Universitat de Girona

HEALTH AND ECONOMIC CONVERGENCE IN THE EUROPEAN UNION (1990-2010): AN ECONOMETRIC APPROACH

Laia MAYNOU PUJOLRÀS

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Laia Maynou Pujolràs

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List of abbreviations

EU- European Union

UE- Unión Europea

UE- Unió Europea

EMU- Economic and Monetary Union

UEM- Unión Económica y Monetaria

UEM- Unió Económica i Monetària

GDP- Gross Domestic Product

PIB- Producto Interior Bruto

PIB- Producte Interior Brut

UML- Unión Monetaria Latina

NUTS- Nomenclature of Territorial Units for Statistics

GDPPC- Gross Domestic Product per capita

PPA- Paridad Poder Adquisitivo

FBCF- Formación Bruta de Capital Fijo

INLA- Integrated Nested Laplace Aproximation

I+D- Inversión y Desarrollo

OLS- Ordinary Least Squares

GMM- Generalitzed Method of Moments

PPS- Purchasing Power Standards

LMU- Latin Monetary Union

ESF- European Social Fund

ERDF- European Regional Development Fund

GMRF- Gaussian Markov Random Field

SPDE- Stochastic Partial Differential Equations

GF- Gaussian Field

DIC- Deviance Information Criterion

NEG- New Economic Geography

EC- Council Regulation

CAR- Conditional Autoregressive Model

AR- Autoregressive

AB- Arellano-Bond

WG- Within-groups estimator

CCE- Common Correlated Effects

PLS- Pooled Least Squares

MA- Moving Average

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Universitat de Girona

Els Dr. Marc Saez Zafra, de la Universitat de Girona, i Dr. Jordi Bacaria Colom, de la Universitat Autònoma de Barcelona,

DECLAREM:

Que el treball titulat 'Health and Economic Convergence in the European Union (1990-2010): An Econometric Approach', que presenta Laia Maynou Pujolràs per a l'obtenció del títol de doctora, ha estat realitzat sota la nostra direcció i que compleix els requisits per poder optar a Menció Internacional.

I, perquè així consti i tingui els efectes oportuns, signem aquest document.

Dr. Marc Saez

Dr. Jordi Bacaria

Girona, 9 d'agost de 2013

Dedicatòria

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Doctoral Thesis Laia Maynou Pujolràs 2013

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1. Thesis summary

1.1. Resum de la tesis

"Amb el fi de promoure el desenvolupament harmònic del conjunt de la Unió, aquesta desenvoluparà i continuarà la seva acció encaminada a reforçar la seva cohesió econòmica, social i territorial. La Unió es proposarà, en particular, reduir les diferències entre els nivells de desenvolupament de les diverses regions i el retràs de les regions menys afavorides." Art. 174 del Tractat del Funcionament de la Unió Europea, Tractat de Lisboa (2009)

L'article 174, objectiu de màxima importància de la Unió Europea (UE), constitueix la principal motivació d'aquesta tesi doctoral. Una de les principals prioritats de la UE és aconseguir la cohesió econòmica, social i territorial, reduint les disparitats existents. Per aquest motiu, amb l'objectiu de facilitar la convergència (reducció de disparitats), durant les dues últimes dècades la Unió Europea ha implementat diverses polítiques. Encara que el propòsit de les polítiques de cohesió va més enllà de la mera convergència econòmica, l'èxit d'aquestes polítiques s'ha mesurat a través de la convergència dels nivells del PIB per càpita regionals. En definitiva, la convergència econòmica ha esdevingut un dels aspectes principals per tal d'avaluar l'efectivitat de la Política de Cohesió Europea (Monfort, 2008).

Aquesta tesis intenta dibuixar una imatge de la convergència de la UE de 1990 a 2010, amb l'objectiu d'analitzar la convergència econòmica, definida comunament com la reducció de les disparitats en PIB per càpita i en productivitat dins de la UE. Tres són els punts centrals d'aquesta tesis. Primer, analitzem la convergència dels disset països que, en l'actualitat, formen part de la eurozona. Segon, expandim l'àrea d'estudi per tal cobrir tota la Unió Europea i, a l'hora, anar més enllà de la mera convergència econòmica. Tercer, demostrem la superioritat de la metodologia utilitzada en cadascun dels articles que conformen aquest treball.

Els tres primers articles de la tesis es centren en els països de la eurozona. Per entrar a la Unió Econòmica i Monetària (UEM), els països candidats van haver de complir amb uns requisits de convergència nominal detallats en el Tractat de Maastricht (1992). Aquestes condicions van ser definides per garantir que, abans d'entrar a la UEM, els candidats haguèssin aconseguit un cert nivell de convergència (nominal). Aquesta condició prové de la teoria de les "Zones Monetàries Optimes", que afirma que la convergència econòmica és un prerequisit per tenir una Unió Econòmica i Monetària òptima (Mundell, 1961). Però, després de més de deu anys des de la seva creació, convergeixen els països de la UEM?

Des del naixement de la UEM, nombroses polítiques han estat adoptades pels Estats Membres de la Unió Europea per conduir-los cap a la convergència econòmica. Amb el propòsti d'avaluar els efectes d'aquestes polítiques, en el primer article analitzem el procés de convergència de les regions de la eurozona a través d'un model economètric espai-temporal. Els resultats del nostre anàlisis mostren que, en termes de PIB per càpita, va existir un convergència significativa entre els països de la eurozona, mentre que, en termes de productivitat, va haver-hi una divergència significativa. El comportament desfavorable de la productivitat podria ser explicat per la diferent evolució de la població activa i de la producció de cada país. Per altra banda, a partir del comportament del coeficient d'interès, la taxa de convergència, concloem que els patrons de convergència/divergència no van ser significatius a nivell regional, mentre que si que ho van ser a nivell de país.

Sobre la base del discurs del primer article, avaluem el resultat específic d'una de les estratègies centrals de la UE. Específicament, analitzem la Política de Cohesió Europea, implementada a través dels Fons Estructurals i de Cohesió, i l'impacte que ha tingut en la convergència econòmica dels països de l'eurozona. Els nostres resultats indiquen, corroborant els resultats del primer article, que la convergència econòmica va ser significativa entre els països de l'eurozona en el període analitzat. A més a més, trobem que els Fons Estructurals i de Cohesió van contribuir positivament al creixement del PIB per càpita de les regions o països que els van rebre. Aquests fons han afavorit les àrees menys desenvolupades de l'eurozona, incrementant el seu PIB per càpita i facilitant el seu camí cap a la convergència.

Per anar més enllà de la mera convergència econòmica, en el tercer article utilitzem el concepte de convergència per avaluar les dinàmiques centre-perifèria dels països de l'eurozona. Des dels vuitantes, Europa ha estat popularment definida com "l'Europa de les dues velocitats", en altres paraules, l'anomenat centre de la UE (ex. Alemanya, França, Bèlgica, Holanda, etc.) en front d'aquells països considerats perifèrics (ex. Grècia, Portugal, Irlanda, etc). Doncs bé, estan convergint aquests dos blocs de països (centre-perifèria)? Els resultats del nostre model dinàmic de dades de panell mostren que la pertinença a l'eurozona ha incentivat el creixement dels països perifèrics, conduint-los cap a la convergència. No obstant, el creixement dels països del centre s'ha ralentitzat, i això ha comportat que divergeixin de la resta de països de l'eurozona. Conseqüentment, trobem que la distància entre el centre-perifèria s'ha reduït en els últims anys (principalment des del 2004), però degut a que el centre ha divergit mentre que la perifèria ha convergit. Aquest resultat no era l'esperat, ja que alguns economistes atribueixen la divergència als països perifèrics. Una explicació podria ser que des de 2003 en endavant, alguns dels països del centre (ex. Alemanya, França) es van estancar i van necessitar adoptar importants reformes en el mercat laboral per fer les seves economies més flexibles. Com a conseqüència, l'atur va augmentar en aquells països que formen el centre de la UE, la tendència cap a la convergència es va aturar, i va començar un període de divergència.

Nombrosos estudis previs han analitzat la convergència econòmica de la UE. La convergència econòmica, no obstant, només pot donar una imatge parcial de les desigualtats entre països (Kenny 2005). El benestar és polifacètic i inclou molts aspectes que van molt més enllà de la renda. Per tant, per tal d'analitzar la reducció de desigualtats en el benestar entre països, semblaria que la renda és una mesura insuficient. És, però, impossible controlar directament totes les dimensions de qualitat de vida. No obstant, és possible utilitzar altres mesures que englobin els factors de benestar (Sen 1998, 1999).

Amb l'objectiu d'anar més enllà de la renda, en el quart article de la tesis analitzem la convergència utilitzant l'esperança de vida i la mortalitat (per diferents causes) en les regions de la UE-27 de 1995 a 2009. En aquest article expandim la nostra àrea d'estudi. En termes només econòmics, tenia sentit analitzar la eurozona donat els seus principis econòmics, però quan considerem la salut com el nostre àmbit d'estudi, necessitem fixar-nos en tots els països de la UE. Els resultats del nostre anàlisi mostren que, en termes de salut, hi ha hagut un procés d'apropament entre les regions de la UE. No obstant, i sorprenentment, no trobem, de mitjana, una reducció en els nivells de dispersió. En conseqüència, si la reducció de la dispersió és la mesura definitiva de la convergència, com diversos autors han assenyalat (ex. Quah, 1993), llavors, el nostre estudi mostra una manca de convergència en salut entre les regions de la UE.

El cinquè, i últim article, surt del tema de la convergència. En els primers quatre articles hem especificat un model dinàmic de dades de panell amb efectes aleatoris, és a dir, permetem que alguns coeficients, i en particular els d'interès, variïn entre els diferents nivells que vam considerar (país, regió i temps). Tot i que hi ha diferents mètodes per tractar aquest tipus de dades de panel, l'estimació més utilitzada és l'estimador pel mètode generalitzat de moments, en primeres diferències, o estimador d'Arellano-Bond (Arellano i Bond, 1991; basat en el treball de Holtz-Eakin *et al.*, 1988). En aquest article, demostrem que la metodologia recentment implementada i utilitzada en els nostres quatre articles, el procés 'Integrated Nested Laplace Approximation (INLA)' basat en un enfocament Bayesia pur, és superior, en termes de manca de biaix i eficiència, que altres mètodes d'estimació consistent per models dinàmics de dades de panell.

1.2. Resumen de la tesis

"A fin de promover un desarrollo armonioso del conjunto de la Unión, ésta desarrollará y proseguirá su acción encaminada a reforzar su cohesión económica, social y territorial. La Unión se propondrá, en particular, reducir las diferencias entre los niveles desarrollo de las diversas regiones y el retraso de las regiones menos favorecidas" Art. 174 del Tratado del Funcionamiento de la Unión Europea, Tratado de Lisboa (2009)

El artículo 174, objetivo de máxima importancia de la Unión Europea (UE), constituye la principal motivación de esta tesis doctoral. Una de las principales prioridades de la UE es alcanzar la cohesión económica, social y territorial, reduciendo las disparidades existentes. Como consecuencia, con el objetivo de facilitar la convergencia (reducción de disparidades), durante las dos últimas décadas la Unión Europea ha implementado varias políticas. Aunque el propósito de las políticas de cohesión va más allá de la simple convergencia económica, el éxito de estas políticas se ha medido a través de la convergencia de los niveles de los PIB per cápita regionales. En definitiva, la convergencia económica se ha convertido en uno de los aspectos principales para evaluar la efectividad de la Política de Cohesión Europea (Monfort, 2008).

Esta tesis intenta dibujar una imagen de la convergencia de la UE de 1990 a 2010, con el objetivo de analizar la convergencia económica, definida comúnmente como la reducción de las disparidades en el PIB per cápita y en la productividad dentro de la UE. Tres son los puntos centrales de esta tesis. Primero, analizamos la convergencia de los diecisiete países que, en la actualidad, forman parte de la eurozona. Segundo, expandimos el área de estudio para cubrir toda la Unión Europea y, al mismo tiempo, ir más allá de la simple convergencia económica. Tercero, demostramos la superioridad de la metodología utilizada en cada uno de los artículos que conforman este trabajo.

