https://ec.europa.eu/regional_policy/sources/docgener/work/2011_01_capital_stock.pdf

[2] Derbyshire, J., Gardiner, B., and Waights, S. (2013) Estimating the capital stock for the NUTS2 regions of the EU27, *Applied Economics*, 45(9):1133-1149.

Where K stands for real net capital stock, δ stands for the depreciation rate and $GFCF$ stands for real Gross Fixed Capital Formation. The subscript t denotes the time period. To run this process three ingredients are needed:

- A value for the initial capital stock K_0
- A depreciation rate δ
- A time series of $GFCF$

The process described can be computed at the desired level of disaggregation (e.g. by sector) if the necessary data are available. The outcome of the present exercise is going to be estimates of regional capital stocks up to the NUTS 2 level, for six branches of activity, for the period 1995-2016.

Data

The following datasets were used to construct the capital stock database:

- AMECO is a database containing historical data and forecasts of the European Commission for the main macroeconomic variables. For the purpose of this exercise, it contains total real net capital stock estimates for all the Member States, which will be used to compute the initial capital stock.
- Regional (NUTS2) real GFCF estimates from Cambridge Econometrics, updated to 2016 by Cambridge Econometrics for the JRC data platform.
- EU-KLEMS is a database containing harmonised data about output, valued added, inputs in production, productivity and capital formation. It is the outcome of an EU funded project. For the purposes of this exercise, it contains estimates of nominal capital stocks for 26 Member States with varying level of details and depreciation rates by sectors and assets (same for all countries), which will be used to compute depreciation rates for each country.
- National Bank of Belgium estimates of nominal net capital stocks by sectors and assets. These data will be used to compute depreciation rates for Belgium, given that this country is missing in EU-KLEMS.
- OECD STAN is a comprehensive tool for analysing industrial performance at a relatively detailed level of activity across countries. It includes annual measures of output, value added and its components, labour input, investment and capital stock. It will use to fill some data gaps in Belgium dataset to compute depreciation rates.

Methodology

Initial capital stock

As described above, the PIM method needs an initial capital stock value to start the computation of the whole series. In order to get initial capital stock values at the regional level, a total initial capital stock estimate at the country level is shared among regions. The initial capital stock estimates at the country level are taken from AMECO, which contains only country totals without any regional or sectoral breakdown. The first step is to get a sectoral breakdown at the country level, and then share those figures among regions. The sectoral breakdown adopted in this exercise (referred to as “CE sectors” from now on), related to NACE2 classification, is the following:

- Agriculture: section A
- Industry: sections B to E
- Construction: section F
- Wholesale, Retail, Transport, Accommodation & Food Services, Information and Communication: sections G to J
- Financial and Business Services: sections K to N

- Non-market services: sections O to U

To get the required sectoral breakdown from country totals, the total figures from AMECO are shared among the CE sectors using shares computed from CE's GFCF data, i.e. GFCF in each sector as a share of total country GFCF, at time 0:

$$K_{Nj,0} = \frac{GFCF_{j,0}}{GFCF_{N,0}} K_{N,0} \tag{3}$$

With subscript j being the sector, N the total by country and 0 denoting the initial period. Once all countries have national data broken down by the CE sectors, the regional breakdown is computed according to the following formula:

$$K_{ij,0} = \frac{\sum_t GFCF_{ij,t}}{\sum_t GFCF_{Nj,t}} K_{Nj,0} \tag{4}$$

With subscript i being the region, j the sector, and N the total by country. The ratio applied to the national figure represents the average share of total GFCF in region i and sector j within total GFCF for sector j at the country level over the whole period. The average share was used in order to avoid any particular year to influence the results.

Depreciation rates

EU-KLEMS provides depreciation rates by sectors and ten assets, which don't vary by country and over time. Depreciation rates are shown for 34 NACE2 sectors. Therefore, there is the need to aggregate these data to obtain a depreciation rate for each one of the CE sectors. The procedure entails the following steps[3]:

1. For each of the EU-KLEMS sectors, computing the average share across time of nominal capital stock by assets within total nominal capital stock also from EU-KLEMS. Nominal capital stock is considered to ensure that the shares sum up to 1, since this would not happen with real capital stock because of different price indices used between sectors and the total economy.

$$\bar{s}_{a,j} = \frac{\sum_t^T \left(\frac{k_{t,a,j}}{k_{t,j}}\right)}{T} \tag{5}$$

   With subscript a denoting the asset, k the nominal capital stock and T the overall number of periods.

2. Multiplying these average shares by assets/sectors with the corresponding depreciation rate and summing, thus obtaining one depreciation rate for each EU-KLEMS sector as a weighted average of depreciation rates by asset, with weights being the shares computed in equation (3).

$$\delta_j = \sum_A \delta_{a,j} \bar{s}_{a,j} \tag{6}$$

   With A denoting the set of assets.

