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Estimating the capital stock for the NUTS 2 regions of the EU-27

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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 EU-27 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 assesses the feasibility of producing comparable estimates of the capital stock at NUTS 2 regional level for the EU-27 and makes some initial estimates. 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 robustness of the capital stock estimates produced, as well as their impact on productivity analysis, and suggests how they can be improved in future updates.

Keywords: Capital Stock, NUTS 2, Estimation, Total Factor Productivity

JEL: O16; O18; O47

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Contents

Introduction

Regional capital stock estimates for Europe are a useful indicator for identifying and targeting lagging regions as part of European cohesion policy. They can also be used as an input in helping to monitor the impact of these policies and to separate regions in need of further support from those which have now developed to a satisfactory level. In addition, there is a need within the academic community for reliable capital stock estimates as they can be used in a variety of ways, such as growth accounting and convergence analysis. Until now, such data have not been available on a consistent and comparable basis, often resulting in academics constructing their own series for particular sub-national analyses (e.g. Mas et al, 2000 and 2006).

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 idiosyncratic methods and varying assumptions, thus compromising comparability. It is not possible, therefore, simply to disaggregate national level estimates into regions and compare across the EU.

The remaining sections of this paper are as follows. Section two describes the outcome of a survey of national statistical offices (NSOs) to ascertain what methodology was being used across Europe to produce capital stock estimates (typically at national level), and reports on the approach adopted by this study, namely the Perpetual Inventory Method based on the OECD Manual (2001, 2009), as well as the underlying assumptions made. The survey of NSOs also reviewed the availability of data inputs necessary to produce capital stock data, and this is reported in Section 3. The data employed to produce the estimates described in this paper were taken from Eurostat or other publicly available sources wherever possible. Section 4 presents and analyses results. Finally, in Section 5 we make some concluding remarks and suggest ways in which the estimates can be improved and the method refined in the future.

1. Methodology

1.1 Survey of European National Statistical Offices

The survey of national statistical offices showed that all responding countries employ some form of Perpetual Inventory Method (PIM) to produce their capital stock estimates, generally based on the 'standard' PIM outlined in the OECD Manual (2001; 2009). There was, however, considerable variability in the assumptions used as the input to this common method. National-level estimates are therefore of questionable comparability. It is not possible simply to disaggregate these estimates into the constituent NUTS 2 regions and produce comparable regional-level estimates in this way.

For this reason, in order to produce comparable estimates for the NUTS 2 regions of the EU it is necessary to employ investment data from the same source (Eurostat) and to employ the same method and assumptions for all regions. This method and the assumptions that are an input to it are described below. The lack of comparability between the national level capital stock estimates of Member States will still impinge upon the NUTS 2 regional estimates presented here. This is because for a number of Member States it was necessary to employ the national-level estimate from the National Statistical Office, disaggregated into the Member State's NUTS 2 regions, in order to establish a base-year estimate for 1995. The NUTS 2 level investment data from Eurostat are then applied to this base in order to build up a perpetual inventory and a capital stock estimate for subsequent years. However, over time this base estimate will impinge upon the resulting capital stock estimates diminishingly because of depreciation and retirement. Any lack of comparability introduced through the process of creating an initial base estimate will therefore also diminish over time. This process is described in a subsequent section.

1.2 PIM method

This section briefly describes the PIM methodology. It begins with the calculation of the gross capital stock, as shown in equation 1 below.

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

where CS 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) $$CS_{t,t} = \sum_{i=0}^{d-1} I_{t-i} * P_{t-i,t}$$

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

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 three 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, for this project 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 18 Winfrey curves in total: six 'S' or symmetric curves, 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) $$F_T = F_0(1 - T^2 / a^2)^m$$

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

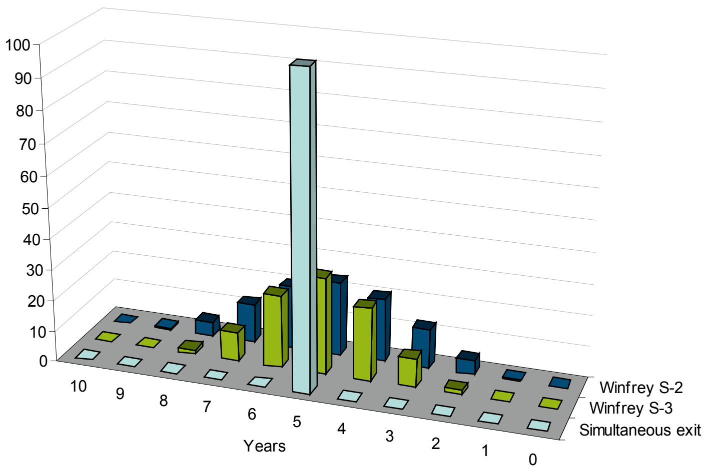
	Winfrey S-2	Winfrey S-3
F_0	11.991	15.610
a	10	10
m	3.7	6.902

To summarise, under Simultaneous Exit all assets of the same cohort retire and are removed from the capital stock at the same time once depreciated to zero. All assets are therefore assumed to remain part of the stock for the duration of the average service life (and it may not, therefore, make sense to talk of an 'average' service life when using this approach, since all assets live for this length of time). By comparison, under the Winfrey set of retirement functions the retirement pattern is bell-shaped around the average service life. Assets of the same cohort do not, therefore, all remain part of stock for the entire average service life or all retire at the same time. The average service life is truly an 'average' using this approach then. 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 for an asset with an average service life of five years. Some of the cohort will not make it to the average service life but some will continue as part of the stock beyond this average. In any one decile only a proportion of the cohort is retired whereas 100% of a cohort, whose value has been depreciated entirely to zero, is retired at five years under Simultaneous Exit.

Combining a separate retirement function with depreciation

Figure 1 – Alternative retirement methods



Source: Cambridge Econometrics calculations

is more complicated than the straightforward 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 Tmax 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 combined with 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 S-2 and linear depreciation

T	Probability of retirment	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
	Value(Hn)	100	77,3	55,1	35,3	19,5	8,9	3,1	0,7	0,1	0,0	0,0

Source: Cambridge Econometrics calculations

There are alternatives to the above method for calculating the capital stock, as outlined in the OECD Manual (2001). 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 can therefore be applied to all EU countries, even where a scarcity of input data exists.

1.3 PIM assumptions

As is clear from the discussion above, the PIM requires several inputs and assumptions to work:

- a base-year capital stock;
- investment series (by sector and asset, depending on disaggregation requirements) to move the capital stock through time;
- a set of average service lives by asset;
- a depreciation function to devalue assets;
- a mortality function used to retire assets.

The data requirements and resulting processing (i.e. issues relating to the base-year capital stock and investment data) are dealt with in the following section. The mortality and depreciation functions have been discussed above. This leaves a brief discussion on average service lives.

A Canadian study, referred to in the OECD Manual (2001, para. 6.42) but not cited, varied average service life estimates for asset types by +/- 50% and found that increasing average service life estimates by 50% results in a 40% increase in the eventual capital stock estimate. A similar effect results from decreasing service life estimates by the same amount. This study drew the conclusion, however, that most service life assumptions are not likely to show this degree of error. Service life estimates are likely to be wrong by no more than 10%. Nevertheless, even this margin of error means that capital stock estimates are likely to have an error margin in the range of +/- 8%.

Service life data were collected from the national statistical agencies in whatever asset classification they had used in their calculations. The results for each country were collated, and a histogram showing the frequency of each value (for individual assets) was created. 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.