Los tres primeros artículos de la tesis se centran en los países de la eurozona. Para entrar en la Unión Económica y Monetaria (UEM), los países candidatos tuvieron que cumplir con unos requisitos de convergencia nominal detallados en el Tratado de Maastricht (1992). Estas condiciones fueron definidas para garantizar que, antes de entrar en la UEM, los candidatos hubieran conseguido un cierto nivel de convergencia (nominal). Esta condición proviene de la teoría de las "Zonas Monetarias Optimas", la cual afirma que la convergencia económica es un prerrequisito para tener una Unión Económica y Monetaria optima (Mundell, 1961). Sin embargo, después de más de diez años de su creación, convergen los países de la UEM?

Desde el nacimiento de la UEM, numerosas políticas han sido adoptadas por los Estados Miembros de la Unión Europea para conducirlos hacia la convergencia económica. Con el propósito de evaluar los efectos de estas políticas, en el primer artículo analizamos el proceso de convergencia de las regiones de la eurozona a través de un modelo econométrico espacio-temporal. Los resultados de nuestro análisis muestran que, en términos de PIB per cápita, existió una convergencia significativa entre los países de la eurozona, mientras que, en términos de productividad, hubo una divergencia significativa. El comportamiento desfavorable de la productividad podría ser explicado per la diferente evolución de la población activa y de la producción de cada país. Por otro lado, a partir del comportamiento del coeficiente de interés, la tasa de convergencia, concluimos que los patrones de convergencia/divergencia no fueron significativos a nivel regional, mientras que si a nivel de país.

En base al discurso del primer artículo, evaluamos el resultado específico de una de las estrategias centrales de la UE. Específicamente, analizamos la Política de Cohesión Europea, implementada a través de los Fondos Estructurales y de Cohesión, y el impacto que ha tenido en la convergencia económica de los países de la eurozona. Nuestros resultados indican, corroborando los resultados del primer artículo, que la convergencia económica fue significativa entre los países de la eurozona en el periodo analizado. Además, encontramos que los Fondos Estructurales y de Cohesión contribuyeron positivamente al crecimiento del PIB per cápita de las regiones o países que los recibieron. Estos fondos han favorecido las áreas menos desarrolladas de la eurozona, incrementando su PIB per cápita y facilitando su camino hacia la convergencia.

Para ir más allá de la mera convergencia económica, en el tercer artículo utilizamos el concepto de convergencia para evaluar las dinámicas centro-periferia de los países de la eurozona. Desde los ochenta, Europa ha sido popularmente denominada como “la Europa de las dos velocidades”, en otras palabras, el considerado centro de la UE (ex. Alemania, Francia, Bélgica, Holanda, etc.) en frente de aquellos países considerados periferia (ex. Grecia, Portugal, Irlanda, etc.). Pues bien, ¿Están convergiendo estos dos bloques de países (centro-periferia)? Los resultados de nuestro modelo dinámico de datos de panel muestran que la pertenencia a la eurozona ha incentivado el crecimiento de los países periféricos, conduciéndolos hacia la convergencia. No obstante, el crecimiento de los países del centro se ha ralentizado, y esto ha comportado que diverjan del resto de países de la eurozona. Consecuentemente, encontramos que la distancia entre el centro-periferia se ha reducido en los últimos años (principalmente desde 2004), pero debido a que el centro ha divergido mientras que la periferia ha convergido. Este resultado no era el esperado, ya que algunos economistas atribuyen la divergencia a los países periféricos. Una explicación podría ser que desde 2003 en adelante, algunos de los países del centro (ex. Alemania, Francia) se estancaron y necesitaron adoptar importantes reformas en el mercado laboral para hacer sus economías más flexibles. Como consecuencia, el paro aumentó en aquellos países que forman el centro de la UE, la tendencia hacia la convergencia se paro, y empezó un periodo de divergencia.

Numerosos estudios previos han analizado la convergencia económica de la UE. La convergencia económica, no obstante, solo puede dar una imagen parcial de las desigualdades entre países (Kenny 2005). El bienestar es polifacético e incluye muchos aspectos que van mucho más allá de la renta. Por lo tanto, para analizar la reducción de desigualdades en el bienestar entre países, parecería que la renta es una medida insuficiente. Aunque resulta imposible controlar directamente todas las dimensiones de calidad de vida, sin embargo es posible utilizar otras medidas que abarquen los factores de bienestar (Sen 1998, 1999).

Con el objetivo de ir más allá de la renta, en el cuarto artículo de la tesis analizamos la convergencia utilizando la esperanza de vida y la mortalidad (por diferentes causas) en las regiones de la UE-27 de 1995 a 2009. En este artículo expandimos nuestra área de estudio. En términos sólo económicos, tenía sentido analizar la eurozona dados sus principios económicos, pero cuando consideramos la salud como nuestro ámbito de estudio, necesitamos fijarnos en todos los países de la UE. Los resultados de nuestro análisis muestran que, en términos de salud, ha habido un proceso de acercamiento entre las regiones de la UE. No obstante, y sorprendentemente, no encontramos, de media, una reducción en los niveles de dispersión. En consecuencia, si la reducción de la dispersión es la medida definitiva de la convergencia, tal y como diversos autores han señalado (Quah, 1993), entonces, nuestro estudio muestra una falta de convergencia en salud entre las regiones de la UE.

El quinto, y último artículo, se sale del tema de la convergencia. En los primeros cuatro artículos hemos especificado un modelo dinámico de datos de panel con efectos aleatorios, es decir, permitimos que algunos coeficientes, y en particular los de interés, varíen entre los diferentes niveles (país, región y tiempo) que consideramos. Aunque hay diferentes métodos para tratar este tipo de datos de panel, la estimación mas utilizada es el estimador por el método generalizado de momentos, en primeras diferencias, o estimador de Arellano-Bond (Arellano y Bond, 1991; basado en el trabajo de Holtz-Eakin *et al.*, 1988). En este artículo, demostramos que la metodología recientemente implementada y utilizada en nuestros cuatro artículos, el proceso 'Integrated Nested Laplace Approximation (INLA)' basado en un enfoque Bayesiano puro, es superior, en términos de insesgadez y eficiencia, que otros métodos de estimación consistente para modelos dinámicos de datos de panel.

1.3. Thesis summary

"In order to promote its overall harmonious development, the Union shall develop and pursue its actions leading to the strengthening of its economic, social and territorial cohesion. In particular, the Union shall aim at reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions" Art. 174 of the Treaty on the Functioning of the European Union, Treaty of Lisbon (2009)

Article 174, a European Union objective of the utmost importance, is the driving force behind this PhD thesis. One of the greatest priorities of the EU is to achieve economic, social and territorial cohesion by reducing existing disparities within the Union. As a result, diverse policies to facilitate convergence (i.e. reduction of disparities) across the European Union have been adopted over the past two decades. While the purpose of the cohesion policy may go far beyond mere economic convergence, the reduction of regional disparities is measured as the convergence of regional levels of GDP per capita. Essentially, pure economic convergence has become a major aspect in assessing the effectiveness of the European Cohesion Policy (Monfort, 2008).

In an effort to analyse economic convergence, commonly defined as the reduction of disparities in GDP per capita and productivity within the EU, this PhD thesis endeavours to paint a picture of EU convergence from 1990-2010. The focal points of this thesis are threefold. First, we apply the convergence concept to only seventeen of the countries that currently form the eurozone. Second, we then expand the studied area to encompass the whole of the EU, and by doing so go beyond simple economic convergence. Third, we prove the superiority of the methodology used in each of the papers in this work.

The first three papers of the thesis are centred on the eurozone countries. To enter the Economic and Monetary Union (EMU), candidate countries had to comply with nominal convergence requisites, which were outlined in the Maastricht Treaty (1992). These conditions were defined to guarantee that, before entering the EMU, the candidates had reached a certain level of economic (nominal) convergence. This requirement stems from the theory of the 'Optimum Currency

Areas (OCA)', which states that economic convergence is a prerequisite to having an effective Economic and Monetary Union (Mundell, 1961). However, after more than ten years since its creation, are the EMU countries converging?

Since the birth of the EMU, numerous policies have been adopted by the Member States of the European Union (EU) to steer themselves towards economic convergence. In an attempt to appreciate the effect of these policies, the first paper analyses the convergence process of the eurozone regions through a spatio-temporal econometric model. The results of our analysis show significant convergence, in terms of GDP per capita across the eurozone countries whereas, in terms of productivity, we find significant divergence. From the behaviour of the coefficient of interest, we can state that the patterns of convergence/divergence are not significant on a regional level, whereas they are on a country level. The non-favourable performance of productivity can be explained by the distinct evolution of the active population and the production of each country.

Building on the discourse of the first paper, we assess the specific outcome of one of the core strategies of the EU. Specifically, we analyse the EU Cohesion policy, implemented through the Structural Funds and the Cohesion Fund, and the impact it has had on economic convergence across the eurozone countries. Our results indicate, corroborating the results of the first paper, that there is significant economic convergence amongst the eurozone countries for the studied period. Moreover, we find that the Structural and Cohesion funds have positively contributed to the GDP per capita growth of the regions or countries which have received them. These funds have favoured the less developed areas of the eurozone by increasing their GDP per capita and facilitating their path towards convergence.

In a bid to go beyond mere economic eurozone convergence, the third paper attempts to use the convergence concept to evaluate the convergence dynamics of the core-periphery among the eurozone countries. Since the late 80s, Europe has been popularly defined as a "two-speed Europe", in other words, the so-called EU core (e.g. Germany, France, Belgium, the Netherlands, etc) coupled with those countries deemed as periphery countries (e.g. Greece, Portugal, Ireland, etc). Are these two blocks of countries (core-periphery) converging? The results of our dynamic panel model show that the eurozone membership has spurred on the growth of the periphery countries, leading them to convergence. However, the core countries' growth has slowed, and this has led to a divergence from the rest of the eurozone countries. Consequently, we found that the distance between core-periphery has been reduced in recent years (largely from 2004), as the core diverged while the periphery converged. This result was not expected, as some economists attribute the divergence to the peripheral countries. One explanation could be that from 2003 onwards, some of the core countries (e.g. Germany, France) were stuck in a rut and needed to adopt crucial labour market reforms to make their economies more flexible. As a consequence, unemployment rose in those countries forming the EU core, the tendency towards convergence stopped, and a period of divergence began.

Numerous previous studies have analysed economic convergence in the EU. Economic convergence, however, can only give a partial picture of the dynamics of inequalities across countries (e.g. Kenny 2005). Well-being is multifaceted and typically involves many aspects beyond income. Therefore, to analyse the reduction of disparities in well-being across countries, it would appear that simple income measures are insufficient. It is of course impossible to directly control for all the dimensions of life quality. However, it is possible to employ summary measures that encompass a wider range of factors of well-being (Sen 1998, 1999).

In an effort to look beyond income, the fourth paper of the thesis analyses convergence using life expectancy and (cause-specific) mortality in the EU-27 regions from 1995 to 2009. In this paper we expand our study area to encompass health, as the eurozone countries are not only the ones expected to reach cohesion in these terms. In terms of simple economic convergence, it made sense to only analyse the eurozone because of its economic principles, but when we widen the scope, we need to focus on all EU countries. The results of our analysis show that, in terms of health, there has been a catching-up process among the EU regions. However, surprisingly, we find no reduction, on average, in dispersion levels. Consequently, if the reduction of dispersion is the ultimate measure of convergence, as various authors have agreed (e.g. Quah, 1993), then our study shows a lack of convergence of health across EU regions.

The fifth, and final paper, goes outside the scope of convergence. In the previous four papers we specified dynamic panel data models with random coefficients, i.e., we allow some coefficients, and in particular the parameters of interests, to vary across different levels (country, region and time). While there are different approaches in dealing with these types of panel data, the estimation which is widely used is the first-difference generalized methods of moments or the Arellano-Bond estimator (AB) (Arellano and Bond, 1991); based on the work of Holtz-Eakin *et al.* (1988). In this paper, we prove that the recently implemented methodology that we use for our models, the Integrated Nested Laplace Approximation (INLA) procedure based on a pure Bayesian approach, is superior, in terms of bias and efficiency, to other consistent estimation methods for dynamic panel data model.

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2. Hypothesis

1.- During the period from 1990 to 2010, the eurozone countries have followed a path, in terms of GDP per capita and productivity, towards convergence.

> 1.1.- The policies employed on a European Union level have propelled these regions towards convergence.
>
> 1.2.- These EU policies have been implemented on a country level, so we do not expect to find significant variations across the regions within a country .

2.- The EU Cohesion policy, implemented through the Structural Fund and the Cohesion Funds, has helped eurozone countries reach convergence in the past two decades (1990-2010).