[3] This methodology is similar to the one followed in the Penn World Table (Feenstra, Inklaar, & Timmer, 2015)

3. For each of the EU-KLEMS sectors, computing the average share across time of nominal capital stock within the corresponding CE sector.

$$\bar{s}_j = \frac{\sum_t^T \left(\frac{k_{t,j}}{k_{t,CE}}\right)}{T} \quad (7)$$

With subscript CE denoting the CE sector.

4. Multiplying these average shares by sectors with the corresponding depreciation rate computed in point 2 and summing.

$$\delta_{CE} = \sum_J \delta_j \bar{s}_j \quad (8)$$

With J denoting the set of EU-KLEMS sectors within the CE sector.

Full breakdowns by sector and assets were available only for 14 countries (AT, CZ, DK, FI, FR, DE, IT, LU, NL, SK, SI, ES, SE and UK) in EU-KLEMS. The procedure outlined above was thus applied only to these Member States and BE, whose data were missing in EU-KLEMS and thus were obtained from the National Bank of Belgium. For all the remaining Member States, and in the absence of any better solution[4], the average of the depreciation rates in "similar" countries were applied. Namely: for BG, HR, CY, EE, HU, LV, LT, PL and RO the average of CZ, SI and SK was applied; for EL, the average of IT and ES was applied; IE was set equal to the UK; PT was set equal to ES.

The data source used for BE has a very similar breakdown to EU-KLEMS except for a few sectors. Two sectors (section G and H) are not further broken down as would be required to match the depreciation rates available from EU-KLEMS. To share those two sectors, data on GFCF coming from OECD STAN were used. Other sectors had to be summed to obtain the breakdown needed. Then, the same procedure outlined above was applied.

Computation of regional capital stocks

It is now possible to compute the capital stock series for each region. Given the initial capital stock, equation (1) is solved for each period.

Sense-checking results

Table 1 shows the comparison between the calculated values by country and the figures from AMECO. In 1995 they coincide since AMECO was taken as the starting estimate. Afterward, the totals computed are the sum of the regional figures estimated following the procedure detailed above, and therefore might differ from AMECO figures. Most of the estimates are broadly in line with AMECO by 2005, but the differences widen slightly by the end of the period, in 2016[5]. Countries whose estimates diverge significantly from AMECO are HU, LV, RO, SI and SK. In particular, the estimates for LV and SI are much higher than the figures in AMECO.

[4] Should more countries be added to EU-KLEMS in future years, the rules could be modified.
[5] It should also be noted that note that the current investment series being used won't exactly match AMECO's in 2016 since they were not produced with the latest update of AMECO. However, since the problem exists throughout the period, this should not have a major effect.

Table 1 Comparison between calculate values and AMECO

	Start period (1995)	Mid period (2005)	End period (2016)	Average
	(bn of 2010 euros)	Calculated value/AMECO	Calculated value/AMECO	Difference in depreciation rates(pp)
AT	741	1.01	1.05	0
BE	743	1.08	1.22	-2
BG	54	1.00	1.05	0
CY	23	1.15	1.16	-2
CZ	315	1.07	1.22	-2
DE	6377	1.01	1.12	-1
DK	471	1.10	1.22	-2
EE	16	1.01	1.06	0
EL	615	0.93	0.96	0
ES	2098	0.96	0.98	0
FI	424	1.11	1.24	-2
FR	4539	0.99	1.08	0
HR	60	1.14	1.18	-2
HU	140	1.25	1.39	-4
IE	233	0.96	1.06	0
IT	4258	0.99	1.04	0
LT	29	1.11	1.21	-2
LU	51	0.98	1.02	0
LV	19	2.00	2.89	-15
MT	9	1.07	1.14	-1
NL	1280	1.09	1.18	-1
PL	381	1.14	1.16	-2
PT	345	1.09	1.18	-1
RO	168	1.31	1.31	-4
SE	1001	0.81	0.81	2
SI	45	1.39	1.72	-6
SK	70	1.34	1.67	-6
UK	3896	0.92	0.91	1
EU28	28401	0.99	1.06	0

These discrepancies can be explained by the different implied depreciation rates. The last column of Table 1 shows the average difference throughout the period between the depreciation rates implied by this exercise and the implied depreciation rates from AMECO estimates. For example, for BE, our estimates are on average 2 percentage points lower than AMECO's ones each period, meaning that our capital stock estimates will be higher than (and thus gradually diverge over time from) AMECO's. These discrepancies cumulate each period and result, for some countries like LV, in large differences between our capital stock estimates and AMECO in 2016, as shown in the fourth column of Table 1. AMECO's capital stock estimates are obtained with the following formula:

$$K_t = K_{t-1} + GFCF_t - CFC_t \quad (7)$$

With CFC_t being consumption of fixed capital as obtained by the national accounts. The initial capital stock estimates are the same between AMECO and in this exercise, the investment series at the country level are also the same, therefore the differences shown in