Based on the survey carried out, for the asset types for which capital stock estimates are produced in this study the following service lives are assumed:

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

Straight-line or 'linear' depreciation is employed to depreciate and retire assets from the stock in the main database. In addition, estimates have been produced based on Simultaneous Exit and two alternative methods, the Winfrey S-2 and Winfrey S-3 retirement functions, and within these calculations the above values have been used as true average service lives.

2. Data

As mentioned previously, the two main data requirements to calculate capital stock using the PIM are a base-year estimate and an investment (gross fixed capital formation) series. Both types of indicator must be available at equivalent levels of disaggregation in order to calculate the required capital stock detail. In addition, if real and nominal calculations are required, as is usually the case, price indices are also necessary.

2.1 Data disaggregation

The dimensions of analysis, i.e. how disaggregated the capital stock could be produced, quickly became apparent from the results of the data survey that was undertaken, as outlined below. The regional (NUTS 2) dimension was a focus of the study and so already given. The time period of analysis was 1995-2007, while in terms of assets and industries, the selections made are described in Tables 3 and 4.

Table 3 – Classification of industries

Industry	NACE Section	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)

Data availability

Capital stock data

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

EU KLEMS data are only available at the national level and therefore other data sources were required to produce estimates at the regional level. If there were no NUTS 2 data available from any source, then a scaling method based on GVA was used, i.e. 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 NUTS 2 level.

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, 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) e.g. warehouse and industrial buildings, commercial buildings, buildings for public entertainment, hotels, restaurants, educational buildings, health buildings, etc., and Other structures (AN.11122) e.g. 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.
Other Assets	AN.112, AN.1114	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.1114) 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.

Investment data

At the national level, Eurostat produces GFCF estimates for the EU-27 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. 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. Other European sources of data include the AMECO database, which has national totals.

At regional level, Eurostat has investment data broken down by industry in current prices only, with incomplete coverage and with no disaggregation by asset type. For most countries, there are at least some data by industry for every NUTS 2 region, although not for the whole time period required. For the entire EU-27, 71% of the totals figures and 68% of the figures by industry are available at NUTS 2 level for the period 1995-2004. This means that for our required period of 1995-2007, 53% of the totals data and 54% of the data by industry were there.

2.3 Data filling-in mechanisms

The following section describes the methodology for producing GFCF estimates by asset, industry and total from the available raw data for each Member State and region.

Investment data

Eurostat data were used wherever possible. If Eurostat data were present but not complete, an investment-ratio approach or investment-output scaling approach was used to complete the data series. If Eurostat sources were not available at all, data from the appropriate national statistical office were 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 NUTS 2 GFCF by industry, the ratio of industry output to total output in the region was used. For creating NUTS 2 GFCF by asset, the asset investment ratios of the nation were used to split total investment for the NUTS 2 region.

The gaps in the national GFCF by asset type were filled using a similar concept 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. Finally, 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 NUTS 2 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 NUTS 2 regions. This was done for both current and constant prices.

Base-year capital stock

For 11 countries, capital stock estimates have recently been produced as part of the EU KLEMS project. 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. Where no KLEMS or NSO data were available, 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. 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.

To some extent this is also true of Latvia because 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 NUTS 2 level.

3. Results

Following the lengthy stages of data survey, collection, processing and filling-in mechanisms, the creation of the capital stock series was a relatively straightforward/mechanical process. The purpose of this section is to examine the robustness of the capital stock 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 base-year capital stock and capital-output ratios at national level. Comparisons against existing regional studies are also made, namely that made in Spain by Mas et al (2006). The general picture of capital stock and capital-labour ratios are then examined across Europe. In order to get finer detail, there is also a country-specific examination of the results for Poland. Finally, some basic total factor productivity calculations are made, and compared against labour productivity, to assess the difference that including capital makes to such productivity calculations.

It should be noted that the statistics mentioned are those which were created using the Simultaneous Exit retirement function. Estimates were also created using two alternative retirement functions, the Winfrey S-2 and Winfrey S-3 functions, but these are not examined here.

3.1 Base-year capital stock (national level)

Table 5 compares the estimates produced at the national level as part of this study with those produced by the relevant NSOs or by EU KLEMS. The final two columns of Table 5 compare our results with NSOs or EU KLEMS estimates for a mid year (2001) and the last year for which comparison is possible, which varies by country (because the last year for which estimates are available varies by NSOs). For a small number of countries there is no estimate available from the NSOs or EU KLEMS for either the mid year of 2001 or for the end year, or for both. Where this is the case N/A has been entered in the table. Where the comparison can be made, Table 5 shows the 2001 estimate and end-year estimate for each Member State to be similar to that produced by the NSOs or EU KLEMS.

Table 5 – Comparison of national-level base-year estimates

Member State	Start period (1995)	Mid period (2001)	End period*
	Billions of euros	CE value / NSO or EU KLEMS value	CE value / NSO or EU KLEMS value
AT	626.2	1.07	1.08
BE	532.3	1.04	1.06
BG	20.7	n/a	n/a
CY	16.6	1.14	1.10
CZ	186.3	1.04	1.05
DE	6213.8	1.06	1.05
DK	544.5	1.04	1.03
EE	10.6	0.76	0.88
ES	1656.2	1.00	0.99
FI	316.9	1.05	1.06
FR	3335.9	1.10	1.12
EL	314.8	n/a	n/a
HU	260.8	0.81	0.85
IE	112.0	1.14	1.26
IT	2382.2	1.10	1.13
LT	24.0	n/a	1.18
LU	54.7	0.92	0.89
LV	58.5	n/a	1.13
MT	6.1	n/a	n/a
NL	1061.5	1.07	1.07
PL	352.7	1.60	1.57
PT	183.9	1.06	1.05
RO	63.8	1.35	1.13
SE	416.1	1.06	1.06
SI	21.3	1.33	1.40
SK	115.2	n/a	1.26
UK	2031.6	1.07	1.08

**The 'end year' for each country varies because the NSOs and EU KLEMS produce capital stock estimates for a differing number of years for each country. For AT, CZ, DE, DK, FI, IT, NL, PT, SE, SI and UK the 'end year' compared against is 2005. For BE, ES, HU, LT, LU, SK and LV it is 2007 and for CY, EE, FR, PL and RO it is 2006. For BG, EL and MT no capital stock estimates are available from any source against which to compare. For Slovakia and Latvia there is no mid-year estimate for 2001 against which to compare.*

From an initial examination of Table 5 the values of the base-year capital stock in 1995 are broadly as expected, given the size of each economy (i.e. the value of its GDP) and the level of development (GDP per capita and sectoral structure). However, a useful way to further check the robustness of the initial base-year estimates for 1995, to which the perpetual inventory used to produce estimates for subsequent years is applied, is to calculate a capital-output ratio for each country. Capital-output ratios for each Member State for 1995 are shown in Figure 2. However, it is useful firstly to consider the factors which may lead to a relatively high or low capital-output ratio before comparing with Figure 2 to see if our expectations in this regard are met and whether, therefore, the base-year estimates for 1995 can be considered more or less robust.

In relative terms, the size of the capital stock in relation to output is a function of many different factors. Neo-classical growth theory implies that the returns to capital diminish at a rate which depends upon the amount of capital already in existence (Aghion and Howitt, 1999). Because these returns diminish, the incentive to save declines over time and economies head towards a 'steady state' where savings offset but do not exceed the depreciation of capital, and the capital stock therefore remains stable (ibid.). This implies convergence, as the capital stock will grow at a faster rate in less developed economies because they will be further from this steady state, and the returns to capital, and therefore the incentives to invest in it, will be greater.

