

Estimating the Capital Stock for the NUTS2 Regions of the EU27

**Research based on a pilot study for
the European Commission, DG Regional Policy**

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Abstract:

To identify and target lagging regions policy makers require statistics to be produced at regional level. In many instances it is not possible simply to compare regional-level statistics produced by Member State national statistical offices as there is variation in the methods and assumptions used to produce them. Capital stock statistics at the national level have been available for most countries of the EU27 for some time, but statistics at the regional level are absent for almost all countries. Where they do exist the methods used to produce them are not consistent across countries.

This paper describes the findings from a pilot project to assess the feasibility of producing *comparable* estimates of the capital stock at NUTS2 regional level for the EU27. The project was carried out on behalf of DG Regional Policy of the European Commission. The paper outlines the method and data employed, and the techniques used to fill missing values. The approach is a Perpetual Inventory Method based on that outlined in the OECD Manual (2001; 2009) on capital estimation, and the data employed were taken from Eurostat or other publicly available sources wherever possible. The paper analyses the estimates produced and suggests how they can be improved and the method used to produce them refined in the future.

Keywords: Capital stock, NUTS2, Estimation.

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1 Introduction

In order to identify and target lagging regions as part of cohesion policy, policy makers require capital stock estimates at regional level. The European Commission wishes to use regional capital stock estimates as an input to help monitor the impact of cohesion policies and to separate regions in need of further support from those which have now developed to a satisfactory level.

The need for regional level estimates has been heightened by the successful development of many regions in accession countries. In the past, countries joining the EU such as Spain qualified for cohesion funding as a single unit. However, the regions of these countries have diverged as their economies have developed and countries no longer qualify as a single entity for support. Some regions in accession countries have become as developed as regions in founder members of the EU, while others have remained lagging. It is necessary to be able to differentiate between the two and to target support accordingly.

In order for regional capital stock statistics to play a role in this process they must be comparable. Not only do most countries not produce regional estimates; those estimates which are in existence are not produced in a comparable way. Indeed, even the capital stock statistics which are widely available at the national level are produced by Member States using varying assumptions, thus compromising comparability. It is not possible, therefore, simply to disaggregate national level estimates to regions and compare across the EU.

For these reasons, from January 2009 to February 2010 a pilot study to investigate the feasibility of producing comparable capital stock estimates for the EU27 at NUTS2 regional level was carried out by Cambridge Econometrics on behalf of DG Regional Policy of the European Commission. This paper describes the study and its findings.

Section two briefly describe the results from a survey of national statistical offices to ascertain what methods were used to produce capital stock estimates, along with the method employed to produce comparable regional capital stock estimates for the EU27 as part of this study. The approach taken was a Perpetual Inventory Method based on that outlined in the OECD Manual (2001; 2009) on capital estimation.

As part of the survey of NSOs a clear picture of data availability was established. Section three describes both data availability and the methods used to complete certain indicators and dimensions of analysis which were required by using the PIM method. The data employed were taken from Eurostat or other publicly available sources wherever possible.

Section four presents and analyses results. Finally, in section five we make some concluding remarks and suggest ways in which the estimates can be improved and the method refined in the future.

2 Methodology

2.1 Introduction

One of the first tasks in the research was to undertake a survey of all the European national statistical offices (NSOs) in order to establish what methods were used to construct national, and, if available, regional capital stock estimates. Once this was established, some common ground between methods and assumptions could be established with a view to adopting a single, unifying framework for the estimation process.

2.2 Results from NSO survey

The NSO survey found that all responding countries that carried out capital stock estimation employed the Perpetual Inventory Method (PIM). However, while there was harmony between the surveyed countries in this respect, there was considerable variation in the assumptions that are used as inputs into the standard approach. Different NSOs employed varying assumptions regarding, for example, average service lives and mortality functions. The sector, institutional sector and asset-type disaggregation of capital stock estimates also varied from country to country, with disaggregation across these dimensions available for some countries but not for others. These details are described further in Section 2.4. For now, the following section describes the PIM methodology and its underlying assumptions in more detail.

2.3 The Perpetual Inventory Method (PIM)

The method employed to create regional capital stock estimates for this project is based on the ‘standard’ PIM outlined in the OECD Manual (2001; 2009). The method is also similar to that employed recently by TNO to produce NUTS2 level estimates for the Netherlands.

The method begins with the calculation of the gross capital stock, as shown in equation 1 below.

$$(1) \quad CS_t = \sum_{i=0}^{d-1} I_{t-i}$$

where CS_t is the capital stock in an asset in year t

I_t is investment in year t

d is the assumed service life of the asset

This values the capital at its historic cost (its cost at purchase). To revalue to prices in year t the equation is modified as in equation 2 below.

$$(2) \quad CS_{t,t} = \sum_{i=0}^{d-1} I_{t-i} * P_{t-i,t}$$

where $CS_{t,t}$ is the capital stock in the asset in year t, in prices of year t

$P_{t-i,t}$ is the price in year t-i with year t as the price base-year

The net capital stock is the gross capital stock shown in Equation 1 and Equation 2 minus the accumulated consumption of fixed capital. This is shown in Equation 3 below.

$$(3) \quad NCS_{t,t} = \sum_{i=0}^{d-1} I_{t-i} * P_{t-i,t} * (1 - i/d)$$

where the inputs are as in Equation 1 and 2, with the addition of $(1 - i/d)$ which represents the writing off of consumed capital and where

d is the assumed service life of the asset

and i is the current year the asset is at within its service life (its age)

Under Equation 3 the writing off of consumed capital (depreciation) is linear in nature, with an adjustment in the first and last year of the asset's service life to ensure that write off occurs in the middle of the year on average. The method of depreciation (the writing off of consumed capital) therefore doubles up as the method of mortality and removal from the stock. The entire cohort is assumed to be removed from the capital stock immediately when its value has depreciated to zero in the final year of its service life. The assumed mortality function is therefore 'Simultaneous Exit' (OECD Manual, 2001, para.6.51).

Linear depreciation has been shown by Maddison (1992) and Ward (1976) to represent a useful approximation of reality when calculating the capital stock. However, the OECD Manual (2001, para.6.64) suggests that Simultaneous Exit is not a very realistic retirement pattern and suggests that bell-shaped patterns, such as the so-called 'Winfrey curves', are more realistic.

In addition to estimates produced using Simultaneous Exit, estimates were also produced using two alternative mortality methods, the Winfrey S-2 function and the Winfrey S-3 function. These functions are stated in the OECD Manual (2001, para.6.56) to be two of the most widely employed. Furthermore, the Winfrey S-3 function was shown to be the most commonly employed by EU countries in the survey of EU national statistical offices described in the previous section.

There are eighteen Winfrey curves in total: six 'S' or symmetric curve, six 'L' or left skewed curves and six 'R' or right skewed curves. The number in the curve's moniker refers to the relative flatness of the curve with S1 being the flattest symmetric curve and S6 being the tallest (i.e. most closely distributed around the average service life).

The curves are described as in equation 4 below.

$$(4) \quad F_T = F_0(1 - T^2 / a^2)^m$$

where F_T is the proportion of the cohort which retires in time period T

F_0 is the proportion of the cohort retiring at the average retirement age

the parameter a determines how the time periods correspond fractionally to the average service life (e.g. $a = 10$ means the time periods are deciles around the average service life)

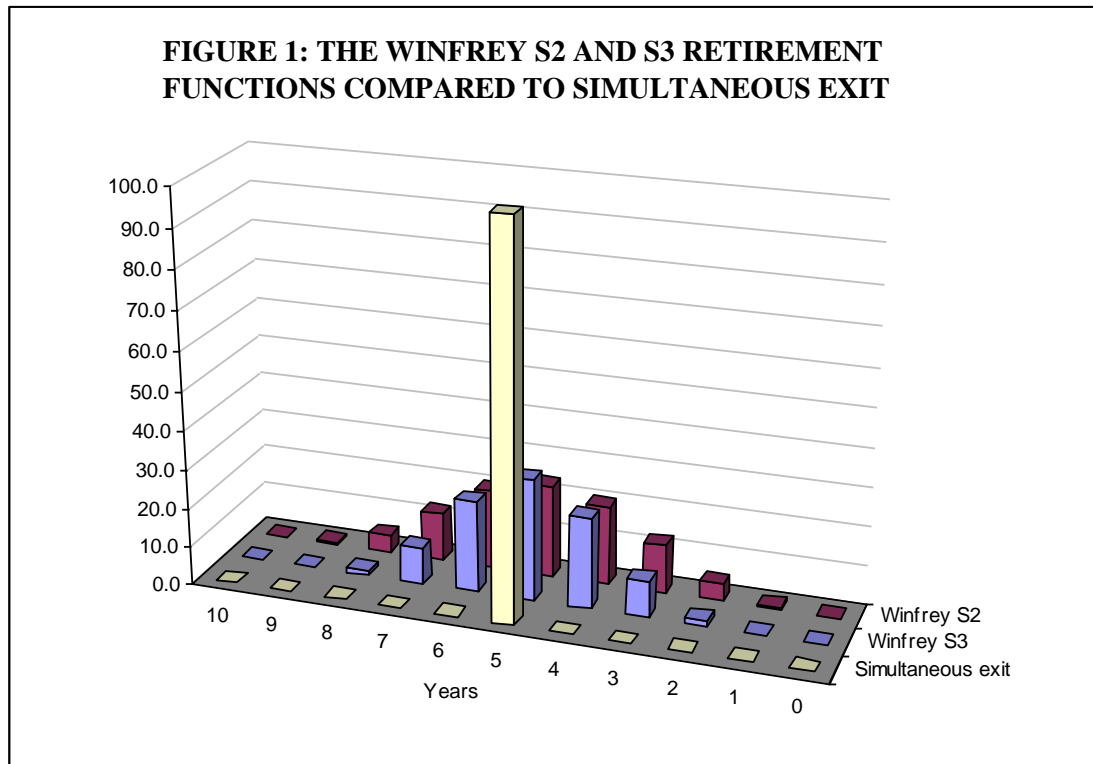
and the parameter m determines the relative flatness of the function

The Winfrey S-2 and S-3 curves used to produce estimates as part of this project have retirement from the stock occur according to a symmetrical pattern where the parameters are as in Table 1 below (OECD Manual, 2001, para. 6.56).

TABLE 1: PARAMETERS FOR WINFREY S-2 AND S-3 CURVES

	Winfrey S-2	Winfrey S-3
F_0	11.991	15.610
a	10	10
m	3.7	6.902

To summarise, under Simultaneous Exit all assets of the same cohort retire and are removed from the capital stock at the same time. In the Winfrey set of retirement functions the retirement pattern is bell-shaped around the average service life and assets do not, therefore, all retire at the same time. The time period around the average service life is broken into units, typically deciles, and a probability of retirement is calculated for each decile and applied to the cohort of assets. The retirement is therefore spread around the average service life as shown in Figure 1 below.



Combining a separate retirement function with depreciation is more complicated than the straight forward way in which depreciation results in Simultaneous Exit in Equation 3 above. The combination of a separate retirement function with linear depreciation is expressed as in Equation 5 below.

$$(5) h_n = \sum_{T=n}^{T_{\max}} g_n(T) F_T$$

where T_{max} is the maximum possible length of service of a particular asset type

$g_n(T)$ is the depreciation schedule of an asset with service life T

F_T is the probability of retirement at age T

h_n is the combined depreciation and retirement function

This shows that the value of the capital stock in time period 'n' is calculated as the sum of the values of the remaining assets of differing service lives, weighted by their probabilities according to the retirement function. Table 2 shows how h_n is calculated for an asset with an average service life of 5 years for the Winfrey S2 retirement function and linear depreciation. The first two columns represent the retirement function, with the numbers 1-10 in the first column (T) being the asset service life and the numbers in the second column the probability of an asset retiring at this age. The value of the capital stock h_n in a particular year 'n' is calculated as the sum of the values in the column 'n'.