Table 1 are due to much higher depreciation rates as implied by the CFC figures. (Pérez & García, 2014) compare depreciation rates for nine European countries, and show that AMECO's rate are generally the highest. The Penn World Tables show depreciation rates in the same order of magnitude as the ones obtained in this exercise, using a similar method (Feenstra, Inklaar, & Timmer, 2015). Therefore, it is seems likely that estimates based on national accounts yield higher implied depreciation rates than estimates based on asset composition. Notwithstanding such differences, it is reassuring to notice that for the EU28 aggregates figures of capital stocks are broadly similar and that the implied depreciation rates are in line.

Table 2 shows the comparison between the calculated values by country and the values for the 23 countries with available capital stock figures on EU-KLEMS. The computed values are broadly in line, but this time tend to be lower compared to EU-KLEMS. These differences are mainly due to different starting points. In this exercise, all the countries' starting points are AMECO's value in 1995, and these in some cases are quite different from the 1995 values in EU-KLEMS, as in the case of HU and LV. Other countries start in later years in EU-KLEMS, like SK which starts in 2004, making comparisons more difficult. Differences in implicit depreciation rates are present also in this case but seems to be somewhat more limited. Although in this analysis depreciation rates are taken from EU-KLEMS, those rates are not used to compute capital stocks within EU-KLEMS, therefore differences in depreciation rates are possible[6]. Overall, the figures of the capital stocks computed from this exercise seem to lie in between AMECO and EU-KLEMS, without being dramatically different in most cases taking also into account the differences in methodologies.

Table 2 Comparison between calculated values and EU-KLEMS

	Start period (1995)	Mid period (2005)	End period	Average
	(bn of 2010 euros)	Calculated value/EU-KLEMS	Calculated value/EU-KLEMS	Difference in depreciation rates(pp)
AT	741	0.93	0.93	1
CY	23	0.90	1.00	-1
CZ	315	0.89	0.92	2
DE	6377	0.97	0.98	0
DK	471	0.85	0.93	1
EE	16	0.91	1.02	1
EL	615	1.20	1.22	0
ES	2098	1.05	1.08	1
FI	424	1.05	1.15	-1
FR	4539	0.93	1.01	0
HU	140	0.59	0.86	2
IE	233	0.99	1.08	0
IT	4258	1.01	1.01	0
LT	29	0.66	0.78	2
LU	51	1.04	1.00	0
LV	19	0.48	0.62	3
NL	1280	0.96	1.07	-1
PL	381	1.41	1.53	-5
PT	345		1.02	-2

[6] See http://www.euklems.net/TCB/2018/Metholology_EUKLEMS_2017_revised.pdf , pages 8 and 9

	Start period (1995)	Mid period (2005)	End period	Average
	(bn of 2010 euros)	Calculated value/EU-KLEMS	Calculated value/EU-KLEMS	Difference in depreciation rates(pp)
SE	1001	1.01	0.90	2
SI	45	0.87	1.06	-2
SK	70	0.51	0.59	3
UK	3896	0.87	0.90	0

Note: End year is 2014 for CY, EE ,EL, HU, IE, IT, LT, LV, PL, PT and SE. For the others is 2015.

Error! Reference source not found. shows the computed estimates for regional capital stock at the NUTS2 level. The different colours follow the quartile of the distribution, meaning that lighter blue regions belong to the first quartile and darker blue regions belong to the last quartile. Eastern European regions generally belong to the bottom of the distribution, while the regions at the top of the distribution are concentrated in Italy, Germany, France, Spain, Ireland and the UK. However, also within those countries regional results vary, with some regions belonging to the lower quartiles.