However, while this neo-classical theory implies a faster rate of growth for capital (and output) in less developed economies and therefore convergence, it also implies that the capital-output ratio of more advanced economies will be higher because they will be nearer to the 'steady state'. According to neo-classical theory the more advanced economies of Western Europe should therefore be expected to have a higher capital-output ratio than the less advanced economies in Eastern Europe. We would expect some 'within country' variation for the same reason. For example, we might expect the more developed northern regions of Italy to have a higher capital-output ratio than the less developed southern regions, similarly the western compared to eastern regions of Poland.

Beyond this neo-classical view, there are other factors which are likely to impact upon the capital-output ratio observed for European countries and regions. The capital-output ratio of a region can depend upon its industrial structure and the nature of demand for its products. If the region's industrial structure is skewed towards manufacturing then the capital-output ratio is expected to be relatively large[1], but even more so if the type of manufacturing tends to be the production of technologically advanced goods for large global markets or energy-related markets involving machinery for extraction or processing, e.g. oil sector.

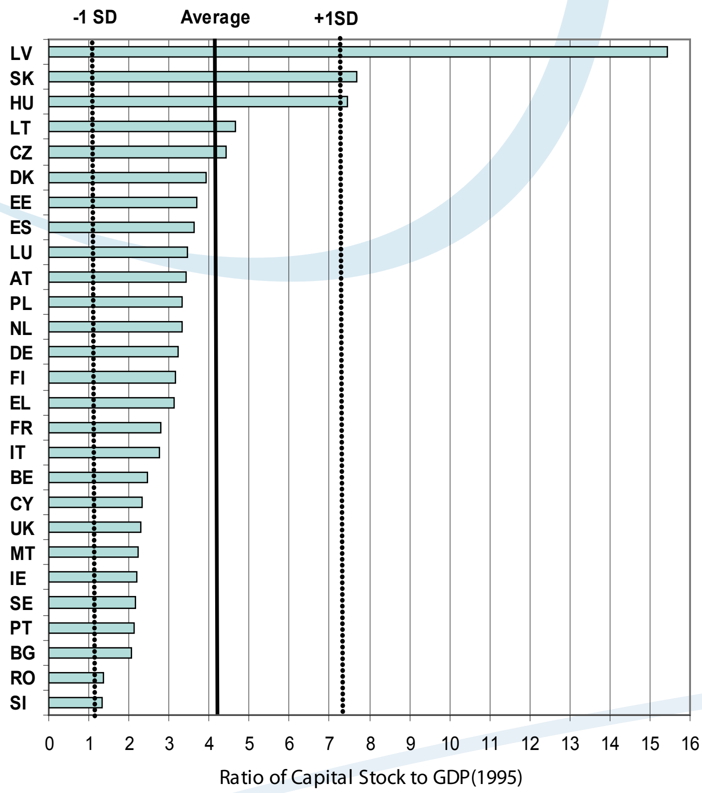
When it comes to services, however, the size of the capital stock in a region is likely to relate to the presence of large agglomerations as service firms tend to be more focused on the supply of local markets. This suggests a higher capital-output ratio in, for example, the regions containing London, Paris, Berlin, Warsaw and other major cities, as well as in the surrounding regions. More peripheral regions would be less expected to have large capital-output ratios in services.

A further factor likely to influence the capital-output ratio of European regions is the cost of inputs other than capital, in particular labour. There is less incentive to substitute labour with capital if the cost of labour is relatively low. Wages are obviously much lower in Eastern compared to Western European regions and also in Southern compared to Northern European regions. The incentive to invest in capital is therefore lower in these regions than it is in Western Europe where wages are considerably higher.

In sum, most of the factors that influence the capital-output ratio imply a distinction between the east and west and north and south of Europe. This is the obvious implication of neo-classical theory as it implies that the less developed countries to the east and south will be further from the 'steady state' and will therefore have less capital in place (though their stock would be expected to be growing more quickly). This is also the implication of the other factors influencing the size of the capital stock discussed above, with the possible exception of industrial structure, as we might expect Eastern European countries to have larger manufacturing sectors.

However, when a capital-GDP ratio is obtained for 1995, as shown in Figure 2, there are some outliers among the new Member States (Latvia, Slovakia and Hungary) which run contrary to the general expectation of a larger capital stock in the more developed Member States to the west. For these countries the capital-output ratio is considerably higher than for the other European countries. In addition, while the results for Slovenia and Romania conform to the expectations outlined above in that their ratios are lower than those of the Western European countries, they probably also represent outliers as their ratios appear a little too low relative to other Eastern European countries. This is especially true of Slovenia which is one of the more advanced Eastern European economies.

Figure 2 – Base-year capital-output ratio



1 However, as will be seen in the subsequent section, the capital stock estimates for manufacturing presented in this paper are lower than those for services because the Eurostat investment data include dwellings in the services sector.

These anomalous results no doubt reflect the quality of the data for the early 1990s and, in particular, the need to extrapolate back the baseline capital stock from more recent estimates for these countries as their NSOs do not currently produce estimates for as far back as 1995. This was not necessary for the other Member States. More broadly, the weighted average EU capital-output ratio is about 3 according to the base-year estimates for 1995 shown in Figure 2, and this provides some reassurance of the relative robustness of these base-year estimates. Estimates of the capital-output ratio for 2002 produced by NIESR (2002) imply that Germany's ratio was just greater than 3, France's was slightly lower than this at about 2.7 and the UK's was lower still at 2.3. This is similar to what can be seen for 1995 in Figure 2. For the majority of Member States then, excluding the obvious outliers highlighted above, the 1995 base-year estimate is considered to be sufficiently accurate. This provides some reassurance that the estimate for 1995, to which the perpetual inventory method described in Section two is applied to produce estimates for subsequent years, is more or less robust for most countries. The results for those countries for which it is clearly inaccurate should be treated with caution, although it is also important to remember that the influence of the base-year estimate weakens over time because of retirement and depreciation.