> 2.1.- These funds, because of the principles that they are based on (additionality and partnership), have also contributed to the increase in public and private debt during the specified study period.

3.- As a result of the policies adopted to establish the EMU, the eurozone countries began a process towards convergence and, as a consequence, the distance between core-periphery countries has been reduced over the past decade.

> 3.1.- However, we suppose that this convergence had not been the same for all countries or throughout the whole period analyzed.

4.- There was convergence in life expectancy and (cause-specific) mortality in the EU-27 regions from 1995 to 2009.

> 4.1.- By analysing regions instead of countries, we were able to observe adequate variability in the health variables of interest in order to estimate the (dis)similarity of their distribution over time.
>
> 4.2.- Assuming a positive relationship between income and health, there has been beta-convergence in health between the EU-27 regions, but not sigma-convergence. This is due to the disparities that still exist, in terms of health variables, across EU countries.
>
> 4.3.- Like economic convergence, the speed of health convergence is neither constant in time nor between regions or countries.

5.- The hierarchical strategy of the Bayesian approach (INLA), implying different prior and hyper-prior assignments, provides a greater flexibility to the estimation procedure for dynamic panel data models.

> 5.1.- This estimation method controls the biases associated with dynamic panel data models i.e., individual effects bias, dynamic panel bias and state dependence.
>
> 5.2.- This control enables consistent estimations of the parameters to be obtained. It is, at least, as efficient as the other estimators commonly used in dynamic panel data models

3. Objectives

General objective

The general objective of this thesis derives from art.174 of the TFEU, Treaty of Lisbon (2009) *[…Union shall aim at reducing disparities between the levels of development of the various regions and the backwardness of the least favoured regions.]*. The main aim is to empirically evaluate the reduction of economic and social disparities in the European Union, through the path of convergence followed by the EU Member States from 1990-2010. This objective is reached through five explicit objectives, each of which is developed into an individual paper.

Specific objectives

1) Analyse the convergence process of the eurozone regions from 1990 to 2010, in terms of GDP per capita and productivity, in order to verify if the policies implemented at the EU level have propelled these regions towards convergence.

2) Examine whether the EU Cohesion policy, implemented through the Structural Fund and the Cohesion Funds, has contributed towards convergence among the eurozone countries during the past two decades (1990-2010).

3) Evaluate the convergence dynamics of the core-periphery among the eurozone countries. Are these two blocks converging?

4) In an effort to look beyond income, analyse convergence using life expectancy and (cause-specific) mortality in the EU-27 regions from 1995 to 2009.

5) Prove that the recently implemented methodology, the Integrated Nested Laplace Approximation (INLA) approach, is superior, in terms of bias and efficiency, to other consistent estimation methods for dynamic panel data model.

4. Papers

Paper 1. Maynou, L., Bacaria, J. and Saez, M. (2013) 'Anàlisis de convergencia de las regiones de la zona Euro' *Ekonomiaz*, nº 82, pp. 200-217.

Paper 2. Maynou, L., Saez, M., Kyriacou, A. and Bacaria, J. (2013) 'The impact of structural and cohesion funds on eurozone convergence (1990-2010)' *Regional Studies* (under revision).

Paper 3. Maynou, L., Saez, M. and Bacaria, J. (2013) 'Convergence dynamics of core-periphery: empirical evidence from the eurozone 1990-2009' *Journal of International Economics* (under revision).

Paper 4. Maynou, L., Saez, M., Bacaria, J. and López-Casasnovas, G. (2013) 'Health inequalities in the European Union: An empirical analysis of the dynamics of regional differences' *European Journal of Health* Economics (under revision).

Paper 5. Maynou, L. and Saez, M. (2013) 'Bayesian estimation of small dynamic panel data' *Journal of Econometrics* (under revision)

4.1. Análisis de convergencia de las regiones de la zona Euro

Maynou, L., Bacaria, J. and Saez, M. (2013) 'Anàlisis de convergencia de las regiones de la zona Euro' *Ekonomiaz*, nº 82, pp. 200-217.

> *"If you can't fly then run, if you can't run then walk, if you can't walk then crawl, but whatever you do you have to keep moving forward."*
>
> *Martin Luther King Jr.*

Análisis de convergencia de las regiones de la zona euro (1990-2010)

Desde el nacimiento de la Unión Económica y Monetaria (UEM), se han implantado políticas en los diferentes países miembros de la Unión Europea (UE) para conducirlos hacia la convergencia económica. Analizamos la convergencia de las 174 regiones que existen en los 17 países de la zona euro en el periodo 1990-2010. Especificamos un modelo econométrico espacio-temporal, utilizando las hipótesis de beta-convergencia condicionada y de sigma-convergencia. Las variables dependientes del modelo son el PIB per cápita y la productividad y las variables explicativas son variables económicas reales. Encontramos que existe beta-convergencia entre los países de la zona euro en términos de PIB per cápita, pero divergencia en términos de productividad, si bien las pautas se producen sólo a nivel de país. Es decir, se confirma nuestra hipótesis de que son las pautas a escala país las que conducen a la hipotética convergencia y que el comportamiento desfavorable de la productividad se debe, sin duda, a un diferente comportamiento de la población activa entre los diferentes países de la zona euro.

Ekonomia eta Moneta Batasuna jaio zenetik, Europar Batasuneko herrialde bakoitzak bere politikak ezarri ditu konbergentzia ekonomikoa lortzeko. 1990-2010 aldian 17 herrialdez osatutako batasunak biltzen dituen 174 eskualdeen konbergentzia aztertuko dugu. Espazio-denborazko eredua ekonometrikoa zehaztu dugu, beta-konbergentzia baldintzatua eta konbergentzia-sigma hipotesiak erabiliz. Ereduaren aldagai dependenteak BPG per capita eta produktibitatea dira, eta aldagai esplikatiboakk, berriz, aldagaia ekonomiko errealak dira. Euro-guneko herrialdeetan beta-konbergentzia ikusten dugu BPG per capitari dagokionez, baina produktibitateari dagokionez dibergentzia dago, nahiz pautak herrialde mailan bakarrik gertatzen diren. Hau da, berretsita geratzen da gure hipotesia; herrialde-mailako pautak direla dira konbergentzia hipotetikora garamatzatenak eta produktibitatearen portaera txarra, dudarik gabe, euro-guneko herrialdeetan biztanleria aktiboaren jokabide ezberdinaren ondorio dela.

Since the birth of Economic and Monetary Union (EMU), policies have been implemented in the Member States of the European Union (EU) to lead them towards economic convergence. This article analyses the convergence of the 174 regions that exist in the 17 euro-zone countries in the years from 1990 to 2010. The article specifies a space-time econometric model using the hypotheses of conditioned beta-convergence and sigma-convergence. The dependent variables of the model are per capita GDP and productivity and the explanatory variables are real economic variables. Beta-convergence is found to exist between the countries of the euro-zone in terms of per capita GDP, but there is divergence in terms of productivity, though only at country level. In other words, the hypothesis is confirmed that it is guidelines at country level that lead to hypothetical convergence and that the unfavourable performance of productivity is due, without doubt, to differences in behaviour between the active populations of the different euro zone countries.

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Índice

Palabras clave: Euro zona, beta-convergencia, sigma-convergencia, núcleo-periferia.
Keywords: Eurozone, beta-convergence, sigma-convergence, core-periphery.

Clasificación JEL: E17, C32, R11.

1. **INTRODUCCIÓN**

La convergencia económica

El concepto de convergencia, en el sentido más general, significa la reducción y la equiparación de las disparidades (Paas *et al.*, 2007). La convergencia es un fenómeno real y a largo plazo que se relaciona muy directamente con los procesos de crecimiento, es decir, existe convergencia cuando los niveles de desarrollo o bienestar, entre dos o más países, tienden a aproximarse (Barro y Sala-i-Martín, 1991).

Existen dos hipótesis de convergencia, la convergencia absoluta y la condicionada (Paas *et al.*, 2007). En la hipótesis de convergencia absoluta, la renta per cápita de los países o regiones converge una con la otra a largo plazo sin tener en cuenta las condiciones iniciales. Los países y regiones pobres tienden a crecer más rápido que

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[1] Laia Maynou es becaria predoctoral de la Generalitat de Catalunya (FI-2011), cuya financiación agradecen los autores.

los ricos y existe una relación negativa entre la media de la tasa de crecimiento y los niveles iniciales de renta. Se asume que todas las economías convergen al mismo estado estacionario.

Por otra parte, la hipótesis de convergencia condicionada asume que la renta por cápita de los países o regiones converge la una con la otra, a largo plazo, siempre que las características estructurales (por ejemplo: tecnología, capital humano, instituciones, tasa de crecimiento de la población, preferencias, tasa de mortalidad infantil) sean idénticas. En la convergencia absoluta, las condiciones iniciales, eran irrelevantes. No obstante, para la convergencia condicionada, el equilibrio varía en función de cada economía, y cada una se aproxima a su único equilibrio. Es decir, la realidad sugiere que existe convergencia condicionada si la relación negativa entre las rentas per cápita inicial y sus tasas de crecimiento se mantienen, solo después de controlar las características estructurales (ver también Mankiw, 1995).

Beta y sigma convergencia

El instrumento tradicional y ampliamente utilizado para medir la convergencia es el análisis de beta-convergencia (regresión del nivel inicial de crecimiento). El punto de partida de la beta-convergencia fueron los estudios de Baumol (1986) y el concepto se hizo popular desde ese momento (Barro y Sala-i-Martín, 1991; Barro y Sala-i-Martín 1992; Sala-i-Martín, 1996). La beta-convergencia se define como la relación negativa entre el nivel de renta inicial y el crecimiento posterior de la renta. Si los países pobres crecen más rápido que los países ricos, debería haber también una correlación negativa entre el nivel inicial de renta y la tasa de crecimiento.

El modelo general de la hipótesis de beta-convergencia fue originalmente especificado como un modelo de corte transversal:

$$g_T = \alpha + \beta y_0 + u \qquad u \sim N\left(0, \sigma_u^2 I\right) \tag{1}$$

donde g_T denota el vector (variable dependiente) de la media de la tasa de crecimiento en el periodo *(0,T)*; y_0 es el vector (variable dependiente) en el momento inicial, *u* es el termino de perturbación, distribuido como una normal de media cero y homocedástico (σ_u^2 es una constante); y α y β denotan parámetros desconocidos.

Según esta hipótesis, existe beta-convergencia si el valor estimado para β es negativo y estadísticamente significativo. La primera ecuación [1] hace referencia a la convergencia absoluta, donde se asume que hay una correlación negativa entre el nivel inicial de la variable dependiente y la tasa de crecimiento de la misma. No obstante, es más razonable suponer que existe una correlación negativa entre la tasa de crecimiento y la distancia de la variable dependiente en relación a su estado estacionario (convergencia condicionada). Por esta razón, se especifica la versión condicionada de la β-convergencia como:

$$g_T = \alpha + \beta y_0 + X\gamma + u \qquad u \sim N\left(0, \sigma_u^2 I\right) \qquad [2]$$

donde X corresponde a la matriz de variables explicativas; y γ corresponde a los parámetros asociados desconocidos.

Otro instrumento utilizado para medir la convergencia, y que se ha hecho popular desde el trabajo de Quah (1993), es la sigma-convergencia. Él mostró que la tradicional relación del nivel de crecimiento inicial, no daba una respuesta clara a la convergencia, ya que la relación tendía a ser negativa si las diferencias en la renta no se habían reducido. Según su hipótesis, existe sigma-convergencia si la dispersión y las desigualdades entre países bajan con el tiempo. Por lo tanto, es interesante utilizar este instrumento, ya que responde directamente a si la distribución de la renta entre las economías está resultando ser más igualitaria.

La convergencia económica ha suscitado, en los últimos años, un auge en la literatura para intentar explicar el acortamiento de las distancias entre países. Existe una amplia literatura sobre convergencia en renta, que utiliza el PIB per cápita como variable para mostrar el bienestar de los individuos. Diferentes autores han investigado la convergencia económica entre países, utilizando en muchos casos la beta-convergencia en términos de PIB per cápita (Barro y Sala-i-Martin, 1992; Mankiw *et al.* 1992; Barro y Sala-i-Martin, 1995; Quah, 1996; de la Fuente, 1997). No obstante, estos estudios no muestran ninguna prueba clara de convergencia absoluta entre países. En todo caso, la evidencia sugiere que los países ricos tienden a crecen más rápido que los pobres (Becker *et al.*, 2003).