Figure 1 Real net capital stock in NUTS2 regions in 2016

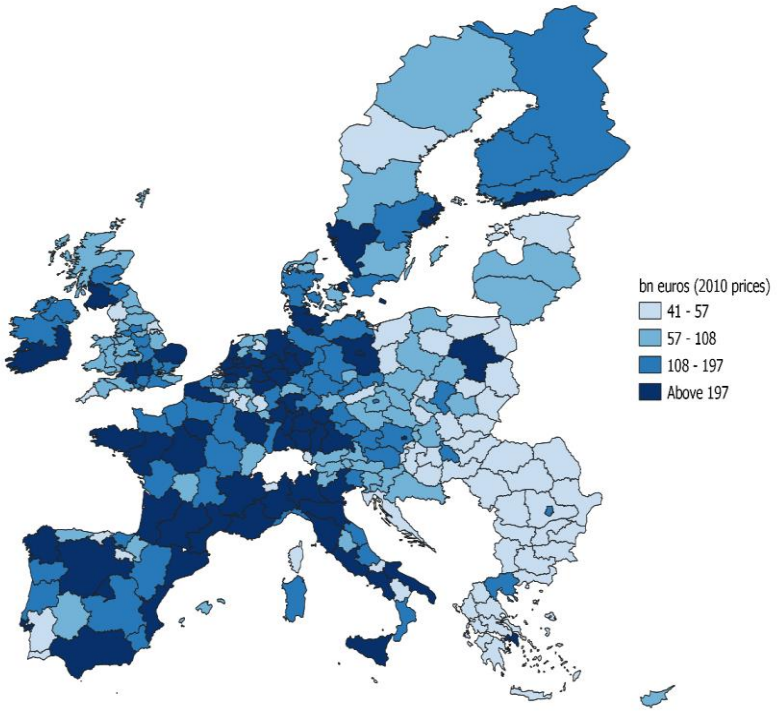


Figure 2 shows the growth in capital stock between 1995 and 2016. In this case, patterns are more clearly identifiable: the eastern European block experiences high growth, probably because of low initial levels of capital; the central-southern block instead grows comparatively less, probably because higher levels of initial capital; within the central block, the regions that grow more belong mainly to Spain, Netherlands, France, Austria and Denmark.

Figure 2 Total growth in real capital stock between 1995 and 2016

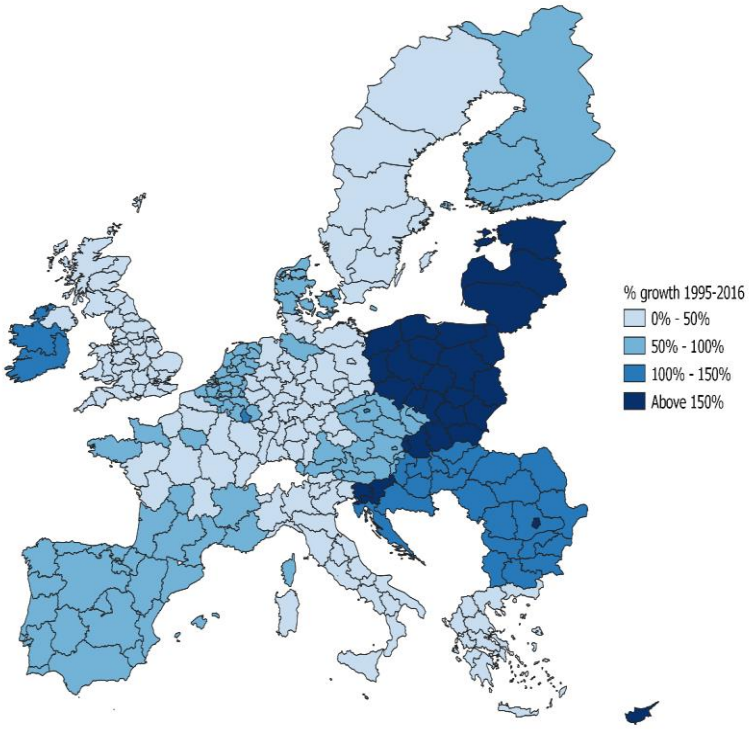
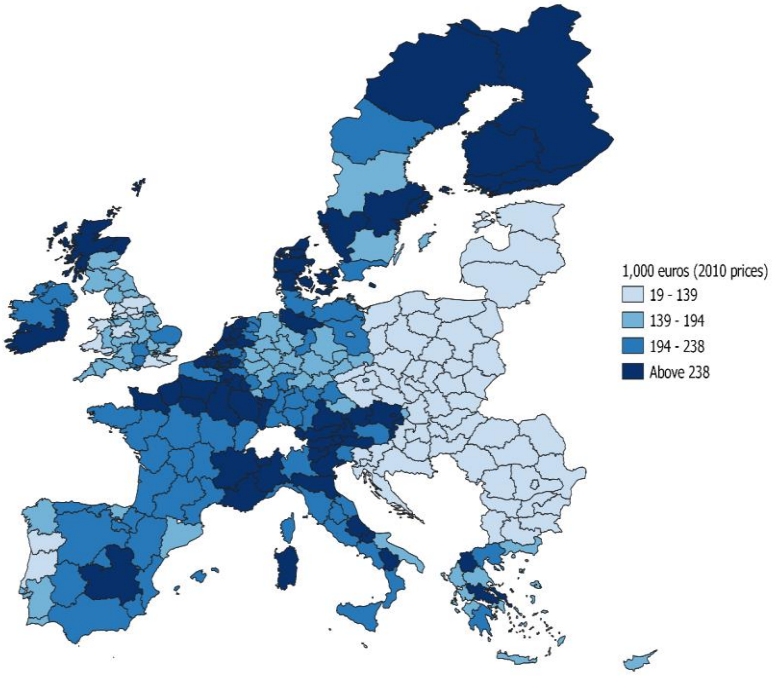