3.2 Comparison of NUTS 2 results against other studies

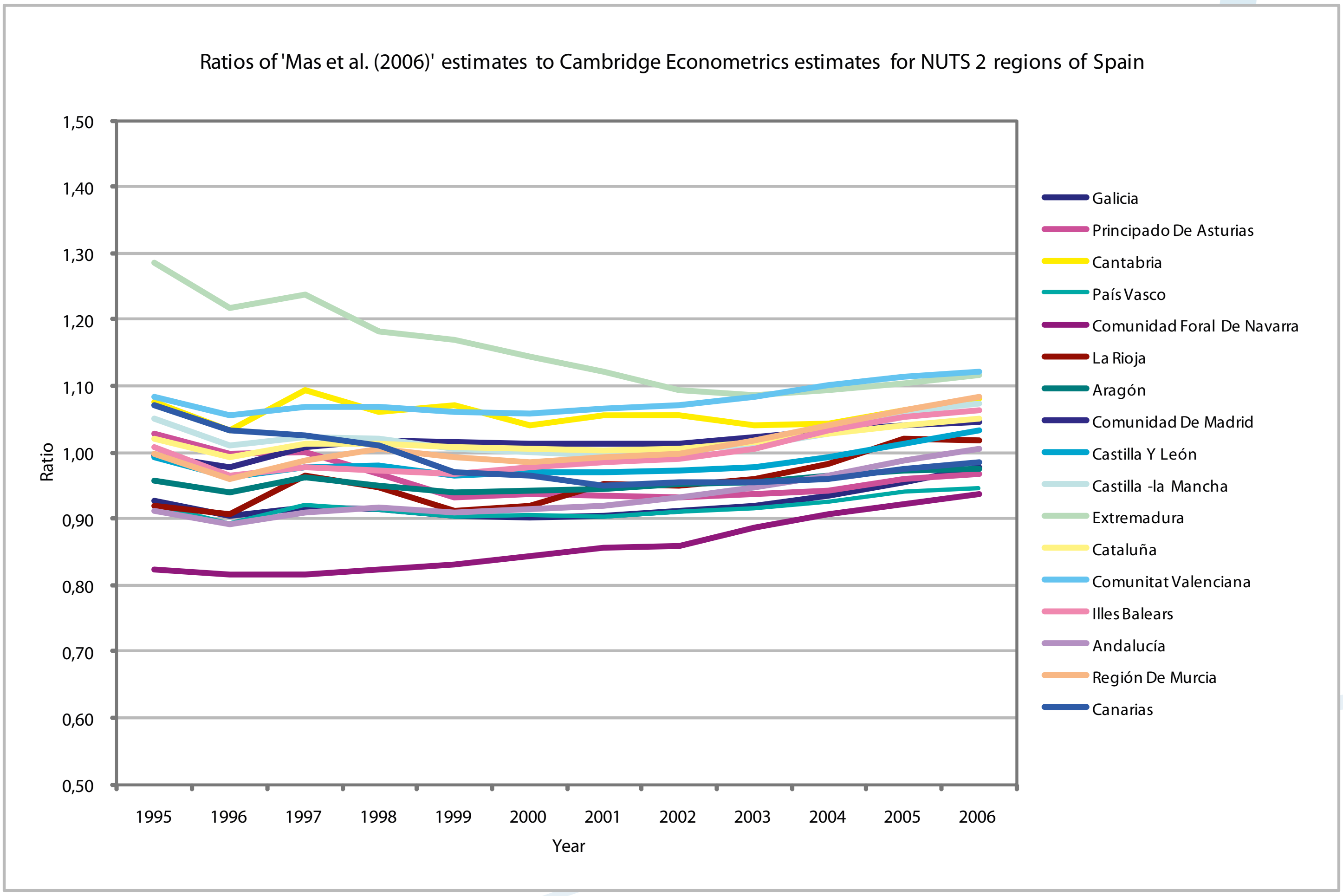
Capital stock estimates are not available at NUTS 2 level for most countries. However, estimates for Spain have been produced by the University of Valencia and the BBVA Foundation and are described in Mas et al (2006). Figure 3 shows a comparison between our estimates and those from Mas et al (2006). The comparison is carried out by taking the ratio of the Mas et al (2006) estimates to those of the estimates produced for this project, i.e. if the ratio is unity then the estimates exactly match; greater than unity indicates that our estimates are lower than those of Mas et al (2006). The resulting ratios become quite similar over time. This convergence is expected because, as stated above, as the calculation period is extended any errors introduced as part of the base-year estimation for 1995 are gradually removed from the capital stock through depreciation, and new investment therefore accounts for an increasing proportion of the stock over time.

3.3 Regional results

Net capital stocks across Europe

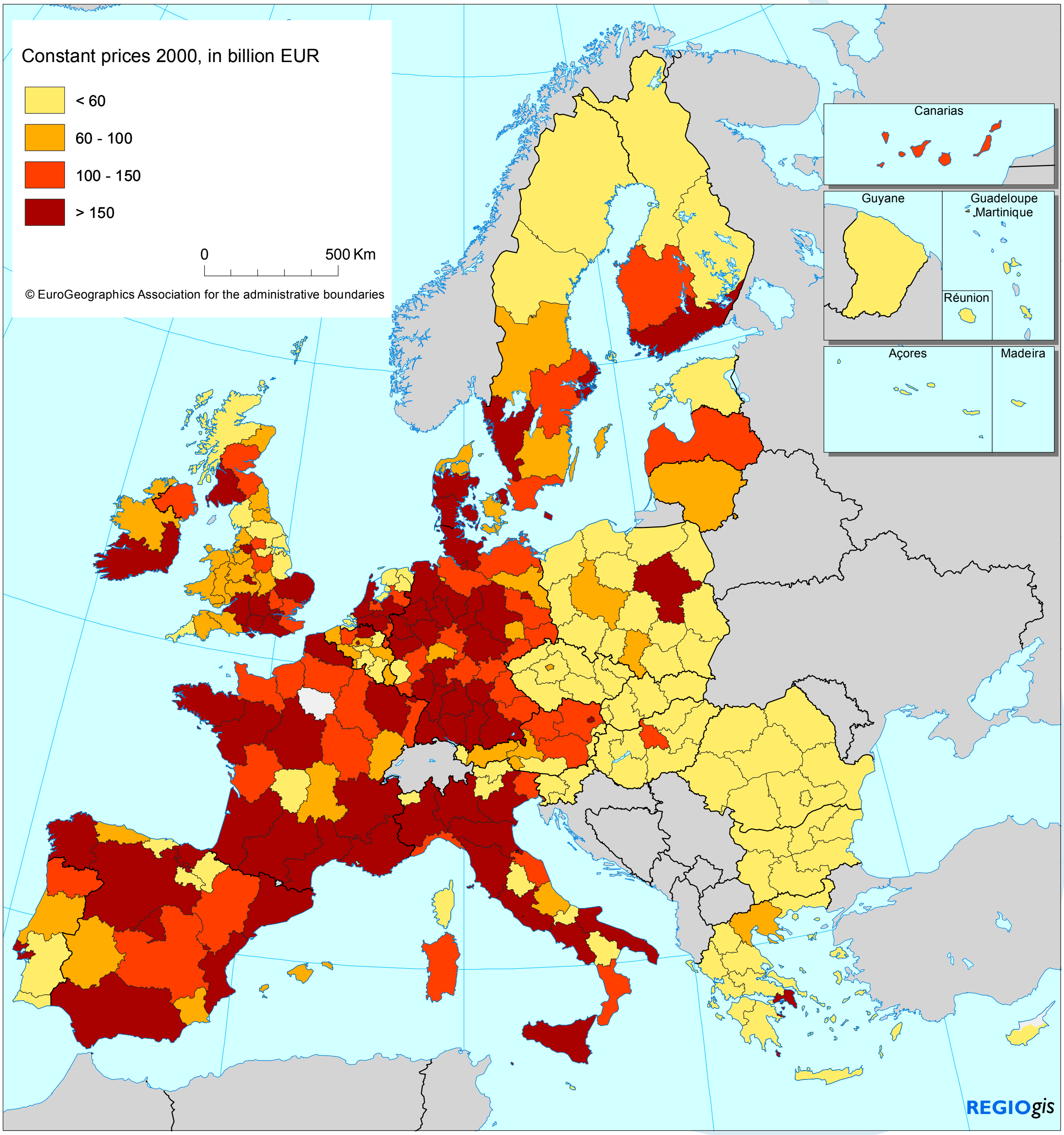
The real net capital stock by NUTS 2 region is shown in Figure 4. The estimates correspond with what might intuitively be expected: the capital stock is generally higher in Western Europe than in the east, with the exception of the region surrounding Warsaw in central Poland. A large amount of capital 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. Some results, e.g. the Andalusia region of Spain and Sicily in Italy, may seem less intuitive than expected but further examination has revealed this is due to the scale effect of the size of capital stock in these countries in relation to that of many of the smaller Member States.