Unión Económica y Monetaria

La Unión Económica y Monetaria (UEM) tiene unas características originales por cuanto se desarrolla a partir del Tratado de la Comunidad Europea (el actual Tratado de la Unión Europea) y el objetivo es que formen parte de ella todos los países de la Unión Europea (UE). El único precedente de unión monetaria que ha existido entre países europeos fue el de la Unión Monetaria Latina (UML) formada el 1865 por Francia, Bélgica, Italia, Suiza y Grecia (1868). La UML no tuvo una construcción institucional como la que ha alcanzado la Unión Europea. La UML fue una Unión bimetálica, basada inicialmente en la plata y luego en oro. Aunque la Unión sobrevivió hasta 1925, no se considera un éxito debido a los altos déficit públicos en los que incurrieron algunos países miembros y al intento de exportar inflación al resto de países (Bae y Bailey, 2003). Sin embargo, a pesar del fracaso de la UML, desde el Tratado Constitutivo de la Comunidad Económica Europea de 1957 (Tratado de Roma), un continuo proceso sobre nuevas bases ha impulsado la creación de una unión monetaria europea. Fue en 1970 cuando se redactó el Informe Werner, basado en la introducción gradual de la moneda única, que necesitaría diez años y acabaría con una moneda única y una única política monetaria. No obstante, la idea no se llevo a cabo debido a la caída del Sistema de Bretton Woods (Ungerer, 1997). La inestabilidad cambiaria y monetaria que sucedió a la caída del sistema de tipos de cambios fijos de Bretton Woods, obligó a la Comunidad Europea en 1979 a establecer el Sistema monetario europeo y el Mecanismo de tipo de cambio, que permitió una mayor estabilidad cambiaría, un avance en la integración económica, una convergencia en la estabilidad de precios y en la práctica un camino irreversible hacia la unión monetaria, considerada necesaria para evitar las devaluaciones competitivas incompatibles con el mercado único europeo.

Fue finalmente en 1989, con la publicación del Informe Delors, donde se establecieron las tres etapas que llevarían a la UEM. Este plan fue oficialmente adoptado en la Cumbre de Roma de 1990. En 1991 los Presidentes de los estados y de los gobiernos de la Unión Europea firmaron el Tratado de Maastricht, donde se establecieron los detalles para la introducción del euro, uno de ellos, el criterio de convergencia nominal (Bagus, 2010). La convergencia nominal basada en la convergencia en las tasas de inflación, los tipos de interés, el nivel de déficit público y de deuda pública en relación al PIB, obliga además a que como mínimo durante los dos años anteriores a formar parte de la moneda única no se produzca devaluación frente a la moneda de ningún otro Estado miembro, de los márgenes normales de fluctuación que establece el mecanismo de tipos de cambio del sistema monetario europeo. Se consideran márgenes normales el 2,25 % de apreciación o depreciación como máximo.

A pesar de la crisis del Sistema monetario europeo de septiembre de 1992, que mostró la dificultad de mantener los márgenes normales de fluctuación entre las distintas monedas, en situaciones de divergencia económica y con fuertes ataques especulativos, el crecimiento económico y los fondos de cohesión económica para los países con un nivel de renta media por debajo del 90 % de la renta de la UE, facilitaron las condiciones económicas para la moneda única. Pero también hubo un *momentum* político. Las condiciones económicas pudieron ser condiciones suficientes, sin embargo las condiciones necesarias fueron un pacto político entre Francia y Alemania. Francia apoyaba la unificación de Alemania, si a cambio Alemania renunciaba al marco para apoyar el euro, según Peer Steinbrück (ministro de finanzas del primer gobierno de Merkel). El derrumbe del muro de Berlín en 1989, sucedió algunos meses después de la presentación del Plan Delors. El plan de la moneda única estaba trazado, solo faltaba que se diesen las condiciones para el gran acuerdo franco-alemán y eliminar las reticencias políticas.

La UEM constituida en 1999 se basó en el pacto, entre los países candidatos de la Unión Europea, para adoptar una moneda única y un sistema monetario común. Para entrar en la UEM, los países candidatos tienen que cumplir unos requisitos basados en la convergencia nominal. Este criterio fue diseñado para garantizar que antes de entrar en la UEM, los países alcanzaran la convergencia económica (Lipinska, 2008) con el fin de cumplir con el requisito de tipos de cambio fijos e irrevocables. Algunos economistas sostienen que la convergencia nominal conduce gradualmente a la convergencia real debido a la estabilidad de precios, la disciplina fiscal, la eliminación de los riesgos del tipo de cambio, la reducción de la incertidumbre, el estimulo a la inversión y al comercio internacional, lo que comporta un mayor crecimiento económico (Marelli y Signorelli, 2010; Buti y Sapir, 1998). Por lo tanto, debido a la afirmación anterior y al criterio de convergencia nominal de Maastricht, si los países consiguen convergencia nominal, estos deberían alcanzar gradualmente la convergencia real.

Sin embargo, de acuerdo con Hein y Truger (2002), aunque estos países consiguieron converger en términos nominales, al principio de la UEM, los países miembros mostraron, en los siguientes años, grandes diferencias en variables reales, como la productividad, el paro o el crecimiento del PIB. Estos autores atribuyen estas diferencias a la incompleta sincronización del ciclo económico de la euro zona y también a los diferentes antecedentes en tasas de inflación y estructuras del crecimiento de estos países.

La convergencia económica ha sido uno de los principales objetivos de la UEM, con la finalidad de conseguir una unión monetaria optima. Para alcanzar este objetivo, la UE ha puesto en marcha diferentes políticas económicas a lo largo de su historia, que han continuado una vez la UEM ha sido establecida en el marco de la UE. Estas políticas se han practicado a escala europea, con la finalidad de hacer convergir los Estado miembros que forman la euro zona.

En este artículo pretendemos averiguar si ha existido convergencia real condicionada en el sentido explicado anteriormente. Nuestra hipótesis es que las políticas implantadas por la UE han sido instrumentadas a escala estatal por cada uno de sus miembros, por lo que no esperamos un comportamiento diferenciado de las regiones respecto al estado al que pertenecen. Aún cuando, algunas de estas políticas, quizás la mayoría, fueron inicialmente diseñadas a escala regional.

Este artículo consta de cuatro secciones. Tras la introducción, en la sección dos, se desarrolla un modelo econométrico espacio-temporal, que sirve para analizar la convergencia económica de los países de la euro zona. En la tercera sección se analizan los resultados del modelo y en el último apartado, discutimos los resultados obtenidos.

2. **UN ANÁLISIS EMPÍRICO DE CONVERGENCIA**

Datos

Nuestro interés es analizar la convergencia de las regiones de la euro zona. Por ello, solo consideraremos los diecisiete países de la Unión Europea (UE) que constituyen la euro zona. Tendremos datos de 174 regiones (nivel *NUTS II- Nomenclature of Territorial Units for Statistics*), correspondientes a diecisiete países de la UE, de 1990 a 2010 (Eurostat).

Modelo econométrico

Hemos especificado un modelo espacio-temporal, utilizando la hipótesis de beta-convergencia condicionada. Se han utilizado como variables dependientes el PIB per cápita, en paridad de poder adquisitivo (GDPPC) (datos de 1995 a 2008), y la productividad, definida como el ratio entre el PIB per cápita (PPA) y la población activa (datos de 1999-2008). Con estas dos variables dependientes hemos creado dos modelos. La matriz de variables explicativas esta formada por diferentes variables económicas y sociales reales de la regiones de la euro zona. Este tipo de variables, a diferencia de las nominales, han sido ajustadas por inflación para poder evitar la influencia de cualquier cambio en el nivel de precios. Las variables utilizadas lo son a nivel regional, aunque hay algunas que lo son a nivel de país, debido a la dificultad de encontrarlas por regiones.

Variables regionales:

- *Empht:* Empleo de alta tecnología. Empleo en tecnología y sectores de conocimiento intensivo a nivel regional (miles de trabajadores).
- *Sec:* Estudiantes de secundaria (porcentaje sobre el total de la población). Suma de los estudiantes del nivel dos (educación secundaria inferior o segunda etapa de la educación básica), de los estudiantes de nivel tres (educación secundaria superior) y de los estudiantes de nivel cuatro (educación post secundaria pero no terciaria) con respecto al total de la población.
- *Univ:* Estudiantes de universidad (porcentaje sobre el total de la población). Suma de los estudiantes del nivel cinco y seis (educación terciaria).
- *Unempl:* Tasa de desempleo (desempleados sobre la población activa). Promedio de la tasa de desempleo de hombres y mujeres.
- *Gc:* Formación bruta de capital fijo (FBCF). Mide el valor en millones de euros de las adquisiciones de activos fijos nuevos o existentes menos las cesiones de activos fijos realizados por el sector empresarial, los gobiernos y los hogares (Sistema europeo de cuentas). Esta variable macroeconómica muestra la inversión que se hace en la economía.
- *Youngunempl:* Tasa de desempleo juvenil (15-24 años). Promedio de la tasa de desempleo juvenil de hombres y mujeres.
- *Empf:* Tasa de actividad femenina.

Variables a nivel de país:

- *Exportaciones:* Tasa de exportación. La variable consiste en el cociente entre el valor de las exportaciones de bienes y servicios y el PIB del país.

- *Importaciones:* Tasa de importación. La variable se define como el cociente entre el valor de las importaciones de bienes y servicios y el Producto interior bruto del país.
- *Bpg:* Balanza comercial (bienes). Esta variable ha sido creada como resultado de la exportación menos la importación de bienes con respeto al PIB del país.
- *Pubexp: Tasa de gasto público*. Esta variable es el resultado de los bienes y servicios comprados por el Estado respeto al PIB del país.

Los dos modelos se han especificado de la siguiente forma:

Producto Interior Bruto per cápita (PPA)

$$\begin{aligned}\frac{GDPPC_{ijt}-GDPPC_{ijt-1}}{GDPPC_{ijt-1}} = {} & \alpha_{ijt}+\beta_{ijt}\log\left(GDPPC_{ijt-1}\right)+\gamma_1\log\left(density_{ijt}\right)+\gamma_2\log\left(empht_{ijt}\right)+\gamma_3\log\left(\sec_{ijt}\right)+\\ & \gamma_4\log\left(univ_{ijt}\right)+\gamma_5\log\left(unempl_{ijt}\right)+\gamma_6\log\left(gc_{ijt}\right)+\gamma_7\log\left(youngunempl_{ijt}\right)+\\ & \gamma_8\log\left(empf_{ijt}\right)+\gamma_9\log\left(\text{exports}_{ijt}\right)+\gamma_{10}\log\left(\text{imports}_{ijt}\right)+\gamma_{11}bpg_{ijt}+\gamma_{12}\log\left(pub\exp_{ijt}\right)+u_{ijt}\end{aligned} \tag{3a}$$

Productividad (Product)

$$\begin{aligned}\log\left(product_{ijt}\right) = {} & \alpha_{ijt}+\beta_{ijt}\log\left(product_{ijt-1}\right)+\gamma_1\log\left(density_{ijt}\right)+\gamma_2\log\left(empht_{ijt}\right)+\gamma_3\log\left(\sec_{ijt}\right)+\\ & \gamma_4\log\left(univ_{ijt}\right)+\gamma_5\log\left(unempl_{ijt}\right)+\gamma_6\log\left(gc_{ijt}\right)+\gamma_7\log\left(youngunempl_{ijt}\right)+\\ & \gamma_8\log\left(empf_{ijt}\right)+\gamma_9\log\left(\text{exports}_{ijt}\right)+\gamma_{10}\log\left(\text{imports}_{ijt}\right)+\gamma_{11}bpg_{ijt}+\gamma_{12}\log\left(pub\exp_{ijt}\right)+u_{ijt}\end{aligned} \tag{3b}$$

En los dos modelos el subíndice i indica región (nivel NUTS II); j país; y t tiempo.

Tanto el término independiente (α) como el coeficiente de interés (β) tienen subíndices, ya que dejamos que sean efectos aleatorios. Es decir, permitimos que los coeficientes varíen entre los diferentes niveles (año, país o región). Cuando el coeficiente varía por región o país asumimos que son variables aleatorias gaussianas idénticas e independientes con una varianza constante. No obstante, si el efecto aleatorio varía anualmente, asumimos un camino aleatorio de orden 1 (incrementos independientes) para un vector aleatorio gaussiano (varianza constante). En la estimación inicial hemos dejado que el término independiente y el coeficiente β varíen en los tres niveles (Cuadro nº 1a y 1b).