Figure 3 Capital-labour ratio in 2016



Error! Reference source not found. show the capital-labour ratio in 2016. Also in this case colours follow the quartiles. The lowest levels of capital-output ratio are concentrated in Eastern Europe (with exceptions located in Portugal and the UK). Regions with capital labour-ratios in the middle quartiles are concentrated in western Europe. Regions with the highest values of capital-labour ratios are not concentrated in a specific area, with instances of such regions in the north, the centre and the south of Europe.

Figure 4 shows capital stock in the manufacturing sector by quartiles. The regions with highest concentration of capital in manufacturing are to be found in different areas of Europe, particularly in IT, DE, ES and FR. Eastern Europe, although also in this case is generally at the low-end of the distribution, features also regions at the top, mainly in PL.

Figure 4 Manufacturing capital stock in 2016

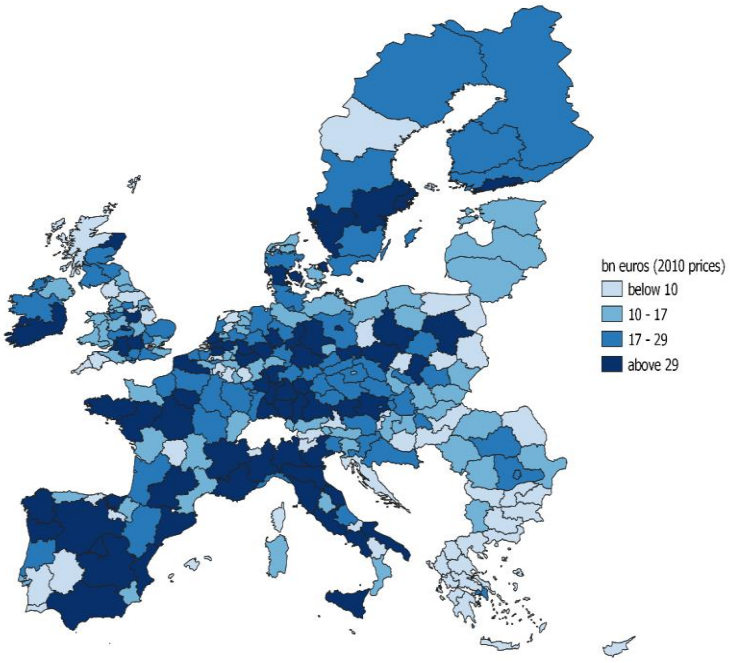


Figure 5 shows capital stock in the agriculture sector by quartiles. The centre-southern block has the highest concentration of capital, but also the regions in the north of Europe belong to the top quartile. Also Eastern Europe has some regions in the top two quartiles.

Figure 6 shows capital stock in financial and business services by quartiles. In this case, capital is concentrated among clusters within countries such as IT, DE, FR, UK and IE, with most of the regions outside these countries belonging to the lowest two quartiles.

Figure 7 shows capital stock in the construction sector by quartiles. Capital in the construction sector is concentrated mainly in the south of Europe, IE, UK and a few regions in RO and BG. The bottom percentile is filled mainly by eastern European regions.

Figure 8 shows capital stock in wholesale retail, accommodation, transportation and ICT by quartile. Capital stock in this set of sectors is quite diffused, with some concentration in IT, FR, ES, UK, IE

Figure 9 shows capital stock in non-market services sector. It can be seen that for this sector capital is highly concentrated in western Europe.