Figure 3 – Comparison of regional estimates for Spain



Source: Cambridge Econometrics calculations

Figure 4 - Real net capital stock in 2007, EU-27



Source: Cambridge Econometrics calculations

Capital-labour ratio

The capital-labour ratio is a useful economic indicator which should be higher in the more well-developed Member States whereas for those areas where labour is relatively less expensive a lower ratio prevails, as stated previously. It can be easily shown that, under certain assumptions, the capital-output ratio is broadly linked to average labour productivity. The relationship between these ratios can be illustrated formally using a Cobb-Douglas production function, show in equation 6 below:

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

Here, Q is output, K is capital, L is labour, and A represents technology, i.e. the way in which production possibilities change over 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:

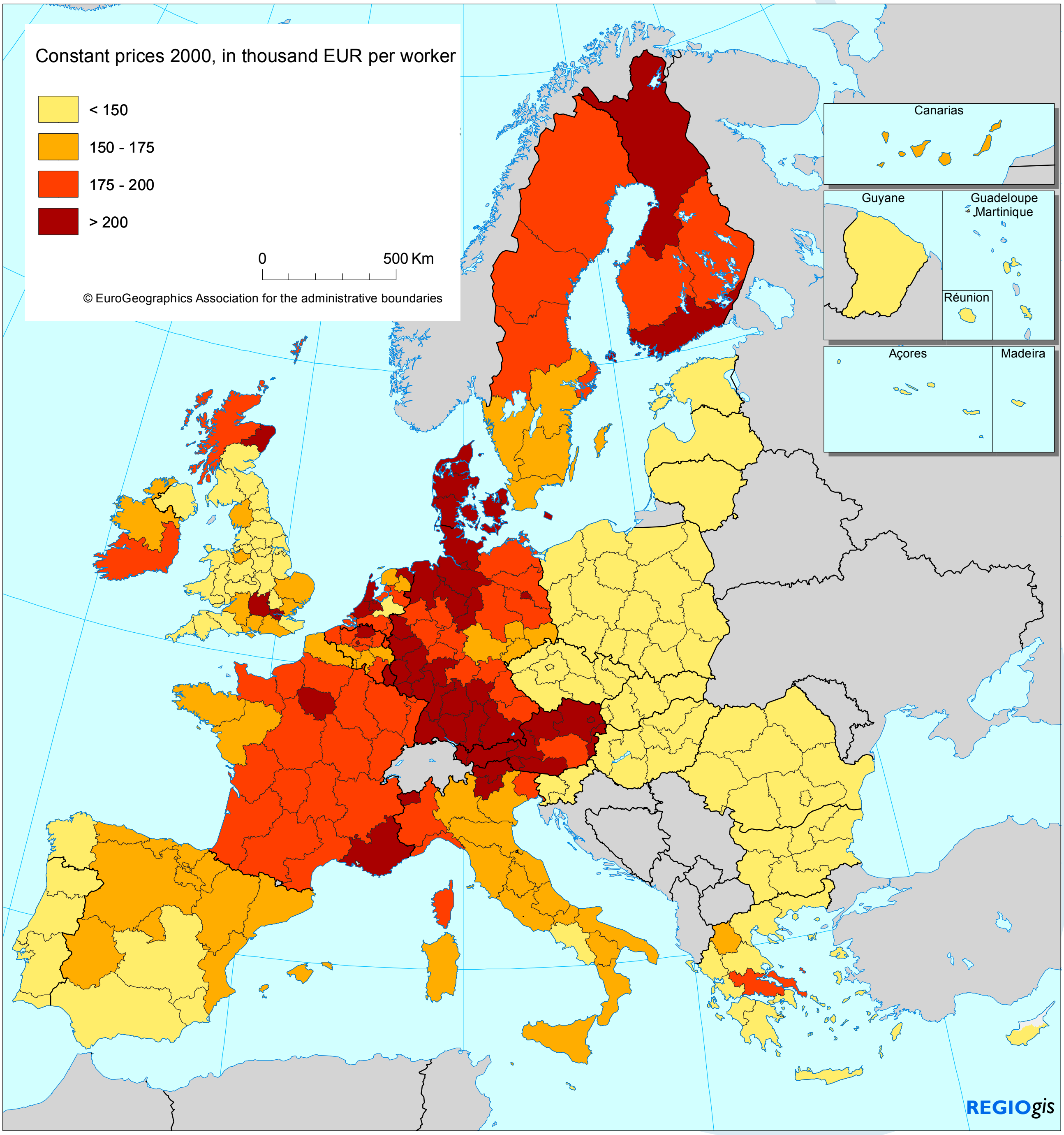
$$(7)\quad \frac{Q_t}{L_t} = \frac{A_t K_t^{\alpha} L_t^{1-\alpha}}{L_t^{\alpha} L_t^{1-\alpha}}$$

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

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

Therefore, labour productivity depends on the level of technology and the capital-labour ratio.