The values in each column of Table 2 are calculated by multiplying the probability of retirement by the depreciation function. An example of the calculations are shown in column 3 ($n=3$) of the table. Column 3, row 6 corresponds to the value of a 6-year asset after 3 years weighted by the proportion of 6-year assets in the total stock. By summing up all these cells in column 3 we get the total value of that cohort of capital stock in year 3.

TABLE 2: COMBINING WINFREY S2 AND LINEAR DEPRECIATION*

T	Probability of retirement	Probability of retirement												
		0	1	2	3	4	5	6	7	8	9	10		
0	0	0.0												
1	0.5	0.5	0.0											
2	4.6	4.6	2.3	0.0										
3	12.5	12.5	8.3	4.2	$0/3*12.5=0$									
4	20.5	20.5	15.4	10.2	$1/4*20.5=5.1$	0.0								
5	23.8	23.8	19.1	14.3	$2/5*23.8=9.5$	4.8	0.0							
6	20.5	20.5	17.1	13.7	$3/6*20.5=10.2$	6.8	3.4	0.0						
7	12.5	12.5	10.7	8.9	$4/7*12.5=7.1$	5.4	3.6	1.8	0.0					
8	4.6	4.6	4.0	3.4	$5/8*4.6=2.9$	2.3	1.7	1.1	0.6	0.0				
9	0.5	0.5	0.5	0.4	$6/9*0.5=0.4$	0.3	0.2	0.2	0.1	0.1	0.0			
10	0	0.0	0.0	0.0	$7/10*0=0$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Value(H_n)	100	77.3	55.1	35.3	19.5	8.9	3.1	0.7	0.1	0.0	0.0	0.0	0.0

*The average service life is five years in this example

2.4 Key assumptions

As has been made clear in the preceding section, a number of assumptions are necessary as inputs into the PIM methodology. As part of the NSO method survey that was undertaken, once it was established the PIM was the predominant, if not only, method that was being used, a second set of questions was asked to establish the underlying assumptions. These assumptions were concerned with the following inputs:

- average service life of assets;
- depreciation method;
- retirement function.

Average service lives With respect to average service lives of assets, the results from the NSO surveys showed a range of assumptions, with little pattern to discern and often no modal dominance. For this reason, the following median service life was taken for the asset type disaggregation to be used in the study:

- Metal products & machinery: 14 years
- Transport equipment: 18 years
- Housing construction: 68 years
- Other construction work: 50 years
- ‘Other’ assets: 38 years

The asset type ‘Other’ is used by national statistical offices as a kind of catch-all category in which each office has placed all the asset types not relating to any of their main categories. The definition of ‘Other’ thus varies greatly across NSOs and the service life assumptions employed are therefore not comparable. However, an assumed service life was still required for the asset type ‘Other’ if capital-stock estimates were to be produced for it. Since the definition of ‘Other’ is so varied across the surveyed countries it was simply assumed that the service life for this asset type is equal to the average assumed service lives for the other four asset types as shown above.

Some work was also undertaken to evaluate how the NSOs arrived at their average service life values. Many NSOs used a combination of methods. For example, NSOs that use tax lives as a starting point for their estimates recognise that tax lives are deliberately under-estimated in order to encourage investment, and so the NSOs subsequently increased the estimates using expert evaluation. In most cases service-life assumptions are arrived at either by use of a survey (the most stringent approach) or through the use of expert evaluation, rather than by simply adopting the values used by another country.

Depreciation function The depreciation function dictates the manner and rate at which the value of an asset declines over time. It is a key assumption for capital stock estimation and in the basic Perpetual Inventory Method applied for the main set of estimates constructed in this study (using a Simultaneous Exit retirement function) it doubles as a retirement pattern too (because assets are assumed to have been entirely removed from the stock as soon as they have been depreciated to zero). Because it is such a significant assumption information was widely available from national statistical offices regarding its use and many responses were achieved. The data show that by far the most common method of depreciation is the straight-line or ‘linear’ method, with only two countries using an alternative method to depreciate.

Retirement function The retirement function is used to remove aged stock from the capital-stock estimates. While information on the assumed retirement function was widely available from national statistical offices that do actually apply one (not all do), the methods used varied widely. From a total of 16 responses, eight alternative specifications of retirement function were employed by national statistical offices. While no retirement

distribution is overwhelmingly the most commonly employed, the Winfrey S3 function is used in four cases which is more than any of the other retirement patterns. As has been described in Section 2.3 above, the combination of linear depreciation and the Winfrey class of retirement functions has been experimented with in this study as an alternative to the more simple (and less realistic) assumption of simultaneous retirement.

2.5 Summary

There are alternatives to the method for calculating the capital stock described in this section and employed to calculate the estimates described subsequently. More detailed methods are, for example, outlined in the OECD Manual (2001; 2009). However, these methods have the disadvantage of requiring a greater number of inputs and assumptions. The method outlined above is relatively simple. Because of this simplicity it requires relatively few inputs and could therefore be applied to all EU countries, even where a scarcity of data exists.

3 Data Survey, Collection and Processing

3.1 Introduction

In order to produce capital stock estimates the PIM requires two main data inputs (not including key assumptions which have already been discussed).

Firstly, unless a time-series of Gross Fixed Capital Formation (GFCF) is available which goes back further than the longest-lived asset, it is necessary to construct a base-year capital stock estimate on which to begin the PIM. Since the longest-lived assets (usually dwellings) have assumed service lives approaching 70 years or more, it was highly unlikely that a full GFCF time-series would be available. Indeed, where available, Eurostat only has GFCF time-series at NUTS2 level going back to 1995. For this reason the estimates analysed below begin in this year and it is therefore necessary to produce a base-year capital stock estimate for 1995 on which to begin the PIM's process of adding GFCF and subtracting consumed capital and retirements. The process by which the base-year capital stock for each country was constructed is described in a subsequent sub-section.

The second of the main inputs is a set of estimates for gross GFCF disaggregated by industrial sector and asset. Since the main reason for creating the estimates examined here was to ascertain the feasibility of producing *comparable* statistics at the regional level, it was decided that the same data sources should be used wherever possible. The first source for data to construct GFCF time-series was therefore the EU KLEMS database (EU KLEMS, 2010). A description of the alternative sources and the methods used to construct a complete set of disaggregated GFCF data is the focus of the second part of this section.

3.2 Data survey

Alongside a review of available Eurostat data, NSOs were also surveyed for availability of the required data as it quickly became obvious that Eurostat could not cope with all the demands placed upon it, particularly when it came to regional-level data.

Investment data

National level Eurostat defines GFCF as: 'Million EUR (SA). Gross fixed capital formation (GFCF, ESA 1995, 3.102) consists of resident producers' acquisitions, less disposals, of fixed assets during a given period plus certain additions to the value of non-produced assets realised by the productive activity of producer or institutional units. GFCF includes acquisition less disposals of, e.g. buildings, structures, machinery and equipment, mineral exploration, computer software, literary or artistic originals and major improvements to land such as the clearance of forests. Values are seasonally adjusted (SA).'

At the national level, Eurostat produces GFCF estimates for the EU27 broken down by asset type and industrial sector. The GFCF data by industry are divided into categories according to the industry in which the assets are being used as means of production. The three industries for which the data are available at national level are summarised in Table 3.

TABLE 3: CLASSIFICATION OF INDUSTRIES

Industry	SIC code	Description
Agriculture	A-B	Agriculture, forestry and fishing (A) and mining and quarrying (B)
Manufacturing	C-F	Manufacturing (C), electricity and gas supply (D), water supply (D) and construction (F)
Services	G-P	Wholesale and retail trade (G), transport (H), accommodation and food service activities (I) information and communication (J), financial and insurance activities (K), real estate activities, (L) professional, scientific and technical activities (M), administrative and support service activities (N), public administration and defence (O) and compulsory social security and education (P)

The GFCF data from Eurostat are also available according to the type of asset that has been invested in. There are five asset types available as shown in Table 4.

TABLE 4: CLASSIFICATION OF ASSET TYPES

Asset type	ESA 95 code	Description
Metal Products & Machinery	AN.11132	Machinery and equipment not elsewhere classified. Examples include machinery for the production and use of mechanical power (except aircraft, vehicle and cycle engines), other general purpose machinery, agricultural and forestry machinery, machine-tools, office computers and electrical apparatus.
Transport Equipment	AN.11131	Equipment for moving people and objects. Examples include motor vehicles, trailers and semi-trailers ships railway and tramway locomotives and rolling stock aircraft and spacecraft and motorcycles, bicycles, etc.
Dwellings	AN.1111	Buildings that are used entirely or primarily as residences, including any associated structures, such as garages, and all permanent fixtures customarily installed in residences.
Other Construction	AN.1112	Non-residential buildings (AN.11121) eg warehouse and industrial buildings, commercial buildings, buildings for public entertainment, hotels, restaurants, educational buildings, health buildings, etc., and Other structures (AN.11122) eg highways, streets, roads, railways and airfield runways bridges, elevated highways, tunnels and subways waterways, harbours, dams and other waterworks long-distance pipelines, communication and power lines local pipelines and cables, ancillary works constructions for mining and manufacture and constructions for sport and recreation.

Asset type	ESA 95 code	Description
Other Assets	AN.112, AN.114	Intangible fixed assets (AN.112) consists of mineral exploration (AN.1121), computer software (AN.1122), entertainment, literary or artistic originals (AN.1123) and other intangible fixed assets (AN.1124), defined as new information, specialised knowledge, etc., not elsewhere classified, whose use in production is restricted to the units that have established ownership rights over them or to other units licensed by the latter. Cultivated asset (AN.114) includes livestock for breeding, dairy, draught, etc. and vineyards, orchards and other plantations of trees yielding repeat products that are under the direct control, responsibility and management of institutional units.

Note that the industrial breakdown and asset type breakdown are published separately by Eurostat, meaning that GFCF for each industry are not available with an asset type breakdown or vice versa.

Table 5 summarises the results of the data survey of Eurostat and NSO data at National level. The obvious finding is that current price data are much more available than their constant price equivalents, particularly when it comes to disaggregation by industry.

TABLE 5: AVAILABILITY FOR NATIONAL INVESTMENT DATA

Country	Totals		Industry		Asset	
	<i>Value</i>	<i>Real</i>	<i>Value</i>	<i>Real</i>	<i>Value</i>	<i>Real</i>
AT	1995-07	1995-07	1995-06*	na	1995-07	1995-07
BE	1995-07	1995-07	1995-04	na	1998-07*	na
BG	1995-07	1995-07	1998-98	na	Na	na
CY	1995-07	1995-07	1995-03	na	1995-07	1995-07
CZ	1995-07	1995-07	1995-02*	na	1995-07	1995-07
DE	1995-07	1995-07	1995-04	na	1995-07	1995-07*
DK	1995-07	1995-07	2000-07*	na	1995-07	1995-07
EE	1995-07	1995-07	1995-05	na	1995-07	2001-07
ES	1995-07	1995-07	1995-03	na	1995-07	1995-07
FI	1995-07	1995-07	1995-04	na	1995-07	1995-07
FR	1995-07	1995-07	1995-03	na	1995-07	1995-07
GR	2000-07	2000-07	1995-04	na	2000-07	2000-07
HU	1995-07	1995-07	1995-04	na	1999-07	2000-07
IE	1995-07	1995-07	1995-04	na	1995-07	1995-05
IT	1995-07	1995-07	1995-04	na	1995-07	1995-05
LT	1995-07	1995-07	1995-04	na	1995-07	1995-07
LU	1995-07	1995-07	1995-07*	na	1995-07	1995-07
LV	1995-07	1995-07	1998-05	na	1995-07	Na
MT	1995-07	2000-07	1995-04	na	1995-07	Na
NL	1995-07	1995-07	1995-04	na	1995-07	1995-07
PL	1995-07	1995-07	1995-04	na	1995-07	1995-07
PT	1995-07	1995-07	1995-04	na	2000-06	2000-06
RO	1995-07	1995-07	2003-04	na	2000-06	2000-06

Country	Totals		Industry		Asset	
SE	1995-07	1995-07	1995-04	na	1995-07	1995-07
SI	1995-07	1995-07	2000-04	na	1995-07	1995-07
SK	1995-07	1995-07	1995-04	na	1995-07	1995-07
UK	1995-07	1995-07	1995-00	na	1995-06	1995-06
% cover	98%	96%	69%	0%	89%	76%

* From National Statistics Office

In addition to Eurostat and national sources, the AMECO database contains GFCF data for the EU27 countries at the national level without breakdown by industry or asset type. AMECO is the annual macro-economic database of the European Commission's Directorate General for Economic and Financial Affairs (DG ECFIN). The main data source is Eurostat (the Statistical Office of the European Commission), complemented, where necessary, by other appropriate national and international sources. These data are available in both constant and current prices and are complete for the years 1995-2007 for all the EU27 countries. AMECO also produces GDP deflators broken down by industry. Both the GFCF data and the GDP deflators produced by AMECO are used in the filling methodology outlined below.