Figure 5 Agriculture capital stock in 2016

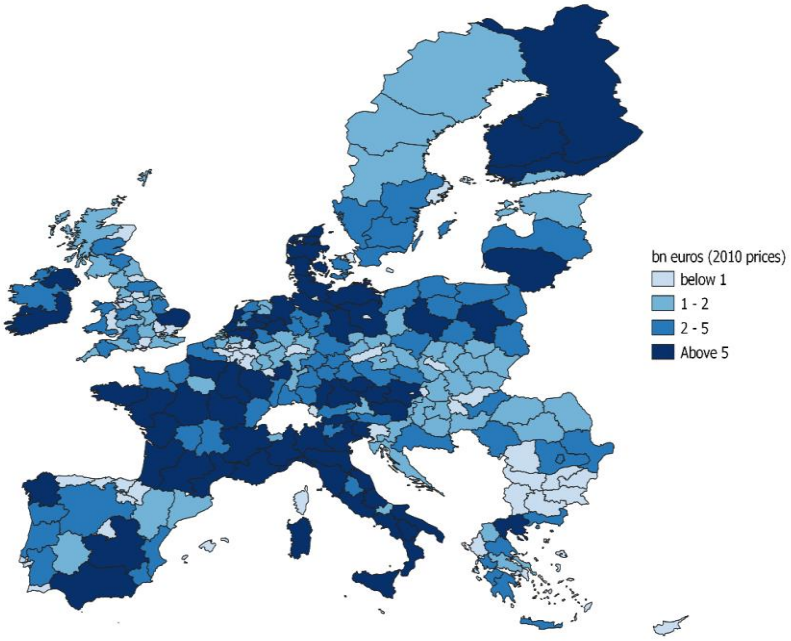


Figure 6 Financial and business services capital stock in 2016

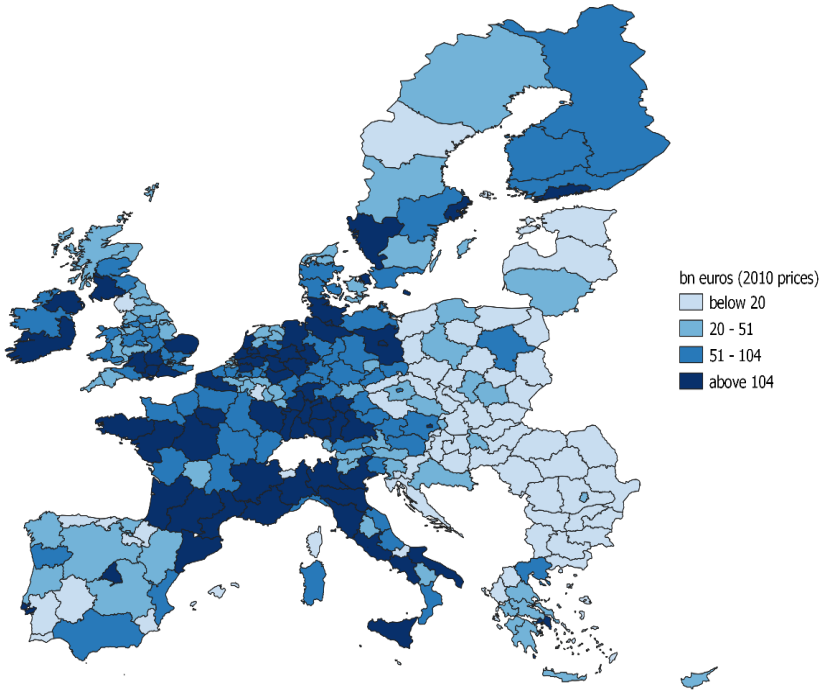


Figure 7 Construction capital stock in 2016

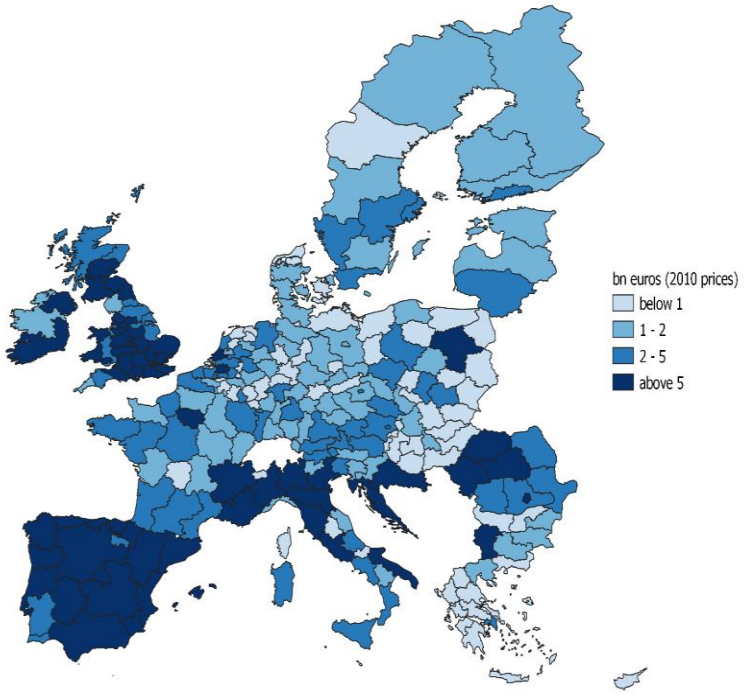


Figure 8 Wholesale retail, accommodation, transportation and ICT capital stock in 2016