Ajuste espacio-temporal

En los modelos 3a y 3b, el término de perturbación, aunque gaussiano, no está idéntica ni independiente distribuido. De hecho, cuando se tienen datos espaciales, como en nuestro caso, la variabilidad de la perturbación no es aleatoria. Existen dos fuentes de extra-variabilidad (Lawson *et al.*, 2003, Barceló *et al.*, 2009): la más importante se denomina ‘dependencia espacial’ y es una consecuencia de la correlación entre áreas. Cuanto más cerca estén las áreas más similares serán; es decir mayor correlación o dependencia espacial entre ellas. Parte de esta dependencia no es en realidad estructural, sino consecuencia de variables omitidas en el análisis. La segunda fuente de extra variabilidad se denomina ‘heterogeneidad’ incorrelacionada o no espacial, debida a variables (no espaciales) que podrían influir en la variable dependiente (Lawson *et al.*, 2003, Barceló *et al.*, 2009).

El término de perturbación en los modelos 3a y 3b también presenta autocorrelación temporal, puesto que una de las dimensiones del problema es la temporal. La extra-variabilidad espacio-temporal debe controlarse, introduciendo dicha estructura en el modelo, so pena de que los errores estándar de los estimadores, y por tanto la inferencia, sea errónea (Greene, 2003).

Específicamente, la heterogeneidad ha sido capturada utilizando el efecto aleatorio asociado con el termino independiente (α_{ijt}). La dependencia temporal ha sido aproximada a través del camino aleatorio de orden uno, asociado al efecto aleatorio del parámetro de interés β_t.

Para la dependencia espacial hemos seguido el trabajo reciente de Lindgren *et al.* (2011) y especificamos una estructura Matèrn (Stein, 1999) en una rejilla irregular (véase gráfico nº 1).

Las inferencias con el ajuste espacio-temporal se han realizado mediante el enfoque Bayesiano, usando el Integrated Nested Laplace (INLA) (Rue *et al.*, 2009; Schrödle y Held, 2011). El análisis se ha hecho con el software libre R (version 2.14.0) (*R Development Core Team*, 2011), a través de la librería INLA (The *R-INLA project*, 2011; Rue *et al.*, 2009).

3. **RESULTADOS**

En el modelo final no hemos incluido la variación por el nivel anual ni en el término independiente ni en el coeficiente de interés ya que no ha mostrado variaciones significativas. Suponemos que esto es debido a que la variación del tiempo ya queda recogida en la especificación el modelo. En el modelo 3a, que recoge la convergencia en PIB per cápita, tanto el término independiente como el coeficiente β, varían por país (α_j, β_j), ya que por región y tiempo no han mostrado una variación significativa. No obstante, en el modelo de productividad (3b), el término independiente sí que ha mostrado variación significativa tanto por región como por país, mientras que el coeficiente β solo por país (α_{ij}, β_j).

Los resultados de la estimación de los modelos se han recopilado en los cuadros nº 2 y 3. Tal y como se ha explicado anteriormente, el coeficiente clave en este análisis es la β. Con lo referido al modelo del PIB per cápita (PPA) hemos encontrado convergencia entre los países de la euro zona, ya que el coeficiente es negativo, -1,43% y estadísticamente significativo (el intervalo de confianza al 95% no contiene el cero). La estimación del modelo nos muestra qué variables explicativas tienen un efecto (estadísticamente) significativo sobre la tasa de variación del PIB per cápita. En este caso la densidad de población (0,16%), la Formación bruta de capital fijo (0,08%), la tasa de actividad femenina (0,53%), la balanza comercial (0,19%) y la tasa de gasto público (0,76%) tienen un efecto positivo, mientras que el empleo de alta tecnología (-0,15%) tiene un efecto negativo sobre la tasa de variación del PIB per cápita.

En el modelo correspondiente al nivel de productividad, no obstante, encontramos divergencia entre los países de la euro zona. En este caso el coeficiente de interés (β) es positivo, 5,02%, y estadísticamente significativo. La variables explicativas que afectan al nivel de productividad de forma positiva son la densidad de población (10,22%), el porcentaje de estudiantes universitarios (1,65%), la Formación Bruta de Capital fijo (0,24%), las importaciones (17,14%) y la balanza comercial (1,09%), mientras que el empleo de alta tecnología (-1,93%), la tasa de desempleo (-5,98%), la tasa de desempleo juvenil (-1,77%), la tasa de actividad femenina (-12,08%) y las exportaciones (-21,77%) tienen un efecto negativo sobre el nivel de productividad.

En el cuadro nº 3, se muestra la media y el intervalo de confianza al 95% de los efectos aleatorios de cada modelo. El cuadro muestra en qué países, regiones o años ha habido variaciones significativas. Por lo que se refiere al modelo de PIB per cápita hemos dejado que haya variación a nivel de país tanto en el término independiente como en el coeficiente β. Para el primero (α_j) no encontramos ninguna variación significativa, mientras que para el (β_j) encontramos variación significativa en los siguientes países: Bélgica, Estonia, Italia y Luxemburgo. Siguiendo en este modelo, en la especificación hemos ajustado el modelo temporalmente, en este caso vemos que los años que son estadísticamente significativos son de 1996 a 2004 y de 2006 a 2008.

Para el modelo de productividad, hemos dejado que varíe en el nivel de región y país para el término independiente, mientras que para el coeficiente β solo varía por país. Los resultados nos muestran que para el término independiente por región (α_i) las regiones que varían son Wien (Austria), Prov. Antwerpen (Bélgica), Prov. Hainaut (Bélgica), Prov. Limburg (Bélgica), Prov. Namur (Bélgica), Prov. Oost-Vlaanderen (Bélgica), Reg. Bruxelles-Cap. (Bélgica), Corse (Francia), Île de France (Francia), Nord-Pas-de-Calais (Francia), Braunschweig (Alemania), Bremen (Alemania), Chemnitz (Alemania), Darmstadt (Alemania), Hamburg (Alemania), Lüneburg (Alemania), Münster (Alemania), Oberbayern (Alemania), Thüringen (Alemania), Dytiki Ellada (Grecia), Notio Aigaio (Grecia), Sterea Ellada (Grecia), Basilicata (Italia), Campania (Italia), Lazio (Italia), Flevoland (Holanda), Gelderland (Holanda), Groningen (Holanda), Centro (Portugal), Norte (Portugal), Bratislavský kraj (Eslovaquia), Stredné Slovensko (Eslovaquia), Západné Slovensko (Eslovaquia), Comunidad de Madrid (España), mientras que por país (α_j) varían significativamente Finlandia, Luxemburgo y Eslovaquia. Por lo que se refiere al coeficiente (β_j), encontramos variación significativa en Estonia, Francia, Alemania, Grecia, Italia, Malta y Eslovaquia. Debido al ajuste temporal, vemos que los años en que encontramos variación son de 2000 a 2003 y de 2006 a 2008.

Los gráficos nº 2a y 2b recogen los resultados de la estimación del modelo. Se puede observar la evolución de PIB per cápita y la productividad, respectivamente, en términos de convergencia, para cada país. Para el modelo de PIB per cápita, podemos ver una tendencia común a la convergencia hasta 2003. A partir de este momento, empieza una tendencia a divergir para la mayoría de países de la euro zona. Por los que se refiere al modelo de productividad vemos también una senda común de convergencia pero que a partir de 2003 se suaviza y se puede ver algún país que diverge. Es importante también en este último modelo, el nivel de productividad de cada país, donde vemos que es diferente entre los países considerados centrales y los considerados periféricos.

4. **CONCLUSIONES**

De los resultados empíricos de nuestro análisis, encontramos convergencia (estadísticamente) significativa en PIB per cápita entre los países de la euro zona. No obstante, no encontramos esta convergencia en términos de productividad; es más, estimamos una divergencia (estadísticamente) significativa. Por lo tanto, se puede decir que los países de la euro zona convergen en PIB per cápita, mientras que divergen en productividad.

La utilización de la convergencia condicionada en la especificación del modelo, nos permite ver qué variables explicativas afectan significativamente al PIB per cápita y a la productividad. En cuanto al PIB per cápita, tenemos que éste se ve afectado positivamente por un aumento del gasto público, de la tasa de actividad femenina, de una mejora en la balanza comercial, de un aumento de densidad de población y de un aumento en la Formación bruta de capital fijo (ordenados de mayor a menor efecto). No obstante, y paradójicamente un aumento en el empleo de alta tecnología tiene un efecto negativo sobre el PIB per cápita.

En relación al segundo modelo, las variables que afectan positivamente al nivel de productividad son un aumento en las importaciones, en la densidad de población, un incremento en la tasa de estudiantes universitarios, una mejora de la balanza comercial y un aumento en la Formación bruta de capital fijo. Por otra parte tenemos las variables que tienen un efecto negativo sobre la productividad como un aumento de las exportaciones, un aumento en la tasa de actividad femenina, un incremento de la tasa de desempleo (total y juvenil) y un aumento en el empleo de alta tecnología.

A partir del comportamiento del parámetro, se debe destacar que las pautas de convergencia (PIB per cápita) y de divergencia (productividad) se producen sólo a escala de país, confirmando nuestra hipótesis de que son las pautas a escala de país las que conducen a la hipotética convergencia. El comportamiento desfavorable de la productividad se debe, sin duda, a un diferente comportamiento de la población activa. En el caso de España, por ejemplo, durante los últimos años ha crecido la población activa, un hecho que no ha venido acompañado de un aumento más que proporcional de la producción, debido a la concentración de la economía en el sector de la construcción como motor económico y a la poca inversión en I+D. Por el contrario, otros países, como Alemania, han visto crecer su población activa, pero al mismo tiempo también sus inversiones en I+D y sus exportaciones, cosa que ha permitido que aumentara la productividad.

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Cuadro nº 1. RESULTADOS DE LA ESPECIFICACIÓN INICIAL DEL MODELO DE PIB PER CÁPITA

β α	Región	País	Tiempo
Región	0,00131)[1] (0,00010)[2] 0,00389 (0,00082)	0,00357 (0,0007) 0,00343 (0,00057)	0,00352 (0,00070) 0,00449 (0,00084)
País	0,00116 (0,00008) 0,01950 (0,00578)	0,00360 (0,00069) 0,01048 (0,00613)	0,00355 (0,0007) 0,02239 (0,00540)
Región País	0,00118 (0,00008) 0,00356 (0,00068) 0,01919 (0,00580)	0,00363 (0,00070) 0,00332 (0,00055) 0,01066 (0,00627)	0,00352 (0,00070) 0,00351 (0,00058) 0,02165 (0,00554)

[1]media; [2]desviación estándar.

Fuente: Elaboración propia.

Cuadro nº 1b. RESULTADOS DE LA ESPECIFICACIÓN INICIAL DEL MODELO DE PRODUCTIVIDAD

β α	Región	País	Tiempo
Región	0,020121 (0,00185)2 0,15273 (0,01232)	0,03775 (0,00758) 0,14702 (0,01106)	0,00684 (0,00241) 0,15781 (0,01182)
País	0,02093 (0,00184) 0,27531 (0,05980)	0,03816 (0,00802) 0,26963 (0,06533)	0,00698 (0,0025) 0,2842 (0,06374)
Región País	0,01985 (0,00183) 0,12706 (0,01021) 0,26896 (0,05921)	0,03839 (0,00815) 0,12288 (0,0096) 0,26178 (0,06073)	0,00666 (0,00234) 0,12655 (0,00986) 0,27578 (0,06199)

[1]media; [2]desviación estándar.

Fuente: Elaboración propia.