Regional level For the NUTS2 regions, Eurostat has total GFCF and data broken down by industry in current prices only with incomplete coverage. There are no data by asset type. For most countries, there are at least some data by industry for every NUTS2 region, although not for the whole time period required. For the entire EU27, 71% of the totals figures and 68% of the figures by industry are available at NUTS2 level for the period 1995-2004. This means that for our required period of 1995-2007 there were 53% of the totals data and 54% of the data by industry.

Capital stock data To recap, the Gross Fixed Capital Formation estimates employed in this project begin in 1995 and, so, a 'base-year' capital stock estimate is required for each country for this year.

National level The EU KLEMS database contains capital stock estimates by the required asset and industry disaggregation for many of the countries required for this project. Therefore, since they have used harmonisation procedures to ensure the data are on a comparable basis, these base year estimates have been used wherever available. Where the country in question was not covered by the EU KLEMS database, national sources were used. Where national data were not available, alternative filling in mechanisms were used as described below.

Regional level The data from EU KLEMS are only available at the national level and therefore other data sources were required to produce estimates at the regional level. If there was no NUTS2 data available from any source, then a GVA scaling method was used. The ratio of capital stock in each industry to GVA in that industry was calculated for each asset type at the national level and then applied to GVA by industry at the NUTS2 level. This is described in more detail below.

3.3 Constructing complete series

The following section describes the methodology for producing GFCF estimates by asset, by industry and total from the available raw data for each Member State. The estimates employ Eurostat data wherever possible. If Eurostat data are present but not complete, the investment-ratio approach or investment-output approach is used to

complete the data series. If Eurostat data are not available at all, the data can still be calculated by converting data in constant prices or current prices with appropriate deflators. Failing that, data from the appropriate national statistical office is used. As a last resort, if GFCF data are not available from Eurostat or from the relevant national statistical office then the investment or investment-output ratios of a similar country are used to produce the estimates and the ratio of regional output to national output is used to split the total investment of the nation. For creating NUTS2 GFCF by industry, the ratio of industry output to total output in the region was used. For creating NUTS2 GFCF by asset, the asset investment ratios of the nation were used to split total investment for the NUTS2 region.

The flowcharts below describe the complete process of producing the GFCF data. Figure 2 illustrates the processing of the national data beginning with the Eurostat and AMECO data and ending with our complete set of estimates and Figure 3 does the same for the NUTS2 data. Figure 4 shows the investment ratios and investment output ratios data-filling technique.

FIGURE 2: PROCESSING OF NATIONAL GFCF DATA

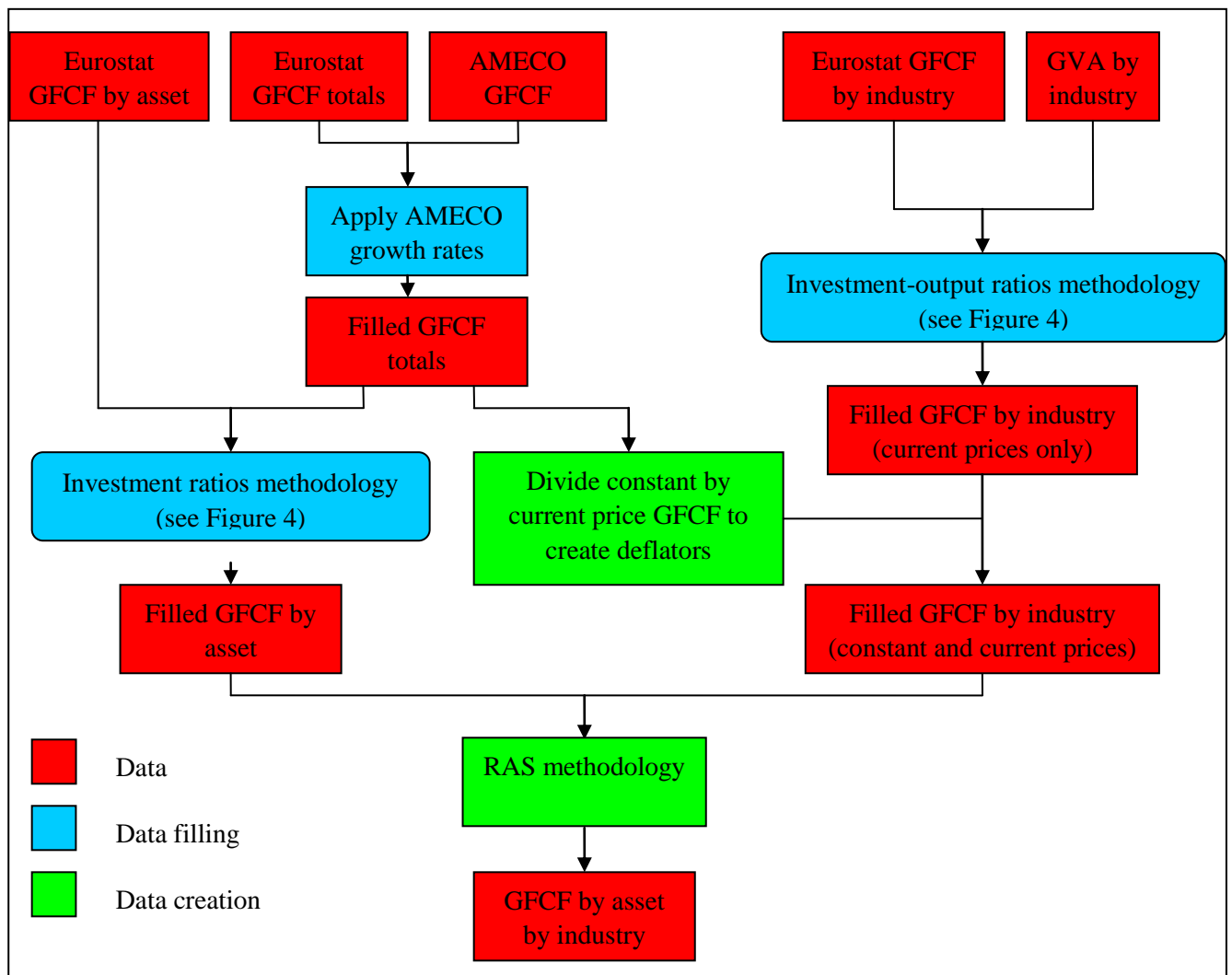


FIGURE 3: PROCESSING OF NUTS2 REGIONAL GFCF DATA

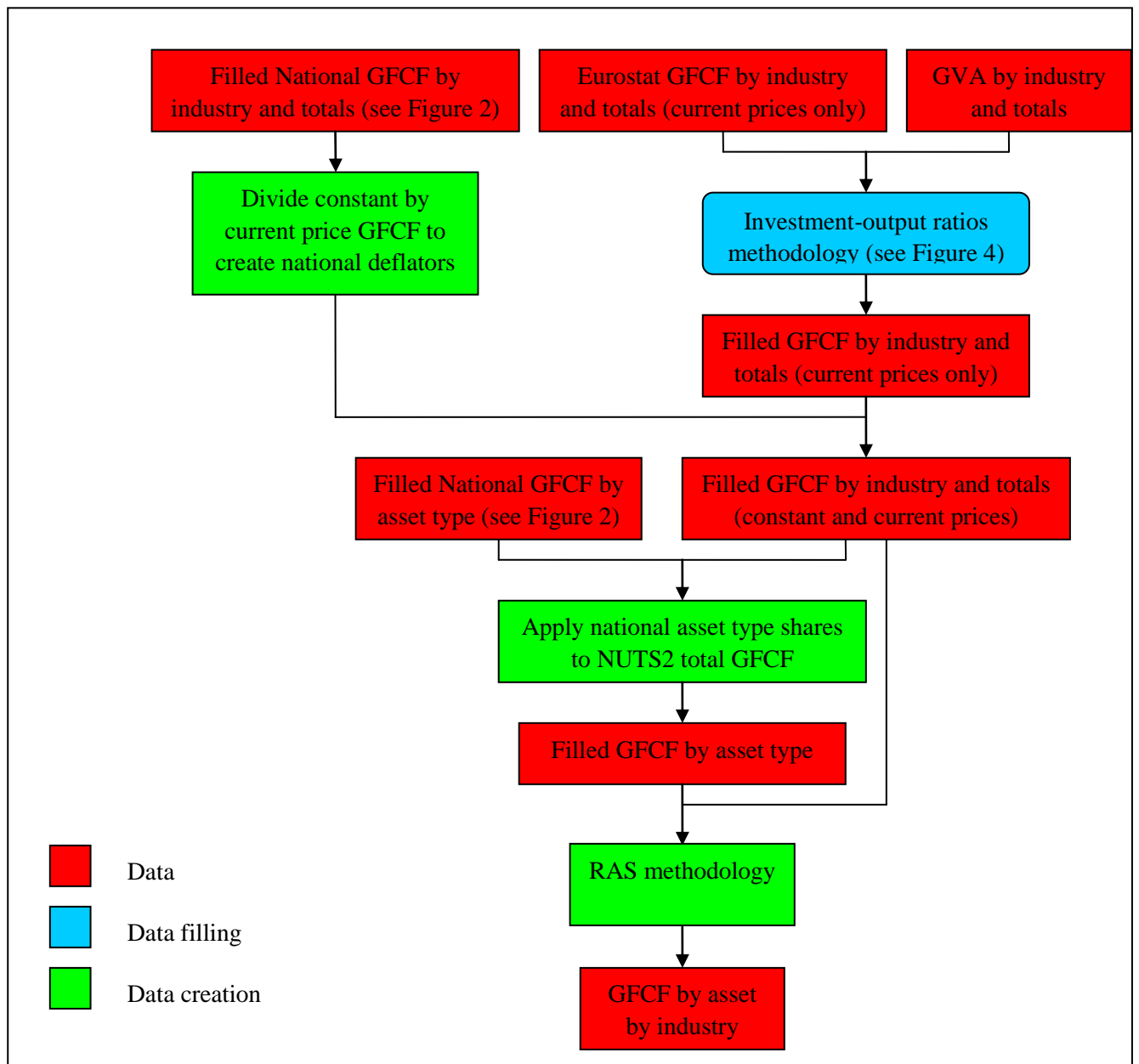
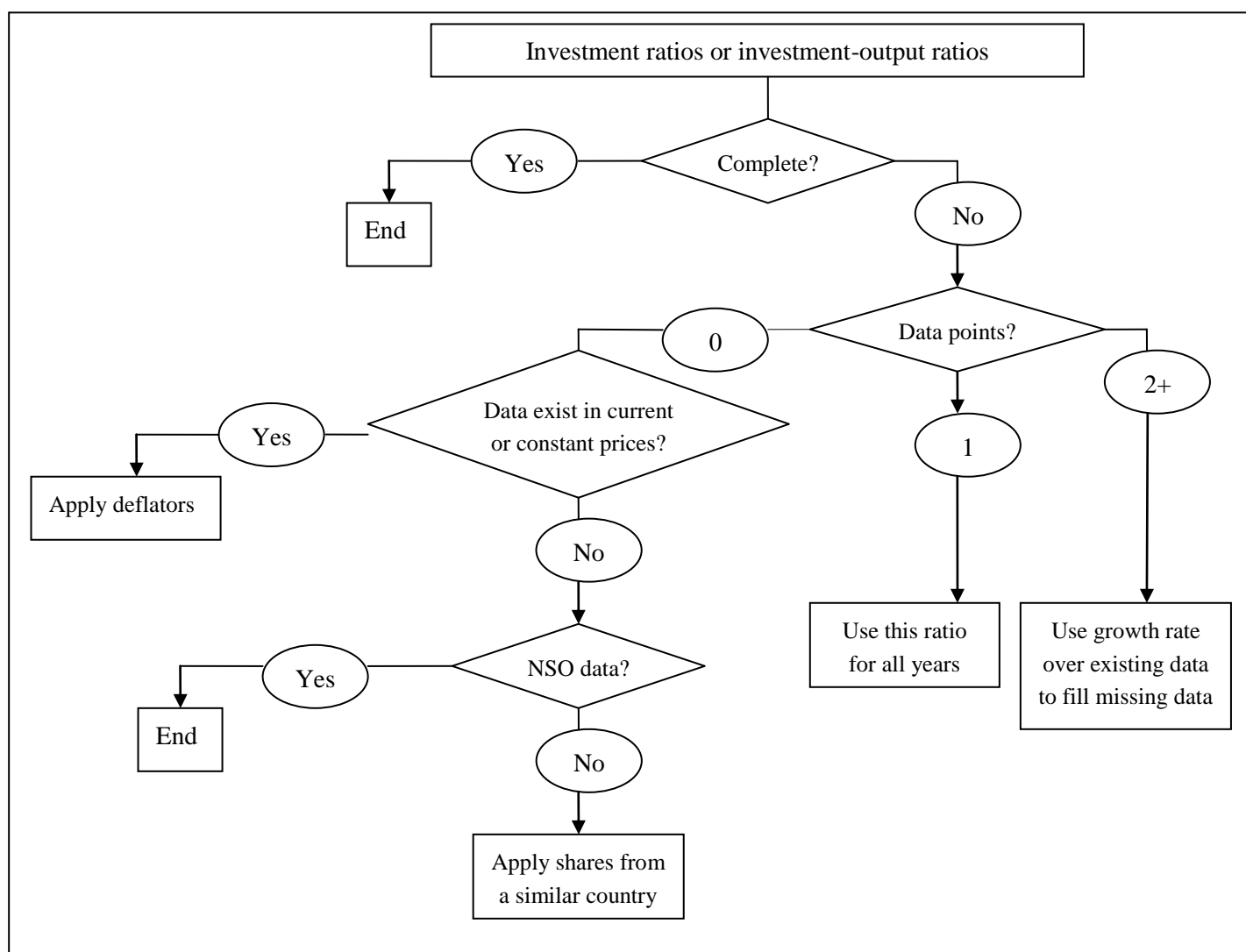