Figure 5 - Capital-labour ratio in 2007, EU-27, all sectors

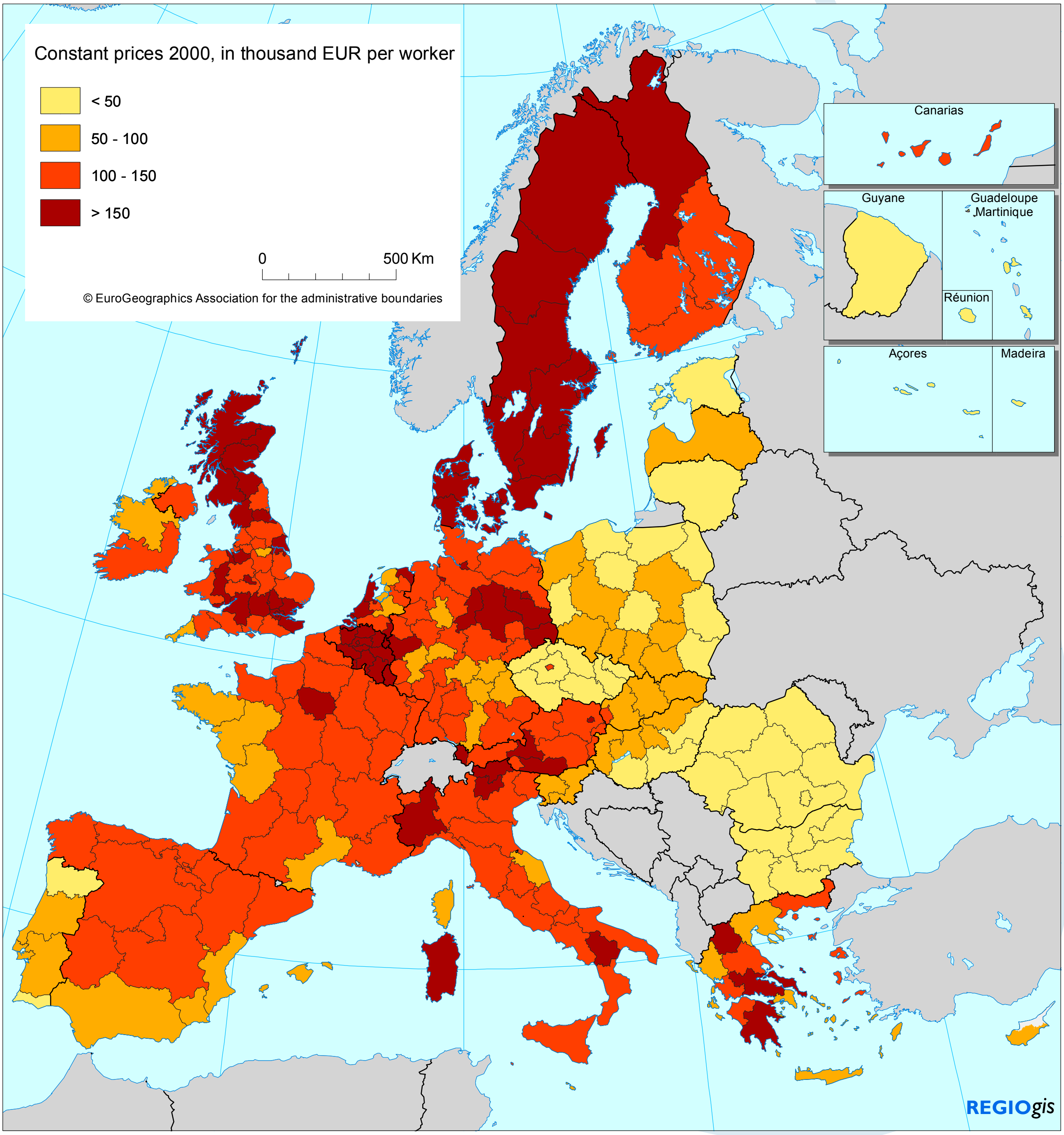


Source: Cambridge Econometrics calculations

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.

Disaggregating the total capital-labour ratio to show manufacturing only, as in Figure 6, shows the same pattern of broad correspondence with expectations with one or two anomalous results again being evident. Some of the Greek NUTS 2 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.

Figure 6 - Capital-labour ratio in 2007, EU-27, manufacturing sector

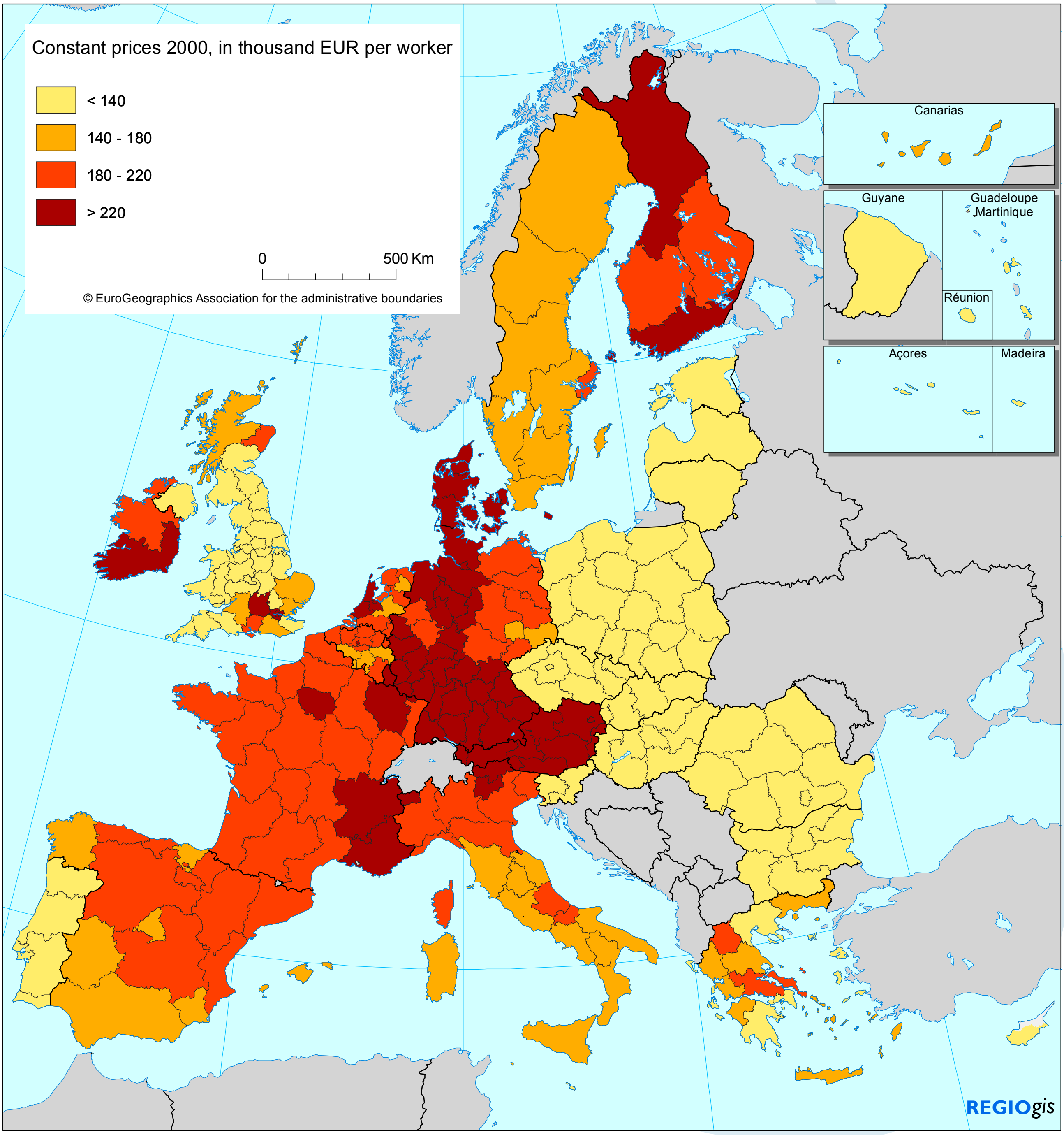


Source: Cambridge Econometrics calculations

The same broad correspondence with intuitive expectations is also present when examining the capital-labour ratio in services in Figure 7 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 ratios examined above commonly exhibit a broad correspondence with intuitive expectations but with a number of obvious exceptions. A further commonality that can be applied 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 7 - Capital-labour ratio in 2007, EU-27, services sector



Constant prices 2000, in thousand EUR per worker

3.4 Focus on Poland

Some of the lack of variation seen within some countries may be because the data examined so far take a broad view of the whole of the European Union and this reduces the variation evident within specific countries. For this reason, in Figures 8-10 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.

Firstly, Figure 8 shows a map of the Polish NUTS 2 regions and some accompanying statistics on economic size and level of development. This helps to highlight the degree of heterogeneity across the Polish regions, from the dominance of the capital-city region (Mazowieckie) and to some extent the second-ranked region (Slaskie), to the grouping of smaller regions which have broadly similar levels of development.

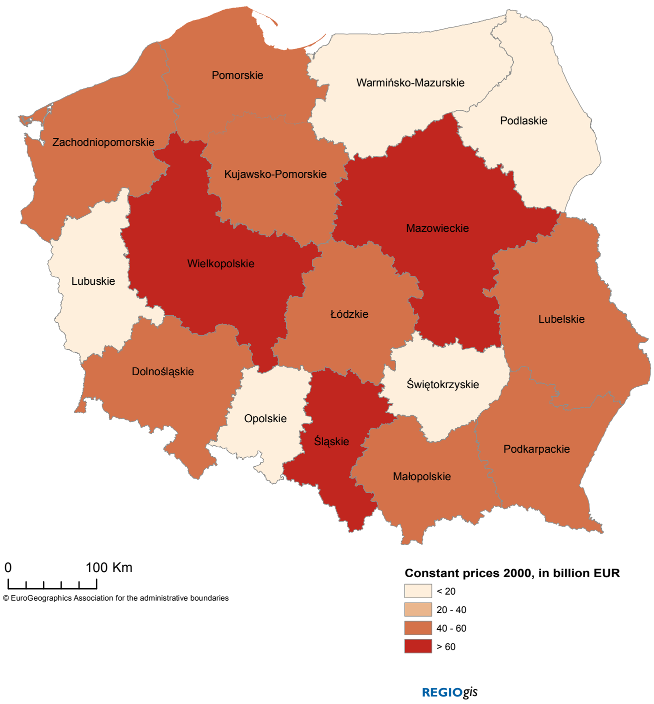
Real net capital stock

Figure 9 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 NUTS 2 regions. The estimates clearly identify the region of Slaskie in the south as having 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 to see whether this region has high labour productivity in accordance with the ratios derived from the production function as described earlier.