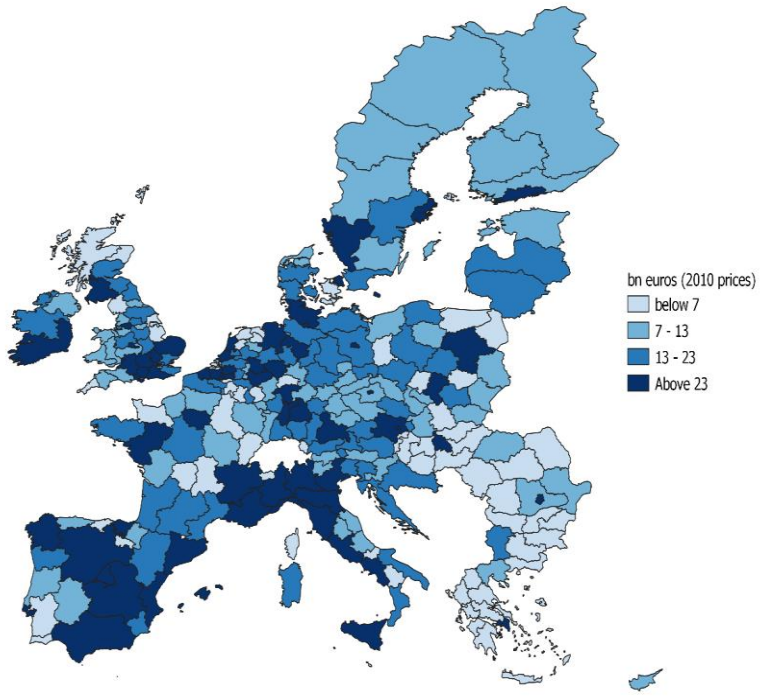
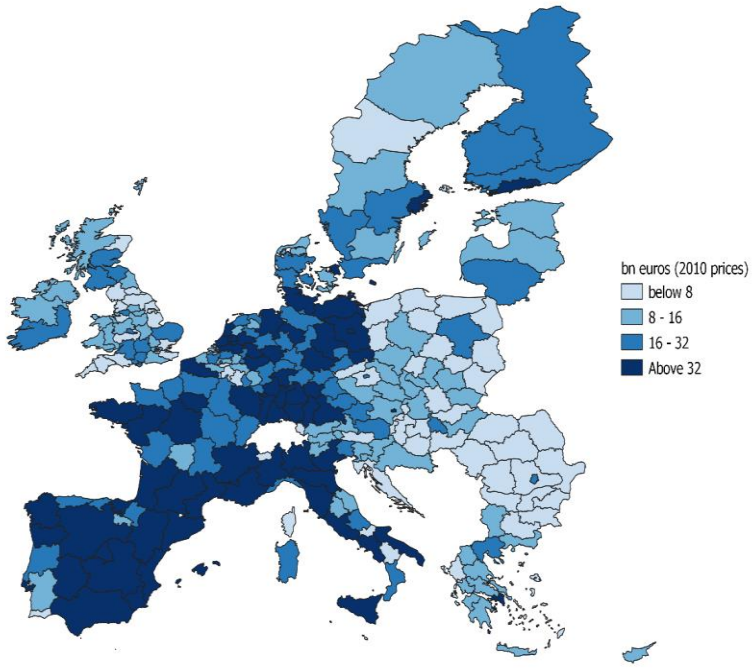


Figure 9 Non-market services capital stock in 2016



The maps presented so far have showed the capital stock distribution by quartiles. However, to better appreciate the order of magnitudes, it is useful to focus on the region with the highest amount of capital stock. Table 1Table 3 shows the first 20 regions by amount of capital stock in each sector. Comparing the quartile values in the maps and the values in the table, it is possible to see that the top regions outclass the others in term of magnitude in all sectors. For example, in the manufacturing sectors the cut-off value of the last quartile was 29 bn, while the top performing region has almost 8 times the capital stock. Moreover, it is also possible to see that the top performing regions belong mostly to a small subset of countries: FR, IT, DE and ES.

Conclusions

The exercise described in this note describes the procedure for producing real net capital stocks at the NUTS2 regional level. Total capital stock figures at the country level are shared using regional investment series. Then, depreciation rates are computed taking into account the asset composition of investments in each country. Finally, the Perpetual Inventory Method is applied to obtain series of capital stock at the NUTS2 level. The PIM is widely used in the literature and by statistical offices around the world, and recommended by the OECD (OECD, 2009).