FIGURE 4: INVESTMENT RATIOS AND INVESTMENT-OUTPUT RATIOS METHODOLOGY



Investment data The GVA data for 1995-2005 are based on Eurostat figures and are filled using data from national statistical offices and other local sources. Where an incomplete series exists at NUTS2 level, interpolation methods have been used which fill gaps in the series from complete series available for aggregates of NUTS2 regions. The totals of regions containing interpolated values are constrained to sum to known totals at higher levels of the spatial hierarchy. In this way, a detailed series has been built up which is consistent with the higher-order regional values available in published statistics. The GVA data for the years 2006 and 2007 are based solely on NSOs and other local sources. These figures are then deflated by industry using the AMECO deflators.

There are a few missing years for one or two countries for total GFCF. In these cases the gaps are filled by applying the growth rates from the AMECO data in both constant and current prices. For the NUTS2 regions, total GFCF from Eurostat exists only for current prices. A ratio of these investment figures to GVA was calculated in each area for the periods where data were available. The growth rates of these investment-output ratios were calculated over the period for which data existed.

Missing years were then filled in by applying this growth rate to the investment-output ratios. If data were available for only a single year then the resultant investment-output ratio was used in all years. These filled investment-output ratios were then applied to the GVA data to produce a complete set of GFCF estimates at the NUTS2 level. These were then scaled such that the NUTS2 regions of a country summed to their national totals. To create the constant price data, GFCF was deflated in each NUTS2 region using deflators calculated for the country as a whole. These deflators were derived from the constant and current price national data from Eurostat.

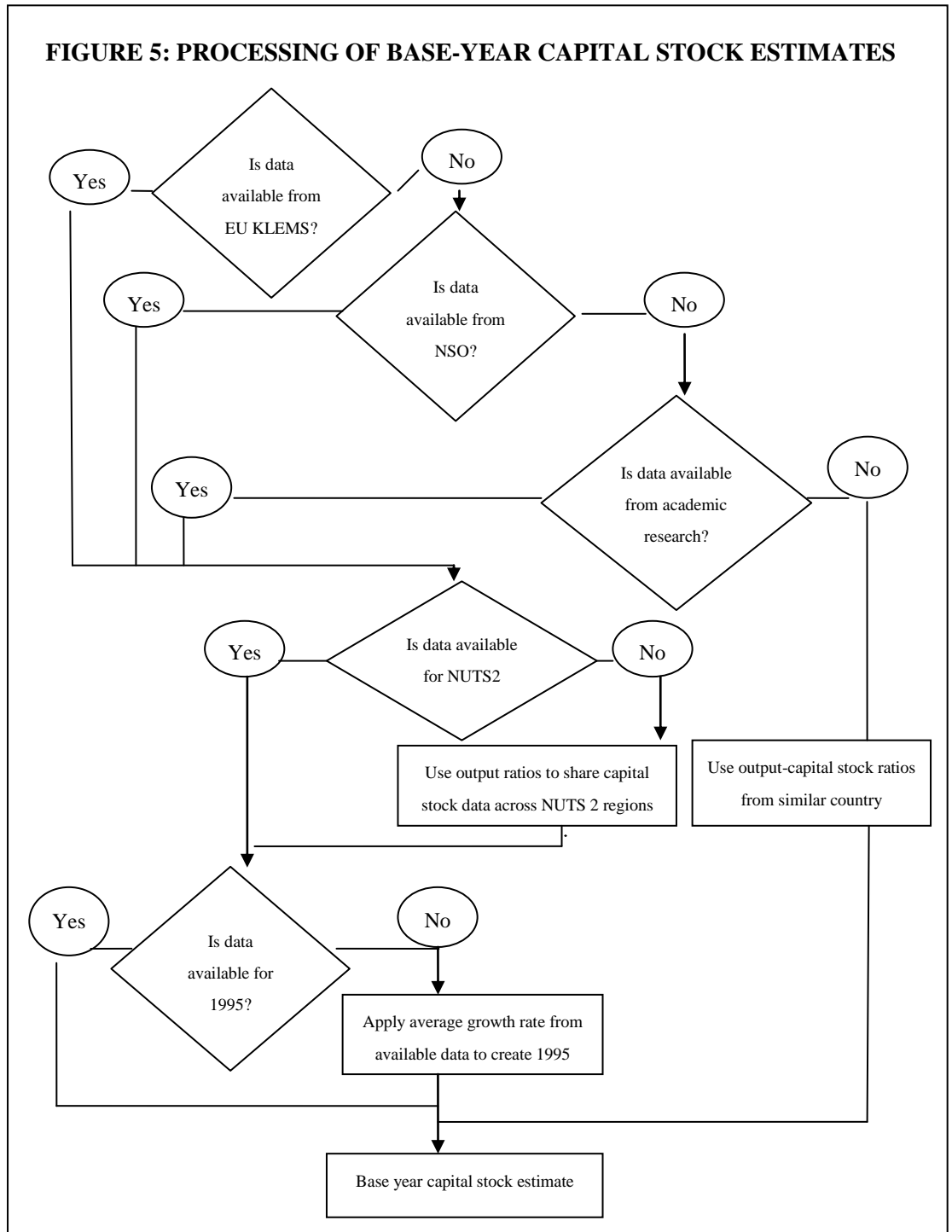
Industry disaggregation National GFCF by industry was produced using the investment-output ratio approach as described previously. These ratios were calculated using GFCF by industry as a share of GVA by industry. In the case of the Czech Republic there were no data at all by industry on Eurostat. Data were instead taken from the Czech Statistical Office and the ratios of GFCF by industry from this data were applied to the total GFCF from Eurostat data. The resulting estimates for GFCF by industry were then scaled to the national totals. The constant price data were created by applying the GFCF deflators created from the national data from Eurostat. Data by industry are available from Eurostat at the NUTS2 level in current prices for some years. As before, data were filled using investment-output ratios. Then for each region, the sum of the investment by industry was scaled so that it summed to the total for that region as calculated previously. The constant price data were produced by applying to each NUTS2 region the GFCF deflators by industry of their respective nations.

Asset disaggregation The gaps in the national GFCF by asset type were filled using a similar method to the investment-output ratios approach. Instead of finding the ratio of investment in an asset type to total GVA it was decided that a better measure to use would be the ratio of investment in an asset type to total investment. These investment ratios were calculated for both current and constant prices and then filled according to the same procedure as with the investment-output ratios. However, there are some countries that had no data by asset type in constant prices. This was because there were no price deflators by asset available for these nations. In these cases we took the price deflators for the country as a whole and applied these to the investment data by asset to produce data in constant prices. For the final database, in cases where there are no data for either constant or current prices and no data are available from their national statistical office then investment ratios by asset of a similar country have been applied to total GFCF. For the NUTS2 regions, there were no raw data by asset type. The data were created by assuming that the asset investment ratios calculated for the nations could be applied to total investment for the NUTS2 regions. This was done for both current and constant prices.

By asset type by industry These estimates by industry for each asset type were produced using the RAS scaling procedure. For each area in each year this procedure takes the figure for GFCF by industry and GFCF by asset. It then produces a set of estimates for GFCF by both industry and asset type that are consistent with the totals.

Base-year estimate of the capital stock For eleven countries capital stock estimates have recently been produced as part of the EU KLEMS project. Since the method used to produce them was the same for all countries it was considered useful to employ this EU KLEMS data to create base-year estimates in these eleven cases. For the remaining countries the base-year has been constructed in other ways, usually based on capital stock estimates produced by the national statistical office. Figure 5 shows the order of preference for sources of an initial capital stock to act as the base-year estimate.

FIGURE 5: PROCESSING OF BASE-YEAR CAPITAL STOCK ESTIMATES



As can be seen from Figure 5, the option of last resort was to construct the base-year estimate based on the output-capital ratio of a ‘similar’ country for which a capital stock estimate for 1995 is in existence. It was only necessary to take this option for three countries: Malta, Bulgaria and Greece. For these three countries there was no capital-stock estimate available from the EU KLEMS database, or from other sources such as the national statistical office, which could act as a base-year estimate for 1995. The base-year estimate for Bulgaria was based on the capital stock in existence in Romania in 1995, re-estimated to the size of the Bulgarian economy based on the output-capital ratio in Romania. The base-year capital stock for Malta was similarly

based on that for Cyprus. The estimate for Greece was based on an average of that for Italy and Spain.

Over the long term calculating the base-year capital stock in this fashion for these three countries will have a limited impact upon the estimates constructed because the inaccuracy introduced will, over time, be slowly eliminated from the stock through retirement and depreciation. However, over a relatively short time-span the inaccuracy introduced as part of this process will have a significant impact upon the results achieved for these three countries. The results for these three countries should therefore be treated with caution.