Figure 8: Stylised facts for the NUTS 2 regions of Poland

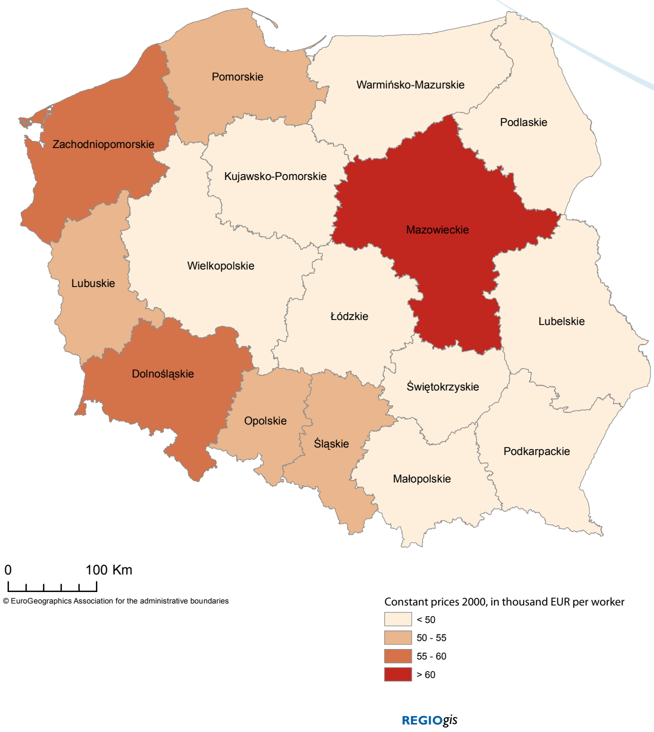
Country	Name	Share of national GVA (%)	Productivity (000s of euro per employee)
pl11	Lódzkie	6.1	11.9
pl12	Mazowieckie	22.5	23
pl21	Malopolskie	7.4	12.5
pl22	Slaskie	12.8	16.4
pl31	Lubelskie	3.7	9.3
pl32	Podkarpackie	3.6	10.3
pl33	Swietokrzyskie	2.5	10.4
pl34	Podlaskie	2.3	12.2
pl41	Wielkopolskie	9.4	15.8
pl42	Zachodniopomorskie	3.9	15.5
pl43	Lubuskie	2.3	12.1
pl51	Dolnoslaskie	8.2	15.8
pl52	Opolskie	2.2	13.9
pl61	Kujawsko-Pomorskie	4.7	13.9
pl62	Warminsko-Mazurskie	2.7	11.8
pl63	Pomorskie	5.7	17.7

Figure 9 - Real net capital stock in 2007, Poland



In summary, the ratios examined above commonly exhibit a broad correspondence with intuitive expectations but with a number of obvious exceptions. A further commonality that can be applied 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 10 - Capital-labour ratio in 2007, Poland, all sectors



3.5 Total Factor Productivity

As a final use of the new data, we calculate total factor productivity (TFP) estimates at the regional level. Until now, work on TFP has been restricted to either national level or nation-specific studies where regional capital stocks are created on a more ad hoc basis. The advantage of a consistent regional capital stock series is that TFP analysis can be undertaken at a lower spatial level across the whole of the EU.

The basic TFP regression is well-known and can be briefly recapped here. TFP is calculated using a conventional residual approach:

$$(10)\ TFP_{ijt} = \exp\{\log(Y_{ijt}) - \alpha \log(L_{ijt}) - (1-\alpha)\log(K_{ijt})\}$$

where:

Y_{ijt} is constant price gross value added in region i for sector j at time t

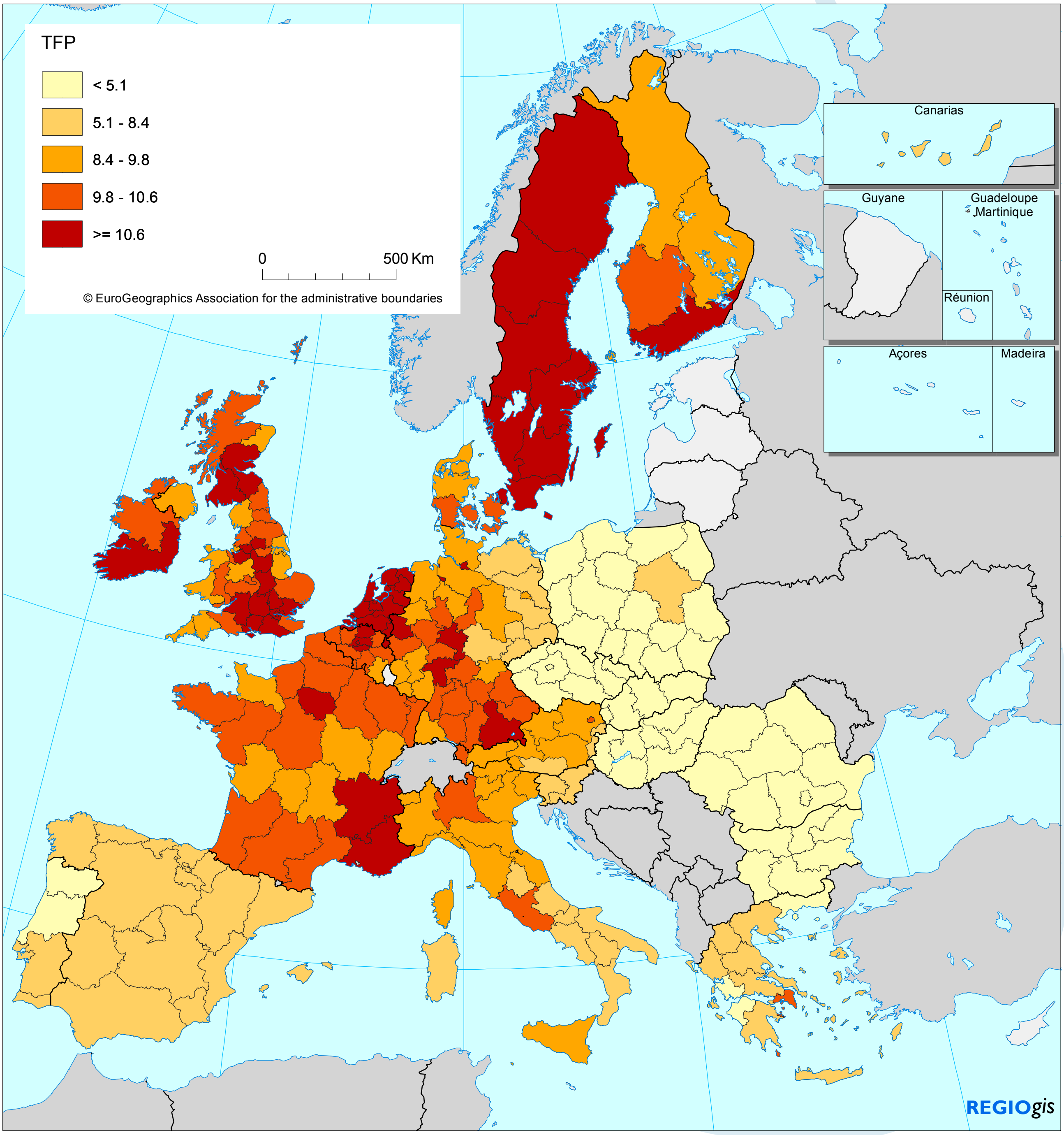
L is total labour input (measured as hours worked)

K is the constant price capital stock

α and (1-α) are factor shares which are sometimes estimated by using wages and rates of return, but in our case we have assumed α to equal two-thirds, which is roughly labour's share of production. It should be noted that, as this section is mainly a demonstration of the use of regional capital stocks, it was not considered central to the point to go into too much detail on this topic.