The AMECO database is used to obtain figures for initial capital stocks. Regional investment series computed by Cambridge Econometrics are used to share totals and to run the PIM equation. EU-KLEMS data, with a small contribution of OECD STAN, are used to compute depreciation rates. Both AMECO and EU-KLEMS are verified international sources, while the investment series compute by CE have undergone a rigorous quality assurance process.

The estimates of regional capital stock paint a coherent picture among countries and sectors. Overall, capital stock is concentrated among regions belonging to the biggest European economies, namely France, Italy, Germany and Spain, with eastern Europe

generally lagging. However, not all regions within those countries fare equally better, especially when looking at different sectors, suggesting patterns of specialisation within countries. Eastern Europe has grown the most over the whole period because of low level of initial capital stocks, while the more mature Western Europe has grown more slowly. High capital-labour ratios are focused in specific areas within the centre, the south and the north of Europe, with eastern Europe showing lower values. Capital stocks in the Manufacturing and WRTAFIC sectors are relatively spread across Europe; Agriculture and FBS are relatively concentrated in certain areas; Construction and Non-market services are very concentrated in specific areas. Country totals obtained as sums of the single regions lie in between AMECO and EU-KLEMS estimates and are broadly comparable, providing reassurance on the robustness of the results.

The capital stock estimates can be easily updated with any new release of the underlying databases using the methodology outlined in this note, potentially including new features of the data (e.g. should new capital stock figures be added in EU-KLEMS).

Table 3 Top-20 regions in each sector in 2016 (million euros)

Rank	Total capital		Manufacturing		Agriculture		FBS		Construction		WRTAFIC		Non-market services	
1	FR1	2,149,548	ITC4	213,437	ITC4	31,307	FR1	1,475,002	ES61	82,353	FR1	222,878	FR1	295,361
2	ITC4	1,111,234	DE11	145,843	ITH3	29,871	DE21	591,195	ES51	74,070	ITC4	183,609	ES61	224,054
3	DE21	877,273	FR1	136,848	ITC1	19,853	ITC4	571,320	ES3	61,246	IE02	124,792	ES3	214,693
4	FR71	680,463	ES51	130,357	ITH5	16,954	FR71	418,159	RO32	55,385	ES51	111,560	ES51	174,155
5	ES3	652,772	ITH5	125,663	ITF3	14,510	FR82	332,543	ES52	53,376	ITI4	107,753	NL33	122,140
6	ES51	648,065	ITC1	113,148	FR61	14,194	ITH3	311,137	UKI3	46,524	ES3	101,194	ES52	118,469
7	ES61	567,615	DE21	108,553	NL41	13,097	DE71	302,412	ES41	33,804	ES61	96,797	FR71	111,136
8	DE11	552,456	ITH3	93,942	ITI1	11,866	DE11	287,077	ES11	29,742	UKI3	75,729	FR82	101,652
9	ITH3	542,346	FR71	88,509	FR52	10,914	ITH5	271,070	ES42	27,409	PL12	75,608	DE21	95,008
10	ITI4	528,195	IE02	72,578	ITF4	10,695	DEA1	266,968	ITC4	22,743	DE21	70,753	ITC4	88,819
11	FR82	521,187	DEA1	70,181	AT12	10,045	NL33	264,485	ES21	18,920	SE11	68,929	ITI4	87,817
12	ITH5	508,805	ES52	67,825	ITI4	9,935	DEA2	257,884	UKJ1	17,504	DK01	64,034	ES41	81,740
13	DE71	499,162	ITI1	67,039	ITG1	9,844	ITI4	253,629	ES24	17,482	DEA1	63,019	NL32	78,826
14	NL33	494,419	DE71	65,303	DE94	9,837	DE6	251,728	FR1	17,473	ES52	62,321	FR3	73,446
15	ITC1	484,312	ITI4	61,695	FR21	9,815	ITC1	239,055	UKH1	16,142	EL3	62,300	ES11	72,717
16	DEA1	469,996	SE23	59,594	NL33	9,566	NL32	228,848	UKM2	15,471	ITC1	62,107	DE3	70,734
17	IE02	456,750	DEA2	59,319	ITG2	9,466	ITF3	218,198	ES53	14,254	DE71	60,578	NL41	69,569
18	DEA2	440,847	SE11	58,362	FI1D	9,313	ES3	217,918	UKN	14,173	DE6	60,248	DE11	68,947
19	NL32	396,032	ES3	57,376	NL22	9,211	IE02	215,093	ES62	13,810	UKJ1	59,721	ES42	68,719
20	ES52	380,033	ES61	56,052	ES61	9,158	AT13	200,931	UKJ3	12,686	AT13	59,343	DE71	66,765