This is also true of Latvia. The Latvian national statistical office currently publishes a national capital stock estimate for 2007 only. Since there is only one year of data there was no basis on which to extrapolate back to 1995. This extrapolation was therefore carried out using the growth rates of the Lithuanian capital stock estimates from the Lithuanian national statistical office.

Indeed, a number of countries had published capital stock estimates at the national level for recent years but not stretching back as far as 1995. In these cases the estimates were extrapolated back to create the base-year estimate.

For the majority of countries, and all of those for which the EU KLEMS database was used as a source, estimates on which to create the base-year were only available at the national level. The ratio of capital stock in each industry to GVA in that industry was calculated for each asset type at the national level and then applied to GVA by industry at the NUTS2 level.

3.4 Summary

GFCF assumptions are the most important input into the PIM for estimating the capital stock. This chapter has described the methodology by which a complete set of appropriately disaggregated GFCF assumptions has been calculated for each of the 27 EU Member States. The GFCF estimates employ Eurostat data for the most part but these are supplemented by data from AMECO and national statistical offices. Where the GFCF time series are incomplete various procedures have been employed to fill missing values (typically the application of an investment ratio or an investment-output ratio).

As for the base-year capital stock, a number of methods were used which should, over time as depreciation effects take hold, be less important for estimating the capital stock value. Nonetheless, for some countries caution remains as to the accuracy of these initial estimates.

4 Analysis of Results

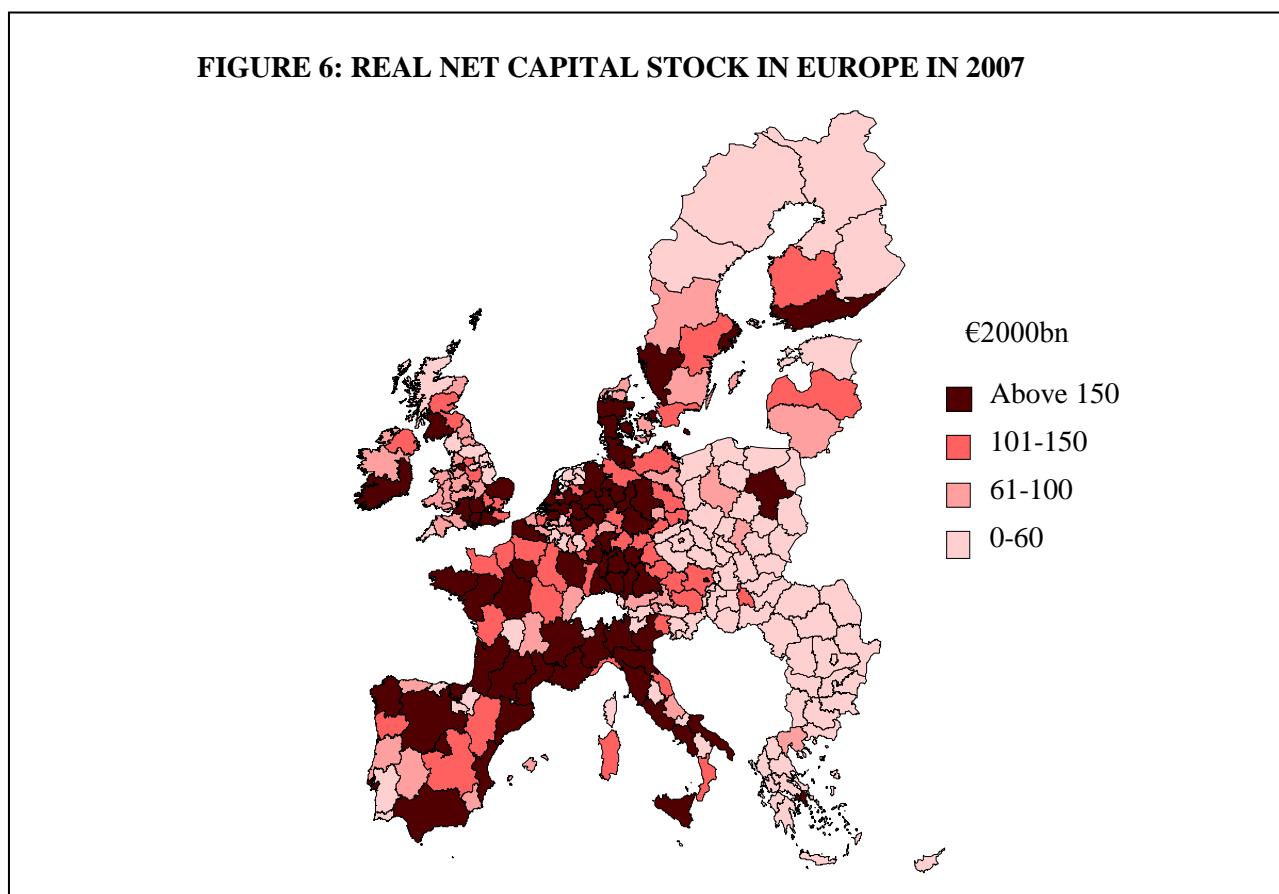
4.1 Introduction

This section analyses the estimates created using the method described in Section 2. The purpose of this analysis is to examine the robustness of the estimates, their usefulness as an input to analyses of cohesion policy, and the expediency of the approach used to create them more generally.

The analyses start with an examination of the real net capital stock in Europe. Labour productivity and the capital-labour ratio are then used to examine the robustness of the estimates, for reasons which are outlined. There is then a country-specific examination of the results for Poland. All of the analyses carried out in this section employ the estimates created for 2007, the most recent year for which statistics were created. The statistics examined are those which were created using the Simultaneous Exit retirement function. Estimates were also created using two alternative retirement functions, the Winfrey S2 and Winfrey S3 functions, but these are not examined here.

4.2 Real net capital stock in Europe

FIGURE 6: REAL NET CAPITAL STOCK IN EUROPE IN 2007



The real net capital stock by NUTS2 region is shown in Figure 6. The estimates correspond with what might intuitively be expected: the capital stock is generally higher in Western Europe than in the east, with the exception of the region

surrounding Warsaw in central Poland. A large amount of capital is concentrated in the highly industrialised north western part of Germany, as well as in the south western part of the country around Frankfurt. A high level of net capital stock runs the length of Italy but is generally more concentrated in its north. However, some results are less intuitively what would be expected. The Andalusia region of Spain has a high net capital stock, as does Sicily in Italy.

4.3 Ratio analyses

In order to allow for the different size of the regional economies when making comparisons, various ratios can be constructed and analysed. Two such ratios have been constructed and are analysed below:

- Output per unit of labour (Labour productivity)
- Capital stock per unit of labour (Capital-labour ratio)

The relationship between these ratios can be illustrated formally using a Cobb-Douglas production function, shown in Equation 6 below:

$$(6) Q_t = A_t K_t^\alpha L_t^{1-\alpha}$$

Here, Q is output, K is capital, L is labour, and A represents technology, ie the way in which production possibilities change through time through the development of new inventions and techniques for production. The technology factor is sometimes known as total factor productivity because it includes all contributions to total production not already reflected in levels of K and L.

The ratios to be analysed can be derived from the production function shown in equation 6 as shown in Equations 7, 8 and 9:

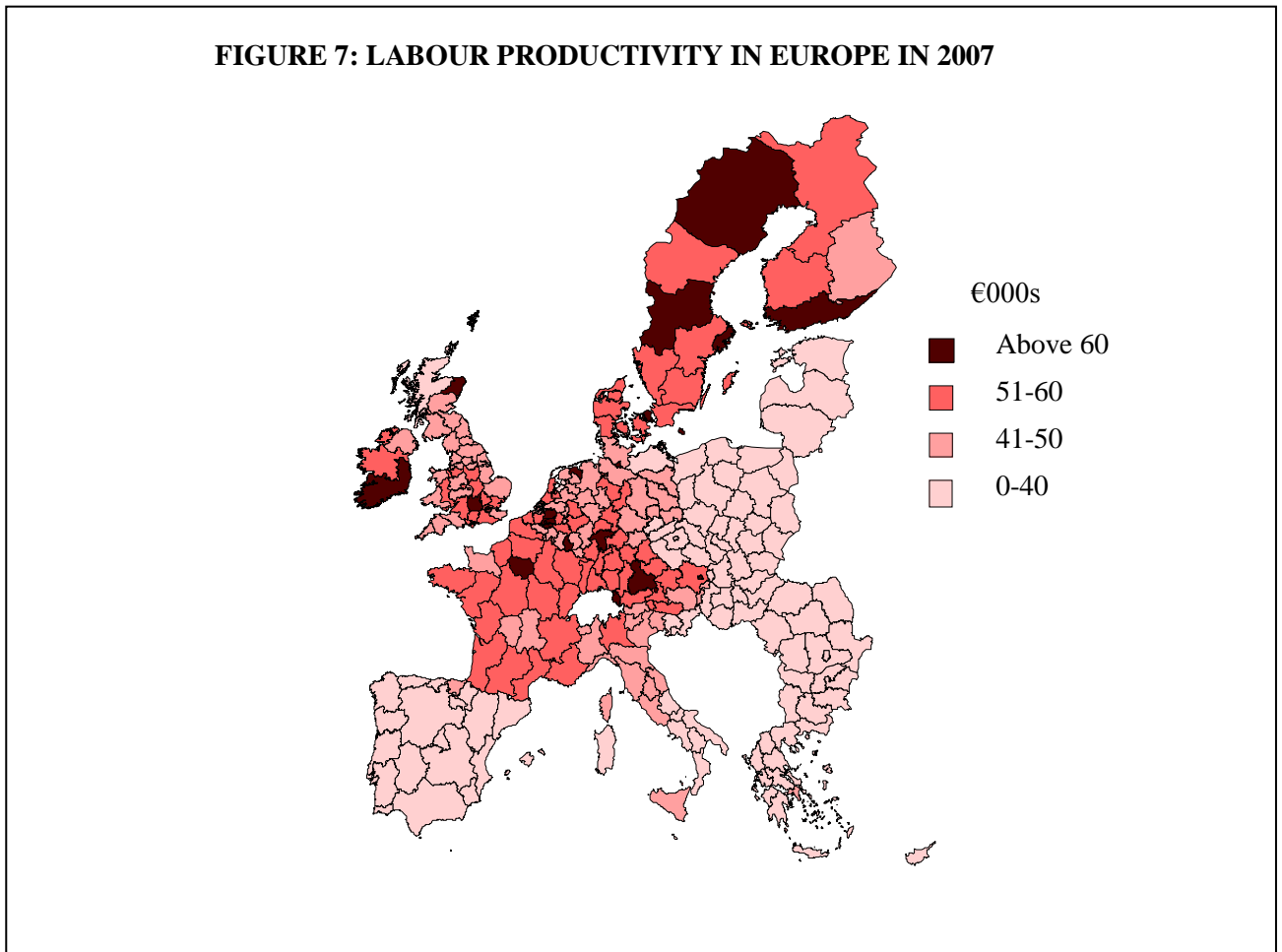
$$(7) \frac{Q_t}{L_t} = \frac{A_t K_t^\alpha L_t^{1-\alpha}}{L_t^\alpha L_t^{1-\alpha}}$$

$$(8) \frac{Q_t}{L_t} = A_t \frac{K_t^\alpha}{L_t^\alpha}$$

$$(9) = A_t \left(\frac{K_t}{L_t} \right)^\alpha$$

Therefore, labour productivity depends on the level of technology and the capital-labour ratio. A similar approach can be applied to derive an expression that relates output per unit of capital to the inverse of the capital-labour ratio. Figures 7-12, below, examine labour productivity and the capital-labour ratio in order to examine the robustness of the capital stock estimates.