Cuadro nº 2. **RESULTADOS DE LA ESTIMACIÓN DE LOS MODELOS FINALES**

Variables dependientes	Tasa de variación anual del PIB per cápita	Productividad
α	-0,1483(0,0824;0,2146)[1]	4,0283(3,6033;4,4488)
β	-0,01428(-0,0212;-0,0075)	0,0502(0,0299;0,0717)
Efectos fijos:		
Density	0,0016(0,0003;0,0029)	0,1022(0,0779;0,1262)
Empht	-0,0015(-0,0023;0,0007)	-0,0193(-0,0308;-0,0078)
Sec	-0,0016 (-0,0036;0,0003)	0,00464(-0,0039;0,0132)
Univ	0,0017(-0,0008;0,0043)	0,0165(0,0044;0,0286)
Unemploy	-0,0007(-0,0049;0,0034)	-0,0598(-0,0792;-0,0404)
Gc	0,0008(0,0004;0,0013)	0,0024(0,0011;0,0038)
Youngunemploy	-0,0012(-0,0046;0,0022)	-0,0177(-0,0272;-0,0082)
Empf	0,0053(0,0026;0,0080)	-0,1207(-0,1966;-0,0449)
Exports	0,0090(-0,0539;0,0353)	-0,2177(-0,3674;-0,0681)
Imports	0,0175(-0,0279;0,0638)	0,1715(0,0178;0,3253)
Bpg	0,0019(0,0006;0,0032)	0,0109(0,0068;0,0150)
Pub exp	0,0076(0,0022;0,0129)	-0,0136(-0,0471;0,0199)
Desviación estándar de los efectos aleatorios:		
Heterogeneidad	0,02370(0,00038)[2]	0,05252(0,00098)
α_i		0,12288(0,00960)
α_j	0,01036(0,00614)	0,26178(0,06073)
β_j	0,00359(0,00069)	0,03839(0,00815)
DIC	-10390,50	-4976,89
Numero efectivo de parámetros	120,43	216,06
-log(mean(cpo))	-2,2909	-1,4639

[1] media (intervalo de confianza al 95%); [2] media (desviación estándar); El intervalo de confianza al 95% no contiene el cero (estadísticamente significativo).

Fuente: Elaboración propia.

Cuadro nº 3. **EFECTOS ALEATORIOS**

Desviación estándar de los efectos aleatorios	Tasa de variación anual del PIB per cápita	Productividad
α_ι		Wien (Austria) 0,15399(0,02164;0,28854)[1] Prov. Antwerpen (Bélgica) 0,15796(0,06302;0,25219) Prov. Hainaut (Bélgica) -0,18623(-0,28462;-0,0875) Prov. Limburg (Bélgica) -0,10737(-0,20475;-0,00965) Prov. Namur (Bélgica) –0,11702(-0,21302;-0,02134) Prov. Oost-Vlaanderen (Bélgica) -0,1224(-0,2153;-0,0293) Reg. Bruxelles-Cap. (Bélgica) 0,48126(0,37368;0,59132) Corse (Francia) 0,2336(0,05154;0,40897) Île de France (Francia) 0,20213(0,07608;0,3230) Nord- Pas-de-Calais (Francia) -0,14438(-0,26105;-0,02681) Braunschweig (Alemania) 0,11188(0,01341;0,20887) Bremen (Alemania) 0,13452(0,02482;0,24235) Chemnitz (Alemania) -0,18381(-0,28255;-0,07862) Darmstadt (Alemania) 0,21245(0,11437;0,30582) Hamburg (Alemania) 0,25559(0,1374;0,37128) Lüneburg (Alemania) -0,14496(-0,24358;-0,04911) Münster (Alemania) -0,10916(-0,2070;-0,00875) Oberbayern (Alemania) 0,19398(0,06594;0,31537) Thüringen (Alemania) -0,24079(-0,34733;-0,12543) Dytiki Ellada (Grecia) -0,12867(-0,23126;-0,02506) Notio Aigaio (Grecia) 0,14836(0,00925;0,28255) Sterea Ellada (Grecia) 0,20029(0,08561;0,31216) Basilicata (Italia) 0,12398(0,01521;0,23306) Campania (Italia) -0,16829(-0,29283;-0,03993) Lazio (Italia) 0,14626(0,02606;0,26242) Flevoland (Holanda) -0,17237(-0,26205;-0,08308) Gelderland (Holanda) -0,10964(-0,20154;-0,01662) Groningen (Holanda) 0,27741(0,18279;0,37202) Centro (Portugal) -0,15297(-0,27186;-0,03426) Norte (Portugal) -0,23951(-0,38096;-0,09578) Bratislavský kraj (Eslovaquia) 0,32145(0,17368;0,46991) Stredné Slovensko (Eslovaquia) -0,13823(-0,27265;-0,0066) Západné Slovensko (Eslovaquia) -0,15018(-0,28261;-0,01819) Comunidad de Madrid (España) 0,21528(0,07749;0,3433)
α_φ	No hay ninguna variación significativa	Finlandia 0,32433(0,04194;0,63098) Luxemburgo 0,71916(0,40021;1,05833) Eslovaquia -0,36374(-0,61412;-0,12186)

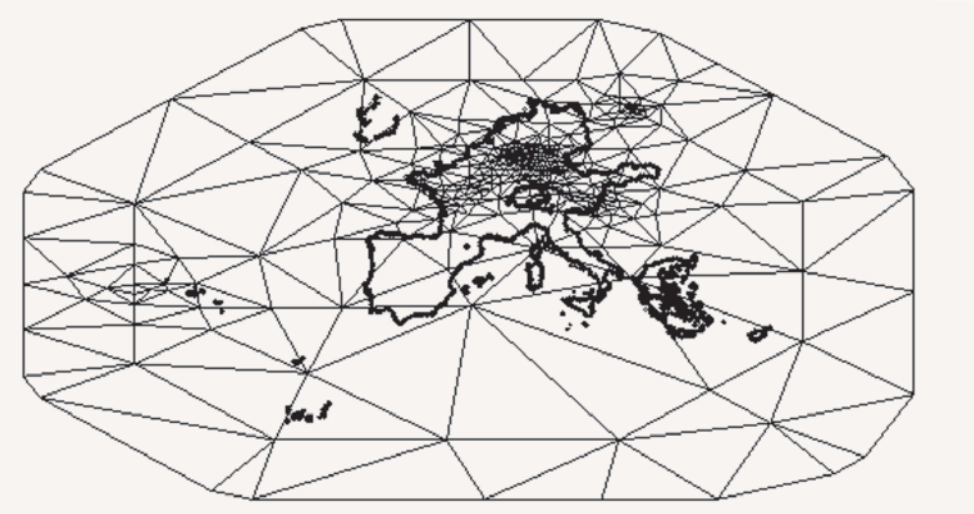
…/…

β_φ	Bélgica -0,00285(-0,00554;-0,00001) Estonia 0,00445(0,00105;0,0078) Italia -0,00270(-0,00526;-0,00013) Luxemburgo 0,00322(0,00024;0,00619)	Estonia 0,08354(0,04867;0,12045) Francia -0,02061(-0,04113;-0,00086) Alemania -0,03202(-0,05234;-0,01246) Grecia 0,08333(0,04211;0,12777) Italia -0,03122(-0,05183;-0,01132) Malta -0,05617(-0,09058;-0,02365) Eslovaquia 0,04103(0,01627;0,06617)
γ year	1996 0,0111(0,00276;0,01944) 1997 0,0221(0,01383;0,03037) 1998 0,01642(0,00838;0,02447) 1999 0,0059(0,002;0,00980) 2000 0,02173(0,01786;0,0256) 2001 -0,00851(-0,01248;-0,00454) 2002 -0,01185(-0,01596;-0,00774) 2003 -0,03587(-0,04011;-0,03163) 2004 -0,00638(-0,01067;-0,00209) 2006 0,01183(0,00746;0,0162) 2007 0,00987(0,00537;0,01439) 2008 -0,03207(-0,03745;-0,02668)	2000 -0,08401(-0,10901;-0,06117) 2001 -0,06541(-0,09021;-0,04234) 2002 -0,04580(-0,07069;-0,02258) 2003 -0,04743(-0,00731;-0,02393) 2006 0,07455(0,04862;0,09882) 2007 0,11041(0,08399;0,13528) 2008 0,12328(0,095053;0,15017)

[1] media (intervalo de confianza al 95%).

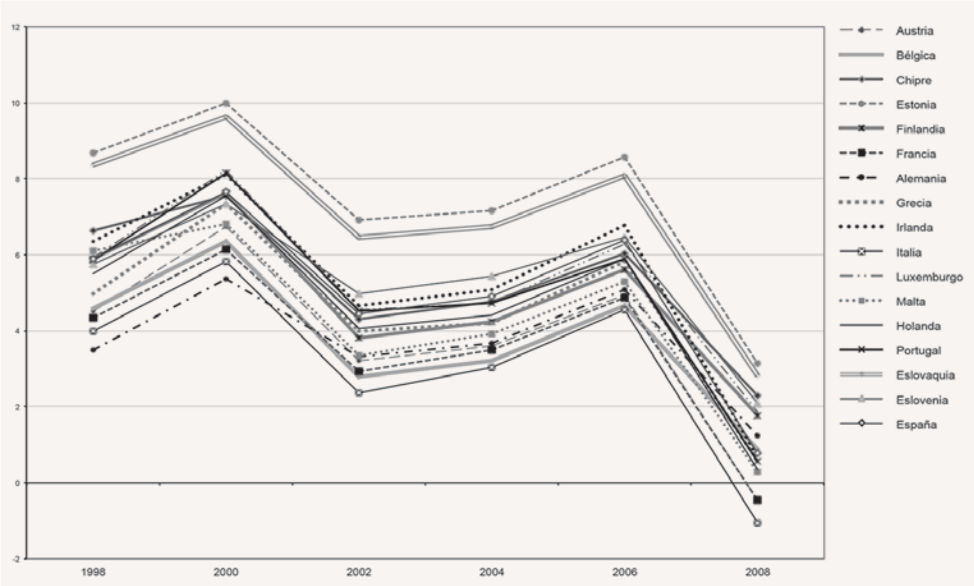
Fuente: construcción propia.

Gráfico nº 1. **TRIANGULACIÓN DEL ÁREA DE ESTUDIO (EURO ZONA)**



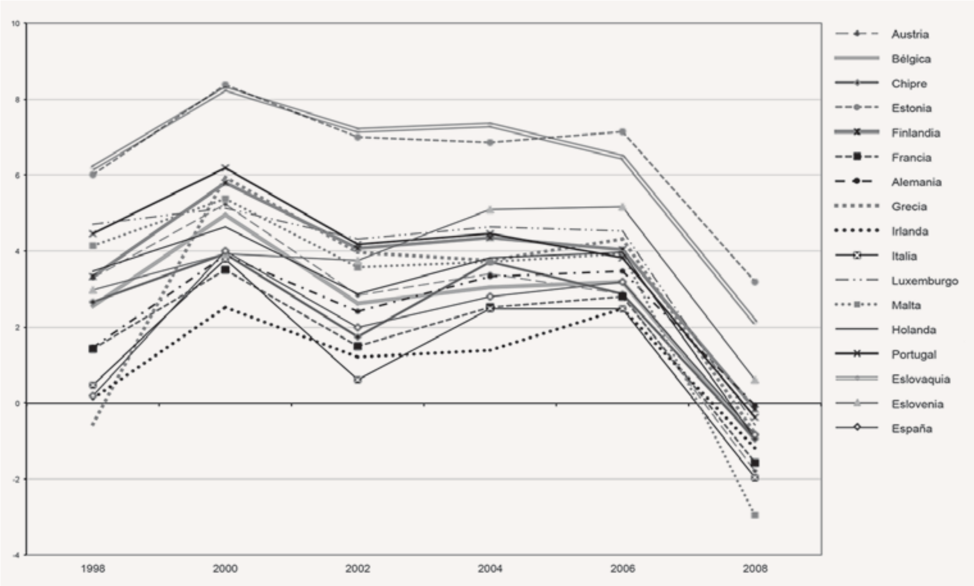
Fuente: Elaboración propia.

Gráfico nº 2a. **EVOLUCIÓN DE LA TASA DE VARIACIÓN ANUAL DEL PIB PER CÁPITA DE CADA PAÍS ESTIMADA POR EL MODELO** (VALORES ESPERADOS)



Fuente: Construcción propia.

Gráfico nº 2b. **EVOLUCIÓN DE LA PRODUCTIVIDAD DE CADA PAÍS ESTIMADA POR EL MODELO** (VALORES ESPERADOS)



Fuente: Construcción propia.

4.2. The impact of Structural and Cohesion funds on eurozone convergence (1990-2010)

Maynou, L., Saez, M., Kyriacou, A. and Bacaria, J. (2013) ‘The impact of structural and cohesion funds on eurozone convergence (1990-2010)’ *Regional Studies* (under revision).