On this basis, aggregate TFP was calculated from 1995 to 2005. Figure 11 shows the map of TFP across Europe for 2005, Table 6 shows the correlation of TFP levels and growth rates against average labour productivity, and Figure 12 shows the difference (in pp) between labour productivity growth over 1995-2005 and the equivalent growth in TFP.

Figure 11 - Total factor productivity in 2005

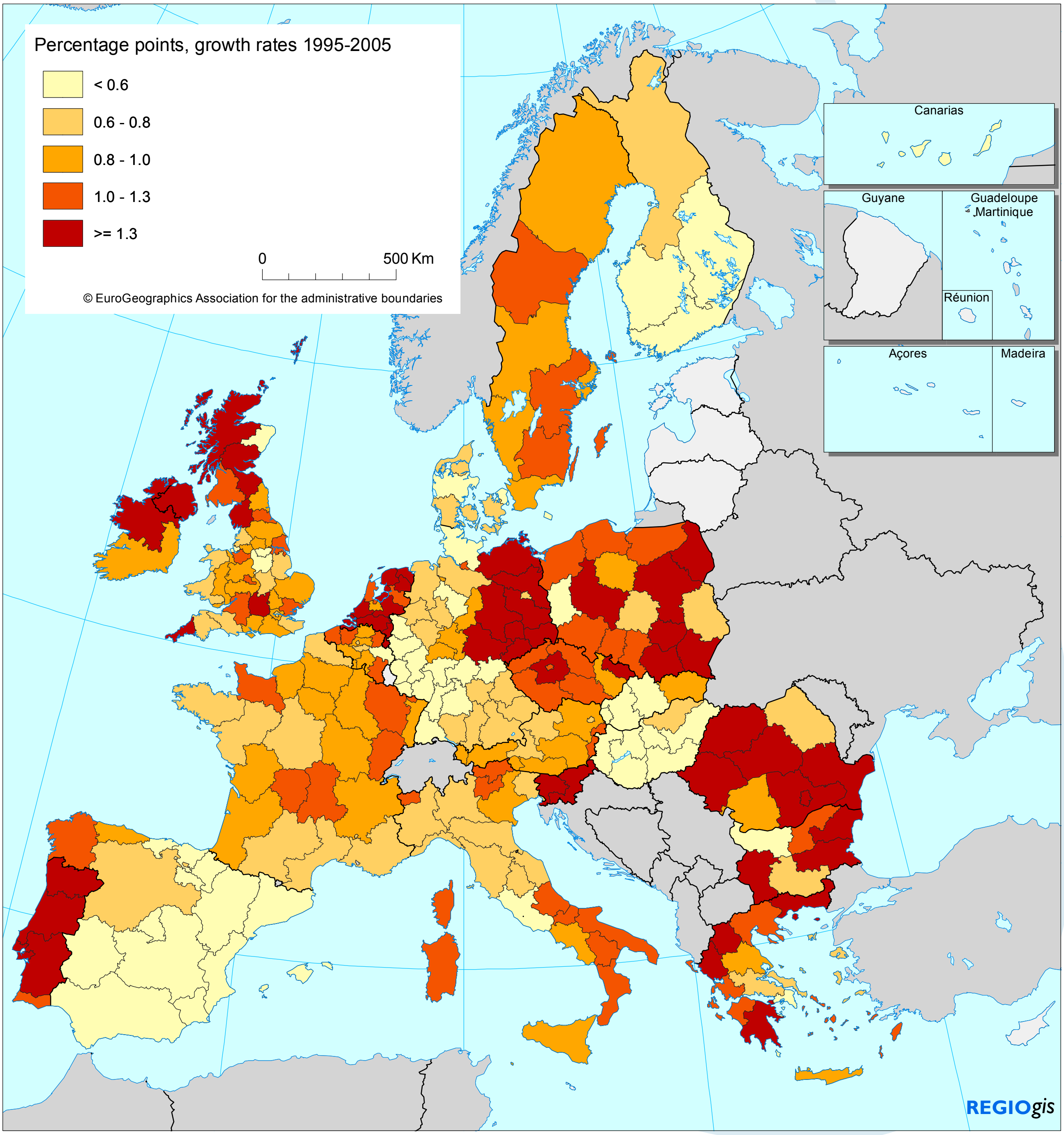


Source: Cambridge Econometrics calculations

Table 6 – Regional TFP – Labour productivity correlation

	Level (1995)	Level (2005)	Growth Rate (1995-2005)
Standard correlation coefficient	0.98	0.98	0.93
Rank correlation coefficient	0.93	0.96	0.93

Figure 12 - Difference between labour productivity growth and TFP growth



Source: Cambridge Econometrics calculations

The map of total TFP shows highest levels in the most well-developed regions of Europe, with a standard picture that is now commonplace when looking at indicators of performance. This is underlined by the high correlation that is evident between TFP and average labour productivity shown in Table 6 – the conditioning of performance against the capital stock does not change the overall picture of regional performance very much. In principle the difference between productivity and TFP growth should reflect the contribution that the capital stock has made to regional performance. In practice this is true, albeit that allowances must be made for the degree of uncertainty surrounding some countries' and regions' capital stock measurements. For example, the largest differences shown in Figure 12 are located around Slovenia, Romania, Portugal and Romania, where the ratio of capital stock to GDP seems unusually low from Figure 2. At the other end of the scale, some negative differences, and those very close to zero, have a high proportion of Latvian and Hungarian regions which seemed to have an over-estimated capital stock from Figure 2, and possibly little subsequent growth. These are extremes, however, and the majority of regions and countries seem to fit within normal boundaries, highlighting the overall success of the exercise but still pointing to where improvements can be made.

Conclusions and Recommendations

Summary of findings

This paper has described a pilot project to assess the feasibility of constructing comparative capital stock statistics at NUTS 2 level for the European Union. The estimates are required, among other things, for 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 NUTS 2 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 that year.

An examination of the capital stock estimates was carried out 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 the capital-labour ratio and total factor productivity.

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 NUTS 2 estimates produced as part of this pilot project do largely correspond with intuitive expectations.

Finally, using the capital stock data to construct a regional TFP indicator seems to yield sensible results, with a strong link to average labour productivity and a broadly expected picture of European regional performance.

In summary, the pilot study was successful in showing that it is possible to produce relatively robust and, crucially, comparable estimates of the capital stock at NUTS 2 level for all EU countries. This work 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.

Recommendations

In summary, to develop and further improve the capital stock statistics produced as part of this report, the following recommendations are made:

- The statistics should 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 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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