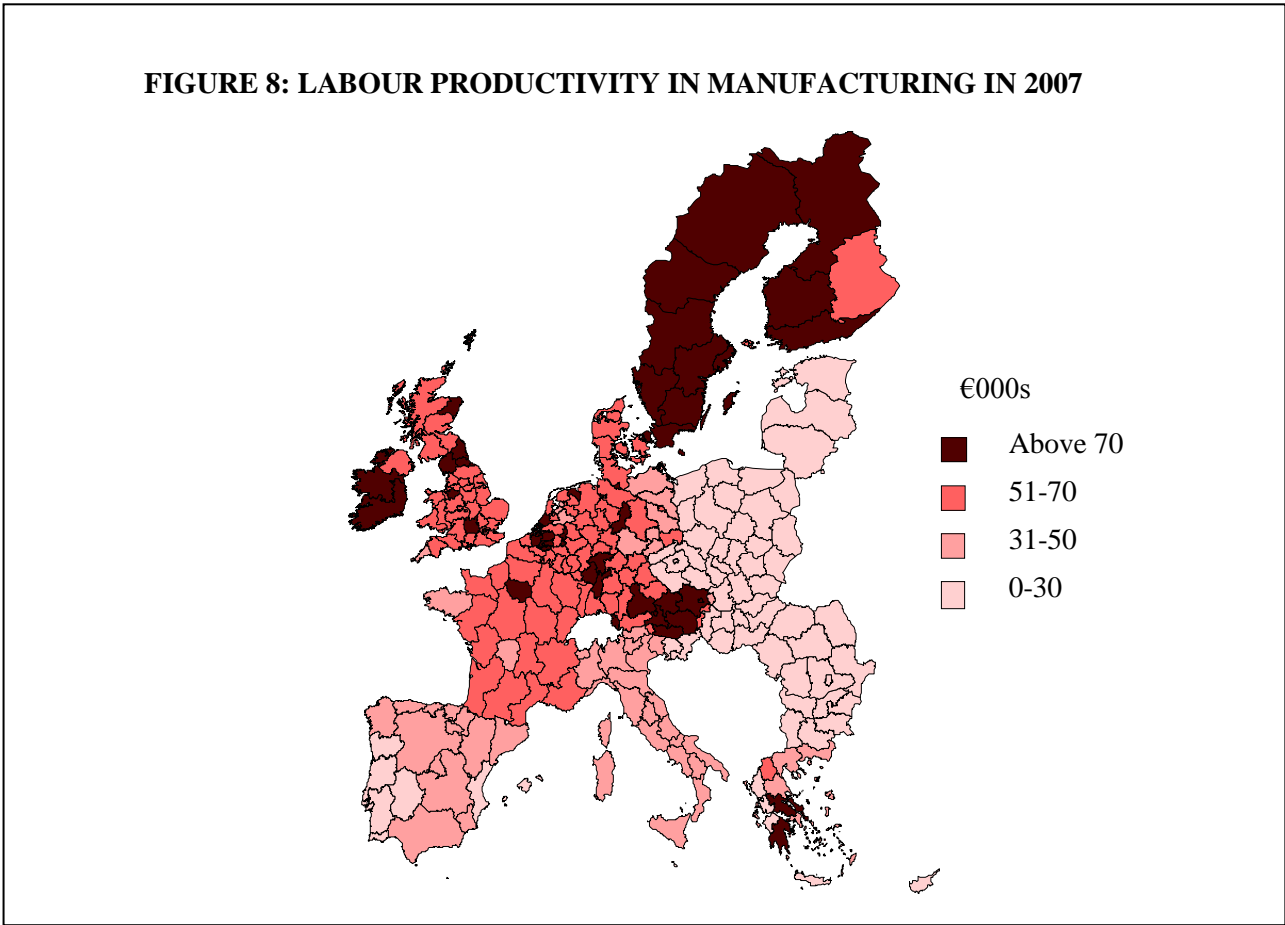
FIGURE 7: LABOUR PRODUCTIVITY IN EUROPE IN 2007



The results for labour productivity also show some correspondence with intuition, although there is perhaps less variation across Europe than might be expected. There is an obvious distinction between the east and west of Europe, and the north of the continent compared with the south, as was present when examining the net capital stock level in Figure 6. The Scandinavian countries to the north have a high labour productivity, reflecting their technology-based and capital-intensive economies. Labour productivity is again relatively high in and around London, in Paris and around Brussels. The north and south western parts of Germany have relatively high labour productivity. Labour productivity is also slightly higher in the north of Italy than in the south.

Figure 7, above, shows the results for total labour productivity. Figures 8 and 9, below, disaggregate this total into manufacturing and services. These results also suggest the estimates achieved are relatively robust.

FIGURE 8: LABOUR PRODUCTIVITY IN MANUFACTURING IN 2007

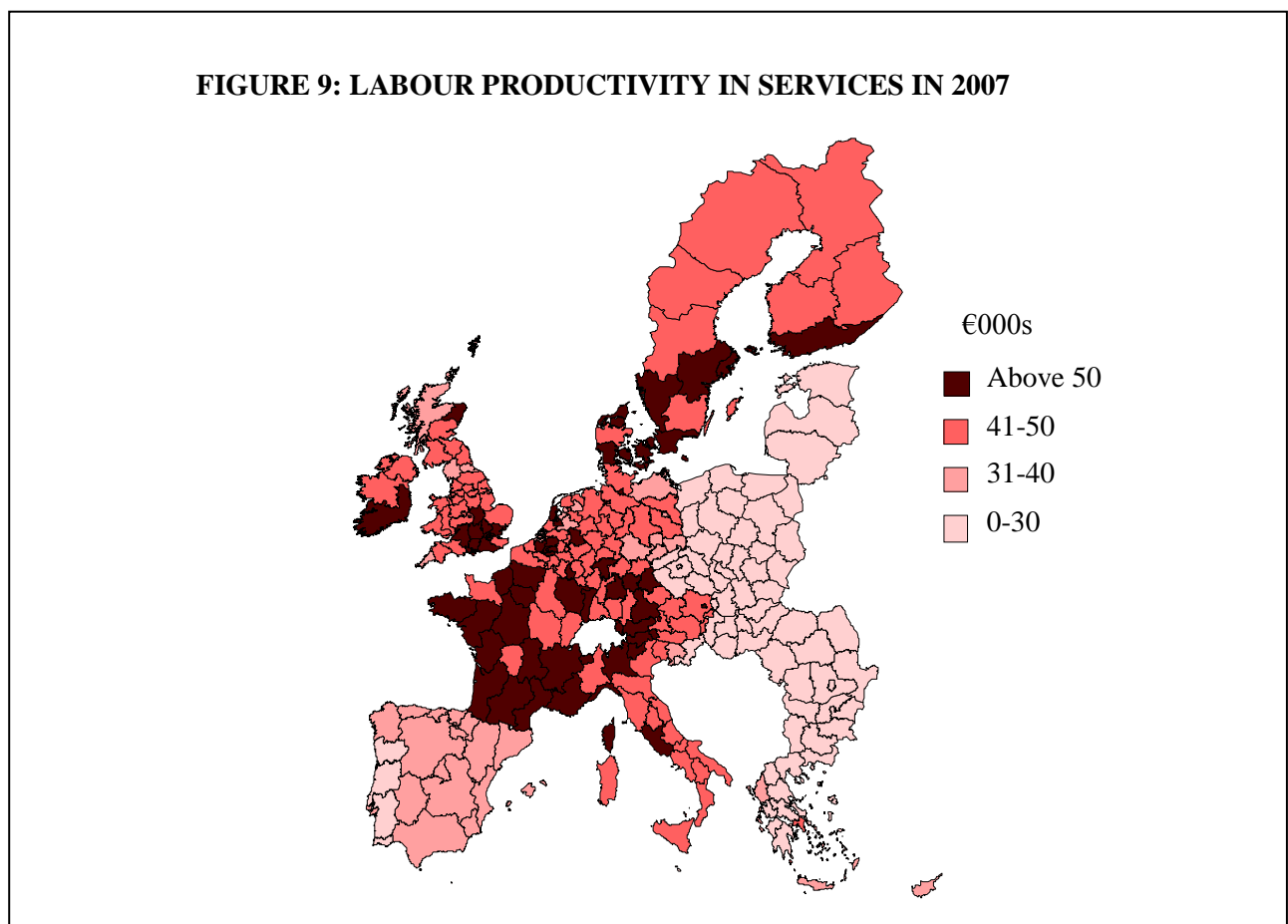


The distinction between the very capital-intensive, technology-based manufacturing economies of Scandinavia and the rest of Europe is also evident here. Ireland also has a relatively high level of labour productivity in manufacturing following a decade where it has attracted considerable Foreign Direct Investment in both manufacturing and services through its low corporate tax rate.

There remain one or two anomalous regions, however. Notably, labour productivity in manufacturing in some parts of Greece is higher than in many regions in Western Europe. The results for Greece, Bulgaria and Malta must be treated with some caution. For these three countries there was no capital-stock estimate available from the national statistical office, or from other sources such as the EU KLEMS database, from which to derive a base-year estimate on which to begin the Perpetual Inventory Method described in section 2. As described in section 5, it was therefore necessary to establish base-year estimates for these countries based on the capital stock in existence in 'similar' countries in 1995 and by applying capital-output ratios to fit that stock to the relative size of the country in question. For example, the base-year estimate for Bulgaria was based on the capital stock in existence in Romania in 1995, re-estimated to the size of the Bulgarian economy based on the capital-output ratio in Romania. Over the long term this will have limited impact upon the estimates constructed because the inaccuracy introduced by constructing the base-year estimate in this way will, over time, be slowly eliminated from the stock through retirement. However, over a relatively short time-span, such as 1995-2007 as in the estimates constructed as part of this project, the inaccuracy introduced as part of this process will still have a significant impact upon the results achieved. However, it was only necessary to resort

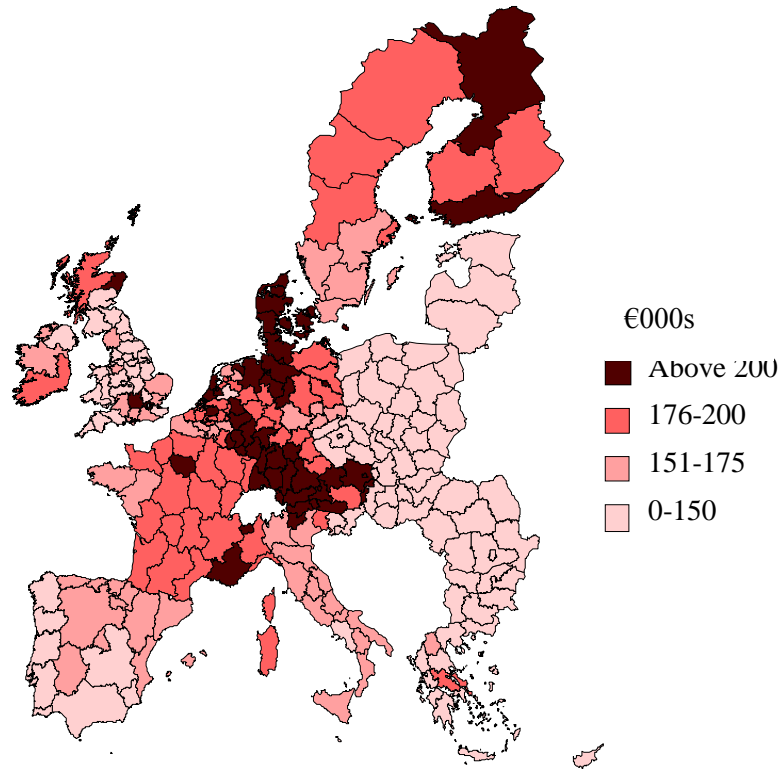
to constructing a base-year estimate in this way for these three countries. The base-year estimate for the remaining 24 countries of the EU came either from national statistical office estimates or from the EU KLEMS database.