> *“There is a remedy which... would in a few years make all Europe...free and...happy. It is to re-create the European family, or as much of it as we can, and to provide it with a structure under which it can dwell in peace, in safety and in freedom. We must build a kind of United States of Europe”*
>
> *W. Churchill.*

The impact of Structural and Cohesion funds on eurozone convergence (1990-2010)

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Abstract

From the birth of the European Union, and in particular after the establishment of the Economic and Monetary Union, the Union has endeavoured to facilitate economic convergence across Europe by providing funds to its poorer regions and countries. The main objective of this paper is to analyse whether the structural and cohesion funds have contributed towards convergence between the eurozone countries during the past two decades (1990-2010). The results of the spatio-temporal econometric model specified in this paper, illustrate that these funds have positively contributed to the GDPPC growth of the countries receiving them. Moreover, we analyse the evolution of public and private debt over the same period, in a cursory attempt to determine if regional funds have, in fact, contributed to this debt increase.

Key words: eurozone, Structural and Cohesion funds, β-convergence, σconvergence

1.- Introduction

The creation of the Economic and Monetary Union (EMU) presents, perhaps, the most ambitious step in Europe's modern history towards deeper economic integration. This ever closer integration within the Union entailed a concern that poorer regions may fall behind and, as a result, the EMU was endowed with a significant increase in its structural and cohesion funds. Furthermore, diverse policies have been implemented in the EU to help these countries manage the convergence.

One of these policies, which were already established in the EU before the EMU was launched, was the provision of regional funds to help the poorer countries and regions of the EU. The vehicles, or financial tools, for this were the Structural Funds and the Cohesion fund. While the Structural Funds had already been operational before the EMU was created, it was under the Maastricht Treaty, that the Cohesion Fund was designed.

These regional funds were created to help the less favoured regions and countries of the EU by boosting their growth and enabling them to reach the economic convergence which was asked for within the Union. However, this injection of funds has not always been followed by profitable investments and over the past decade there has been an increase in both private and public debt. The chief reason for such increases is to be found in the principles that these funds follow: partnership and additionality.

Existing literature that attempts to explain the impact of regional funds on regional and country growth across Europe has reached a consensus on the issue (see Martin, 2003; Gripaios *et al.*, 2008; De Michelis, 2008; Mohl and Hagen, 2010; Marzinotto, 2012; Becker, 2012). Some authors have found the regional funds have had a (small) positive impact on growth (García-Solanes and María-Dolores, 2001; Ederveen *et al.*, 2002; Cappelen *et al.*, 2003; Dall'erba, 2005; Ramajo *et al.*, 2008; Mohl and Hagen, 2010; Becker *et al.*, 2010), especially in 'Convergence Objective'[1] regions (Bussoleti and Esposti, 2004; Puigcerver-Peñalver, 2007; Becker, 2012). Whereas other authors have not found any significant results in terms of regional convergence (Fagerberg and Verspagen, 1996; Sala-i-Martin, 1996; Boldrin and Canova, 2001; Esposti and Bussoletti, 2008; Dall'erba and Le Gallo, 2008; Dall'erba *et al.*, 2008; Hagen and Mohl, 2008) and yet others have found significant convergence at a national (country) level (Midelfart-Knarvik and Overman, 2002; Beugelsdijk and Eijffinger, 2005; Ederveen *et al.*, 2006). It would appear that the cohesion funds allocated to reach objectives differing from the "Convergence Objective" have a negative or non-significant effect (Montresor *et al.*, 2010; Fiaschi *et al.*, 2011). Becker (2012) points out that, for EU structural funds as a whole, more funds do not mean more growth.

Arguably, important reason for these inconclusive results include the specification adopted (e.g. cross section, static panel, dynamic panel, with or without spatial effects, etc), the choice of the variable of interest (e.g. GDP per capita, labour productivity, total factor productivity, etc.), the estimation technique utilised (e.g. OLS, within-group –fixed effects- estimation, GMM estimation, etc), and of the data at hand (e.g. country or regional-level, period and regions considered, dataset used, etc.).

The main objective of this paper is to analyse whether the structural and cohesion funds have actually helped the eurozone countries to reach convergence in the past two decades (1990-2010). Moreover, it will be interesting to scrutinize the evolution of public and private debt during the specified study period, and to determine if these funds have even contributed to its increase. To do

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[1] Concept detailed in section 1.2.

this, we specify a dynamic panel data model, based on the conditional β-convergence hypothesis, which will allow us to analyse the convergence between the eurozone regions in the period 1990-2010, and explore the impact of the regional funds on that convergence.

Our work contributes to previous literature in several ways. First, we use a much more recent study period (1990-2010). Among the papers we have quoted above, only three of them cover a period beyond 2004 (Mohl and Hagen, 2010 -1995-2005; Becker, 2010 -1989-2006-; and Montresor *et al.*, 2010, 1989-2006). Second, although some other papers use dynamic panel data models (Ederveen *et al.*, 2002; Bussoleti and Esposti, 2004 and 2008; Hagen and Mohl, 2008 and 2010) we are the only ones using a random coefficient model. In this sense, we allow the coefficients of interest, the coefficient associated to lagged GDP per capita PPS and the effect of the structural and cohesion funds, to vary in time and/or spatial units (i.e. countries or regions). In order to specify this model, we use a Bayesian approach which, in contrast to frequentist alternatives, allows us to easily make inferences on the unit-specific coefficients (variation in time and/or between spatial units). Third, while it is true that many of the papers we have quoted above explicitly control for spatial effects (Dall'erba, 2005; Dall'erba and Le Gallo, 2008; Dall'erba *et al.*, 2008; Ramajo *et al.*, 2008; Hagen and Mohl, 2008 and 2010; Montresor *et al.*, 2010; Fiaschi *et al.*, 2011), most of them used a static panel and therefore they cannot control the influence of time on convergence (except Hagen and Mohl, 2008 and 2010), nor can they control the spatial effects through spatial econometric techniques (using spatial weights matrices) (except Ramajo *et al.*, 2008). In our case, we manage to adjust the spatial and temporal effects through the techniques provided by the Bayesian approach.

The paper is organised as follows. Section one continues summarizing the main characteristics of the EMU and the Structural and Cohesion Funds. Section two describes the convergence hypothesis. The data setting and the methodology are explained in section three, while section four details the results of the models and section five is where the discussion and conclusion are made.

1.1.- Economic and Monetary Union (EMU)

The Economic and Monetary Union (EMU) still exhibits its original characteristics which were drawn up in a former treaty of the European Community, and which involves all the European Union (EU) countries as its main objective. The precedent for a unique monetary union was the Latin Monetary Union (LMU) formed in 1865 by France, Belgium, Italy, Switzerland and Greece (in 1868). However, the Latin Monetary Union did not have the institutional structure that the present day EMU has. It was a bimetallic union which was initially based on silver and then on gold. Although it survived until 1925, it was not considered a success because of the budget deficits that some member states incurred and the attempt to "export inflation" to others in the form of large numbers of minor silver coins (Bae and Bailey, 2003).

Despite the failure of the Latin Monetary Union the objective was never abandoned and the Treaty of Rome (1957), which was designed to reconstruct the economies of Europe, established a new economic basis and was the first step towards the creation of the monetary union. It was in 1970, when the Werner Report was written (Werner Report, 1970), that a three stage plan to gradually adopt a single monetary policy and a single currency within ten years was drawn up. However, this idea was never accomplished at the time because of the collapse of the Bretton Woods system (Ungerer, 1997). The exchange rate and monetary instability which arose after the breakdown of Bretton Woods forced the European Community to establish the European

Monetary System and the Exchange Rate Mechanism in 1979. This system would allow for not only greater exchange rate stability, but a move forward in European integration, as well as a convergence in price stability and, in practice, an irreversible path to the monetary union; all of which were considered necessary to avoid competitive devaluations which were incompatible with a single European market.

After subsequent attempts to launch the EMU, in 1989 the Delors Report (Delors, 1989), proposesd a three stage plan towards creating the EMU was instigated. The plan was then officially adopted at the Summit of Rome in 1990, and would eventually lead to the Single European Act. In December 1991, when the Heads of States or Governments of the European Union signed the Maastricht Treaty, the details of the introduction of the euro were set down; one of those details being the nominal convergence criteria (Bagus, 2010).

Nominal convergence was based on the convergence of inflation rates, interest rates, the level of public deficit and public debt related to GDP. Moreover, the participating Member States were obliged to follow the Exchange Rate Mechanism of the EMU for at least two years, which meant that the exchange rates of the participating states were frozen and they could not devalue their currency.

Despite the European Monetary System crisis of September 1992, where the difficulty of keeping fluctuation margins amongst the different currencies in situations of economic divergence and strong speculative attacks was more than evident, economic growth and cohesion funds (for countries with an average income below 90 per cent of an EU income), provided the economic conditions for a single currency. While these economic conditions may have been sufficient, a political agreement between France and Germany was needed whereby France would support German unification if Germany renounced the mark for the euro (Peer Steinbrück - Finance Minister of Merkel's first government).

The EMU was finally launched in 1999, was based on an agreement to adopt a single currency and a common monetary system by the candidate Member States of the European Union. In order to join the EMU, the candidate countries had to fulfil nominal convergence requirements, which were set out in the Maastricht Treaty (in 1992). These criteria were designed to guarantee that countries would reach economic convergence before joining the EMU (Lipinska, 2008) while complying with the fixed exchange rate requirement . As some economists have stated, nominal convergence gradually leads to real convergence because of price stability, fiscal discipline, exchange-rate risk removal, reduction in uncertainty, investment stimulus and international trade; all of which lead to stronger economic growth (Buti and Sapir, 1998; Marelli and Signorelli, 2010). So, bearing this in mind and coupled with the Maastricht nominal convergence criteria, if countries reach nominal convergence, they would gradually reach real convergence.

However, according to Hein and Truger (2002), although countries managed to converge in nominal terms at the beginning of the EMU, in the years following, member countries showed large disparities in real variables, such as productivity, unemployment and GDP growth. Hein and Truger attribute these differences to an incomplete synchronization of the business cycle across the euro area and also to the different backgrounds in growth and inflation rates of the member states.

Economic convergence has been one of the principal objectives of the EMU, in order to reach an optimum monetary union, and to do so the EU implemented a range of economic policies. These policies have been carried out at a European level, with the aim of reaching convergence among all the eurozone Member States.

1.2.- Structural and Cohesion Funds

The Structural and Cohesion Funds are the main funding programmes of the European Union for supporting social and economic restructuring across the EU. Financial support is targeted at a national level through the Cohesion Fund, and at a regional level through four Structural funds. In both cases, EU money is directed towards the poorest and most disadvantaged countries or regions.

The main objective of the Structural Funds is based on the political conviction that the Union needs policies that facilitate integration and ensure that everyone can benefit from integration (Samecki, 2009). The European Social Fund (ESF) was established in 1958 and was then followed by the European Regional Development Fund (ERDF) in 1975. From that moment, the idea of structural funding grew immensely. In the 1980s, three new, but poor, countries entered the EU (Greece, Spain and Portugal) and they were able to edge closer to the EU average income with the help of the regional funding. This went further with the creation of the Cohesion Fund (1994), designed to encourage economic converge among the EU members and guide them into the EMU.

The aim of the Cohesion Fund, as is defined in the Maastricht Treaty, is to promote balanced and harmonious development, in particular, by reducing social and economic disparities between regions. It is the primary EU instrument for mobilising territorial assets and potentials and addressing the territorial impacts generated by European integration (Samecki, 2009).

For 2007-2013, cohesion policy focuses on three objectives:

- *Convergence (formerly Objective One):* regions corresponding to the Nomenclature of Territorial Units for Statistics (NUTS), level II, which have a per capita Gross Domestic Product (GDP) of less than 75% of the EU average. The basic idea is to reduce regional disparities. There are two groups under this umbrella, those regions covered by the Convergence Objective and those receiving phasing-out assistance[2]. The Convergence Objective is financed by the European Regional Development Fund (ERDF), the European Social Fund (ESF) and the Cohesion Fund.

- *Regional Competitiveness and Employment (formerly Objective Two):* regions not covered by the Convergence Objective or receiving phasing-out assistance. This aims to create jobs and make regions more attractive for investors. The regions covered by this objective receive phasing-in assistance. It is financed by the European Regional Development Fund (ERDF) and the European Social Fund (ESF).

- *European Territorial Co-operation (formerly Objective Three):* this objective is basically designed to fund cross-border co-operation (between countries or regions) among EU Member States. The European Territorial Co-operation objective is financed by the European Regional Development Fund (ERDF) and supports cross-border, transnational and

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[2] Ten new countries have joined the EU since 2004, all poorer than existing member countries. Due to this, the regional rankings were changed and the status of the sixteen regions that had previously fallen under this objective prior to enlargement was changed to phasing-out assistance. This is a statistical effect and does not mean that these sixteen regions were better off, but simply experience a change in their rank due to the entry of poorer countries.

interregional co-operation programmes.