FIGURE 9: LABOUR PRODUCTIVITY IN SERVICES IN 2007



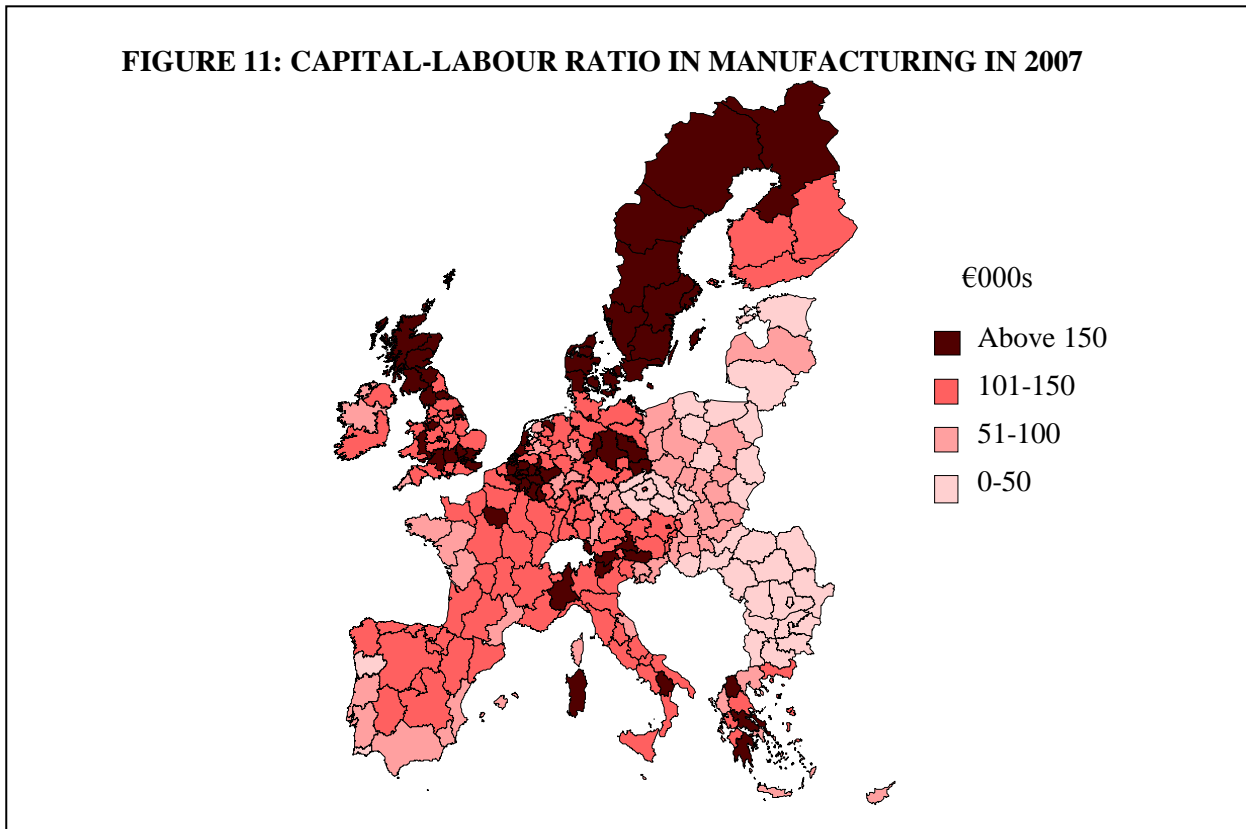
The results for labour productivity in services show some correspondence with what might intuitively be expected. There is perhaps less variation within some countries, such as France and Spain, than might be expected but there are concentrations of high labour productivity around London and the south east of the UK, around Dublin, Frankfurt, Paris and Brussels and in the more southern parts of Scandinavia close to or around the main urban centres in these countries. Again the general east to west and north to south distinction that would be expected is present. Figures 10-12, below, use the capital-labour ratio to examine the robustness of the estimates.

FIGURE 10: CAPITAL-LABOUR RATIO IN 2007



As expected, the capital-labour ratio tends to be higher in the more well-developed Member States whereas for those areas where labour is relatively less expensive a lower ratio prevails. Disaggregating the total capital-labour ratio to show manufacturing only, as in Figure 11, shows that the same pattern of broad correspondence with expectations with one or two anomalous results is again evident here. As with the previous Figures, the broad correspondence with expectations relates to the lower capital-labour ratio in eastern compared with Western Europe, and in northern compared with southern Europe. More specifically, there are clusters of regions with a relatively high capital-labour ratio around the southern parts of Belgium, the South East of England, in the technologically-advanced countries of Scandinavia and in northern parts of Germany.

FIGURE 11: CAPITAL-LABOUR RATIO IN MANUFACTURING IN 2007



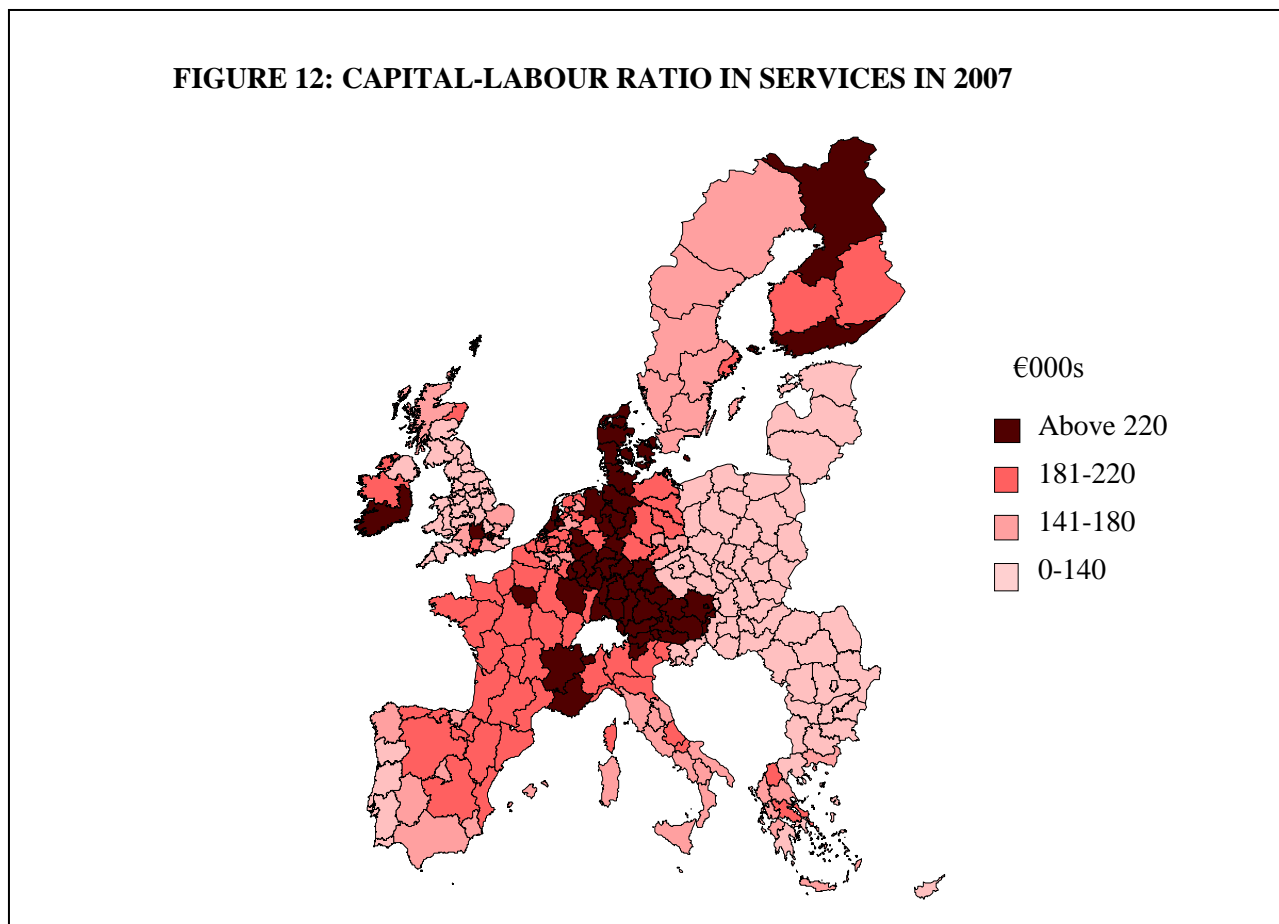
As in Figure 8, some of the Greek NUTS2 regions have an unexpectedly high capital-labour ratio in manufacturing. The unusual method used to construct the Greek base-year capital stock, as described in the previous section, is likely to explain this. Sardinia also has an unexpectedly high capital-labour ratio and the reason for this is less immediately obvious.

The same broad correspondence with intuitive expectations is also present when examining the capital-labour ratio in services in Figure 12 but there is probably less variation within countries than may be expected.

Across the two identifiable sectors, manufacturing is seen to have a lower capital-labour ratio than services. This is a counter-intuitive result. However, for most countries this anomaly exists in the starting capital stock for 1995 and is therefore a feature of the data rather than the method used to construct estimates. The explanation, or part of it, may lie in the inclusion of the housing stock within the services sector. In the national accounts, the value added of the real estate sector includes actual and imputed (for owner-occupiers) rentals for the provision of housing, and the associated capital is the housing stock. Consequently, this activity is highly capital-intensive.

In summary, the Figures examined above commonly exhibit a broad correspondence with intuitive expectations but with a number of obvious exceptions. A further commonality that can be applied to many of the Figures is less variation within countries than might be expected. For the majority of the Figures this is true of the Eastern European countries in particular, though less variation between the regions of these countries than in Western countries may be expected due to their generally lower level of development and their lower labour costs which reduce the incentive to build the capital stock.

FIGURE 12: CAPITAL-LABOUR RATIO IN SERVICES IN 2007



Some of this lack of variation within some countries may be because the Figures examined so far take a broad view of the whole of the European Union and this perhaps reduces the variation evident within specific countries.

For this reason, in Figures 13-15 below the focus is on a specific examination of one of these countries in particular: Poland. A country-specific examination can add further to an understanding of the robustness of the estimates and their potential usefulness. Poland is a particularly good candidate for specific examination as it is intuitively expected that the west of the country would have a higher capital stock than the east. This is because the west is the location of the country's most developed urban centres, such as Poznan and Wroclaw, and also because it borders the developed countries of Western Europe. The eastern regions, by contrast, are much more rural in nature, are less densely populated with fewer large urban centres and, of course, border the less developed countries beyond the European Union's border to the east.

4.4 Country specific analysis: Poland

Figure 13 corresponds with these expectations to some extent. There is a region in the east of Poland which has a high net capital stock but it is the region surrounding Warsaw. The other eastern regions of the country, from Podkarpackie in the south to Mazury in the north, generally have a lower net capital stock than many of the western Polish NUTS2 regions. The estimates clearly identify the region of Slask in the south to have a high net capital stock. This is one of the most industrialised regions in the whole EU and so a further check on the robustness of the estimates for Poland is

whether this region has a high labour productivity in accordance with the ratios derived from the production function as described earlier. Figure 14 shows the labour productivity in manufacturing in Poland.

FIGURE 13: REAL NET CAPITAL STOCK IN POLAND IN 2007

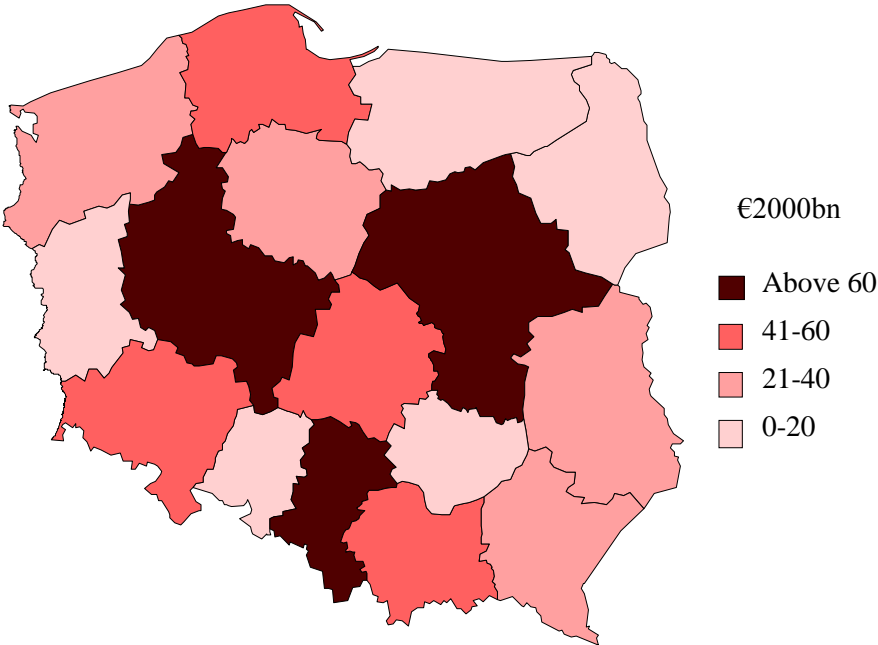
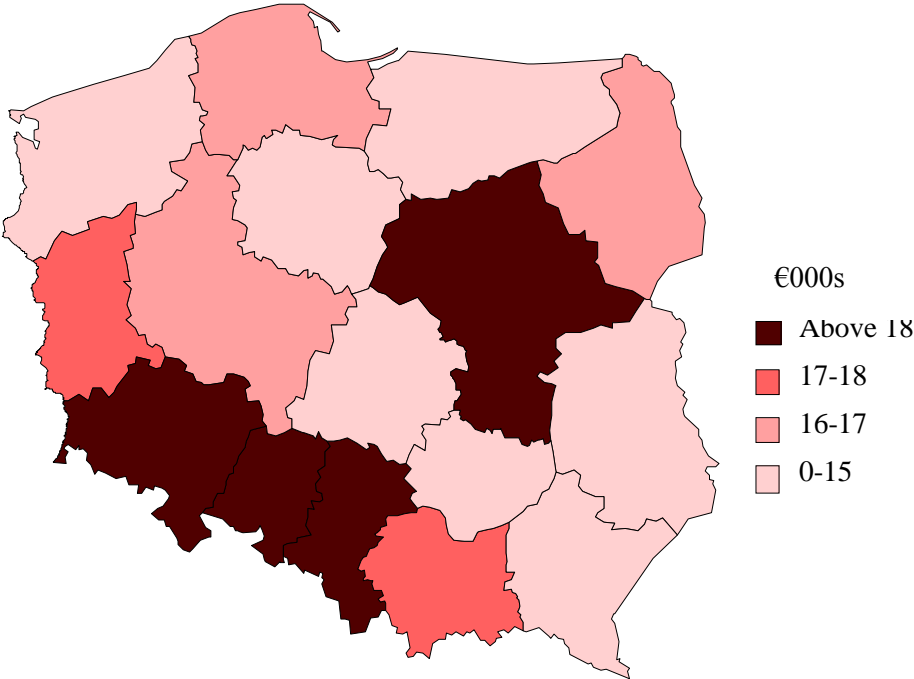


FIGURE 14: LABOUR PRODUCTIVITY IN MANUFACTURING



The estimates again highlight Slask and, this time, its neighbouring regions to the west as having a relatively high labour productivity in manufacturing. However, it can be seen from the colour-coded banding of regions in the key to the right of the map that, as was evident when examining the broad EU maps, the absolute difference between regions is small. The region surrounding Warsaw has a relatively high labour productivity too, as would be expected. The distinction between the eastern regions of Poland and those in the west is more evident still when it comes to the capital-labour ratio in manufacturing as shown in Figure 15.

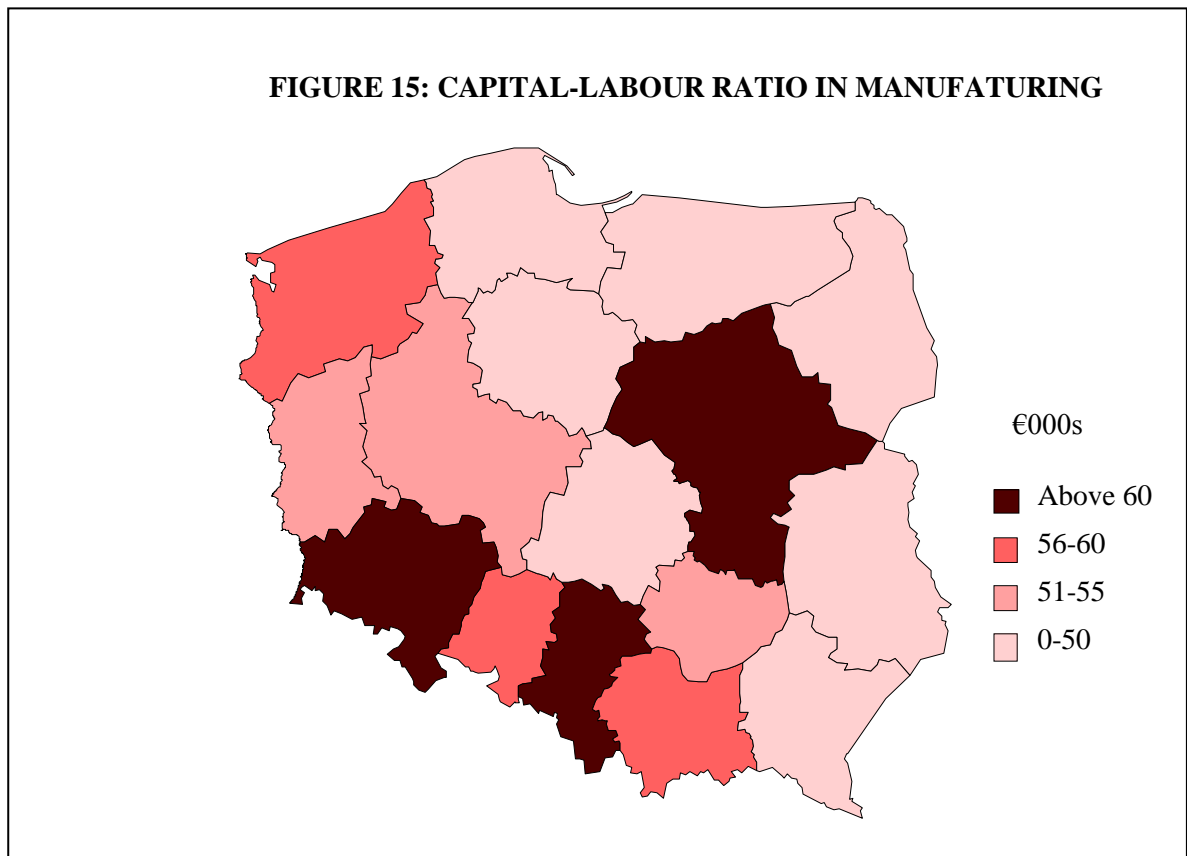


Figure 15 shows there to be a greater absolute variation between NUTS2 regions in Poland when it comes to the capital-labour ratio. The variation between east and west, again with the exception of the region surrounding Warsaw, is still more distinct here than in Figures 13 and 14. Slask, the most industrialised region in Poland, and its surrounding regions have a relatively high capital-labour ratio, as does the region surrounding one of Poland's relatively technologically-advanced urban centres, Wroclaw, in the south west of the country.

5 Conclusions and Recommendations

This paper has described a pilot project to assess the feasibility of constructing comparative capital stock statistics at NUTS2 level for the European Union. The estimates are required by the European Commission to assist with monitoring the impact of cohesion policies and to identify regions requiring further assistance.

A standard and relatively simple method has been employed as, given the available data, simplicity is required to produce comparable estimates for all NUTS2 regions of the EU. The approach employed was a Perpetual Inventory Method based on that described in the OECD Manual (2001; 2009) on capital stock estimation. Under this approach, for any one year the capital stock is essentially a three-way interaction between a revaluation to the current year's prices of the capital stock from the previous year, the depreciation and retirement of capital due to its consumption, and the addition to the stock brought about through investment in this year.

The estimates examined in section 4 employed a linear depreciation function and a Simultaneous Exit retirement method, but estimates for all regions were also produced using two alternative methods of retirement: the Winfrey S2 and the Winfrey S3 bell-shaped retirement functions. These estimates are also available.

An examination of the capital stock estimates produced as part of this pilot project was carried out in section 4 of this paper to ascertain the robustness and usefulness of the method and the statistics produced using it. This initially examined the net capital stock before focussing on an examination of labour productivity and the capital-labour ratio. The production function implies that labour productivity depends on the level of technology and the capital-labour ratio and such a focus can therefore shed light on the robustness of the estimates.

The examinations carried out suggest that the capital stock estimates are broadly robust. Obvious distinctions between the east and west and north and south of Europe are evident, as would be expected. Other results are less expected. Some of these, such as the relatively high capital stock in some parts of Greece, are due to the method used to construct the estimates for those countries. For Greece, Bulgaria and Malta the base-year estimate was constructed based on capital-output ratios from 'similar' countries. There is a European-wide requirement for national statistical offices to produce national estimates of the capital stock. It is being brought into enforcement in phases. Ireland, for example, published capital stock estimates for the first time at the beginning of 2010 in order to comply with this requirement. The requirement will eventually ensure that all EU countries publish national level estimates. When Bulgaria, Greece and Malta comply it will then be possible to reproduce the estimates for these countries using their national estimates to produce a more robust base-year estimate and, therefore, to improve the statistics for these countries considerably.

A specific focus on Poland, however, has provided some further reassurance that even when the examination is made at the narrower geographic level of a single country the NUTS2 estimates produced as part of this pilot project do largely correspond with intuitive expectations.

In summary, the pilot project was successful in showing that it is possible to produce relatively robust and, crucially, comparable estimates of the capital stock at NUTS2 level for all EU countries. This project has for the first time brought into existence

regional-level capital stock estimates for the whole of the EU, produced using the same method in each case. They can therefore provide a useful input into policy decision making, assessment of cohesion policies and identification of regions requiring further support. Furthermore, the method employed is sufficiently simple to be replicable and for the statistics to be regularly updatable.

Indeed, each additional year of update will improve the statistics further even if no refinement to the method occurs. This is because the further from the base-year estimate the current year of estimates is, the less impact of any errors introduced when constructing the base-year estimate because of the depreciation and retirement of assets in this initial base estimate.

In summary, to develop and further improve the capital stock statistics produced as part of this report it is recommended that:

- The statistics be updated annually because the further from the base-year the end period of the estimates is (currently 2007), the less impact of any errors introduced as part of the process of creating the base-year estimate because of depreciation and retirement (as mentioned above). This means that the statistics would improve year-on-year as they are updated.
- The first estimate used in the RAS scaling procedure to create the investment data by sector and asset assumed that there was no known information on the sector asset split. This first estimate, which is then re-calibrated, therefore assumed that the split was equal. The estimates resulting from this process could be improved by finding a data source for this first estimate.
- The estimates for Greece, Bulgaria and Malta should be recalculated using capital stock estimates from each country's national statistical office for the base-year, once these become available.
- The base-year capital stock for Latvia was based on an estimate of the capital stock for 2007 from the Latvian national statistical office. However, because only one year of estimates existed, it was necessary to extrapolate these back to 1995 using growth rates from the Lithuanian capital stock. As the Latvian NSO produces more years of estimates these can be used to extrapolate back to 1995 instead.
- Some anomalous results are likely to be caused by the inclusion of the housing stock within the services sector. The value added of the real estate sector includes actual and imputed (for owner-occupiers) rentals for the provision of housing, and the associated capital is the housing stock. This is included in the services sector resulting in it having a higher level of capital stock than manufacturing. If a way could be found to disaggregate this out from services then this would improve the results. However, there is currently no basis on which to do this.

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