Apart from the three objectives, the cohesion policy is supported by four key principles:

Partnership: Community action is developed through a collective process involving authorities at European, regional and local level, social partners, and organisations from civil society. So, there is close cooperation and consultation between the European Commission and the Member States. Partnership applies to all stages of the programming process, from design, through management and implementation, to monitoring and evaluation.

Concentration: this principle can be divided into three aspects. Concentration of resources (mainly to poorest regions and countries), concentration of effort (investment effort focused on specific aspects) and concentration of spending (funding allocated to each programme).

Programming: cohesion policy funds multi-annual national programmes which are aligned to EU objectives and priorities.

Additionality: the funding arriving through structural or cohesion funds must not replace national spending by a member country. The main objective of this principle is to ensure that the contribution of the structural funds really does add value.

To better understand the importance of this funding it is worthwhile looking at some of the calculations made by Kyriacou and Roca-Sagales (2012) for the years 1995-2006. Kyriacou and Roca-Sagales classify three types of countries, in terms of their payments received (annual mean for the whole period, share of GDP). The poorer cohesion countries (Portugal and Greece) receiving payments higher than 1.6% of their GDP, the other two cohesion countries with a percentage between 0.75% and 1%, and finally, the non-cohesion countries with payments that represent less than 0.25% of their GDP (see Figure 1 in page 27).

1.3.- Additionality and partnership: public and private debt

As previously mentioned, according to the principle of additionality the Union assistance should not induce Member States to reduce their own cohesion efforts, but should be additional to these efforts (Evans, 1999). This assistance may not be used to replace public or private expenditure of the Member States. The following rule must be fulfilled: average annual spending in real terms should not be less than in the previous programming period.

Consequently, in order to receive funding from the EU, the Member States have also had to make investments. This could be one of the reasons for the increase in public and private debt in the recent years. To be able to enter the funding programmes, member states had to put up some money and, in most of the cases, they have needed to finance themselves with the help of the banking sector or by issuing Treasury bonds.

While the principle of additionality can explain the rise in public debt, the principle of partnership explains the increase in private debt. As previously described, the structural and cohesion funds coming from the EU ask for a collective process which involves authorities at European, regional and local level, social partners, and organisations from civil society. So, not only do public authorities take part in national investments, but so too do private institutions. This means that, in order to receive regional funds, private institutions and organizations have also collaborated with private funds.

2.- Convergence hypothesis

The concept of convergence, in its most general sense, is the reduction or equalising of disparities (Paas *et al,* 2007). Convergence is a real and long run phenomenon which is directly related to growth processes, that is, there is a convergence when the welfare or development levels, between two or more countries, tend to approach in time (Barro and Sala-i-Martín, 1991).

There are two well-known convergence hypotheses, the absolute and the conditional convergence hypothesis (Paas *et al*, 2007). In the absolute convergence hypothesis, the per capita incomes of countries or regions converge, in the long run, without taking into account the initial conditions. The poorer countries and regions tend to grow faster than the richer ones and there is a negative relation between the average growth rates and the initial levels of income. It is assumed that all the economies converge to the same stationary state (Paas *et al*, 2007).

On the other hand, the conditional convergence hypothesis assumes that, in the long run, the per capita incomes of countries and regions converge provided that their structural characteristics (e.g. technology, human capital, institutions, population growth rates, preferences) are the same (Paas *et al*, 2007). In the absolute convergence, the initial conditions were irrelevant. However, for conditional convergence, the equilibrium varies in each economy, with each tending towards its own equilibrium.

2.1.- Beta and sigma convergence

The instrument widely used to measure convergence is the analysis of beta-convergence (Paas *et al*, 2007). Beta-convergence analysis initiated from studies made by Baumol (1986) and from then on the concept became popular (Barro and Sala-i-Martín, 1991, 1992; Sala-i-Martín, 1996; Fischer and Stirböck, 2004). Beta-convergence is defined as the negative relation between the initial income level and the subsequent income growth.

Another instrument used to measure convergence, which became popular with the work of Quah (1993), is sigma-convergence. Quah showed that the traditional relation of the initial growth level was not giving a clear answer to convergence, as the relation tended to be negative if the differences in income were not reduced. According to his theory, there is sigma-convergence if the dispersion and inequalities between countries are reduced over time.

3.- Methods

3.1.- Data setting

Our interest lies in the economic convergence of the eurozone, so we only consider the seventeen European Union countries that constitute the zone. Specifically, the data used are for 174 regions at the NUTS II level for these seventeen EU countries from 1990 to 2010 (obtained from EUROSTAT).

3.2.- Econometric model

The model was specified based on the well-known beta-convergence hypothesis (Baumol, 1986; Barro and Sala-i-Martin 1991, 1992; Sala-i-Martin, 1996), originally specified as a cross-section model:

$$g_T = \alpha + \beta y_0 + u \qquad u \sim N\left(0, \sigma_u^2 I\right) \qquad [1]$$

where g_T denotes the vector of (dependent variable) average growth rate in the period (0,T); y_0 is the vector of (dependent variable) initial levels; u is a zero-mean and homoskedastic (σ_u^2 was the constant variance) normally distributed disturbance term; α and β and denote (unknown) parameters.

As previously explained, the beta-convergence hypothesis states that β–convergence exists if the estimated value for β, the coefficient of interest, is significantly negative. The absolute β-convergence hypothesis (equation [1]) rests on the assumption that there is a negative correlation between the initial level (of the dependent variable) and the growth rate (of such variable).

However, it is more reasonable to assume that a negative correlation exists between the growth rate and, rather than level, the distance of the level of the dependent variable from its steady state equilibrium. Therefore, poorer regions do not necessarily grow faster than richer regions, because the latter may be even further from their steady state equilibria (Baumont *et al.*, 2002). Therefore in this paper we use the conditional specification of the β-convergence hypothesis:

$$g_T = \alpha + \beta y_0 + X\gamma + u \qquad u \sim N\left(0, \sigma_u^2 I\right) \qquad [2]$$

where X is a matrix of explanatory variables (of convergence); and γ the associated (unknown) parameters.

As explanatory variables we considered only real and not nominal variables. Once the country met the criteria of nominal convergence and adopted the Euro, changes in the price level would be (theoretically) temporary and would be controlled by the European Central Bank. Changes in price levels therefore would only distort the analysis. Due to the difficulty of obtaining some variables at the regional level, we also considered a few variables at country level. We primarily use economic variables, but we also use variables representing the level of education. In this way we try to distinguish the most specific characteristics of the country or region (further details can be found in Maynou *et al.*, 2013).

Regional level:

Gc: Gross fixed capital formation	This consisted of resident producers' acquisitions, fewer disposals of fixed assets during a given period plus certain additions to the value of non-produced assets realized by the productive activity of producer or institutional units (European System of Accounts). It was measured in millions of euro.

Unempl: Unemployment rate	Ratio of unemployed (both sexes) over active population.
Youngunempl: Young unemployment rate	Ratio of youth (15-24 years old) unemployed (both sexes) over youth active population.
Empf: Female employment rate	Ratio of female employed over active population.
Empht: High-tech employment	Employment in technology and knowledge-intensive sectors (thousands of employees).
Sec: Percentage of secondary students	Ratio of the sum of level 2 students (lower secondary or second stage of basic education), level 3 students (upper secondary education) and level 4 students (post-secondary non-tertiary education) over total population.
Univ: Percentage of university students	Ratio of the sum of level 5 and 6 students (tertiary education) over total population.

Country level:

Eusfcf: Structural and cohesion funds	Structural and cohesion funds received (% of GDP).
Exports: Export rate	Ratio of the value of exported goods and services over the country's GDP.
Imports: Import rate	Ratio of the value of imported goods and services over the country's GDP.
Bpg: External balance	The ratio of exported goods minus imported goods over the country's GDP.
Pubexp: Public expenditure rate	Ratio of goods and services bought by the State over the country's GDP.

In contrast to more standard models, we have not specified cross-section models, but rather spatio-temporal panel data models. In particular, we specified the following dynamic panel data model (Maynou *et al.*, 2013):

Gross Domestic Product per inhabitant, in PPS (GDPPC)

$$\frac{GDPPC_{ijt} - GDPPC_{ijt-1}}{GDPPC_{ijt-1}} = \alpha_j + \beta_t \log\left(GDPPC_{ijt-1}\right) + \gamma_{1j} \log\left(eusfcf_{ijt}\right) + \gamma_2 \log\left(density_{ijt}\right) + \gamma_{3j} \log\left(empht_{ijt}\right) + \gamma_4 \log\left(\sec_{ijt}\right) +$$
$$\gamma_5 \log\left(univ_{ijt}\right) + \gamma_6 \log\left(unempl_{ijt}\right) + \gamma_{7j} \log\left(g_{ijt}\right) + \gamma_8 \log\left(youngunempl_{ijt}\right) +$$
$$\gamma_9 \log\left(empf_{ijt}\right) + \gamma_{10j} \log\left(\mathrm{exports}_{jt}\right) + \gamma_{11j} \log\left(\mathrm{imports}_{jt}\right) + \gamma_{12}\, bpg_{jt} + \gamma_{13j} \log\left(pub\exp_{jt}\right) + u_{ijt}$$

[3a]

where j denoted country $(j=1,\ldots,17)$; i region $(i=1,\ldots,174)$; t year $(t=1995\ 1996,\ldots,\ 2008)$; α, β and γ denoted unknown parameters; and u, was a normally distributed disturbance term.

Some of the coefficients, and in particular the coefficients of interest, β and the effect of the structural and cohesion funds, γ_1, have subscripts. This is because we have allowed coefficients to be random effects. That is to say, we have allowed them to be different for the various levels we have considered. Thus, for example, β varies per year, there is insufficient variation across countries, and the effect of the structural and cohesion funds, γ_1, varies across countries, in this case there is no variation over time for this coefficient[3]. With respect to the other explanatory variables, the random effects are associated with different ones depending on the final model.

When the random effects vary by country we have assumed they are identical and independent Gaussian random variables with constant variance. When the random effects vary by year, we have assumed a random walk of order 1 (i.e. independent increments) for the Gaussian random effects vector (although we have also assumed a constant variance).

3.3.- Spatio-temporal adjustment

In the model, the disturbance term, although Gaussian, is not identically and independently distributed. In fact, with spatial data, as in our case, the variability in the observed cases is usually higher than expected, which produces overdispersion and, more importantly, is not random. It is essential to distinguish between two sources of extra variability here (Lawson *et al.*, 2003, Barceló *et al.*, 2009). Firstly, the largest source is usually named 'spatial dependence' and is a consequence of the correlation between the spatial unit and the neighbouring spatial units, generally the adjacent geographical areas. The closer areas are much more similar than the more distant ones. Part of this dependence is not really a structural dependence, but mainly due to variables that are not included in the analysis. The second source is independent, spatially uncorrelated extra variability, called uncorrelated or non-spatial heterogeneity, which is due to the unobserved non-spatial variables that could influence the dependent variable (Lawson *et al.*, 2003, Barceló *et al.*, 2009). In our case, there is also temporal dependency, as we have temporal data in our database.

To take into account this spatio-temporal extra-variability, we have had to introduce some structure into the model. Otherwise, in the case of a linear model (i.e. when the dependent variable is continuous and, therefore, Gaussian) the estimator's standard errors and, as a result, all the inference based on them, would be wrong (Greene, 2003). Specifically, while heterogeneity has been captured using the random effect associated with the intercept (α_j), temporal dependency has been approximated through the random walk of order 1 associated to β_t.

For spatial dependency we have followed the recent work of Lindgren *et al.* (2011) and specified a Matèrn structure (Stein, 1999). In short, we have used a representation of the Gaussian Markov Random Field (GMRF) explicitly constructed through stochastic partial differential equations (SPDE) which has as a solution a Gaussian Field (GF) with a Matérn covariance function (Lindgren *et al.*, 2011). To sum up, instead of using the Matérn in a regular lattice, which is the usual practice and would imply an estimation with a high computational cost as well as one that is weak in terms of efficiency (Lindgren *et al.*, 2011), we have specified the structure of the spatial Matérn covariance in a triangulation (Delaunay triangulation – Hjelle and Daehlen, 2006)

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[3] We have a preliminary estimation of the model allowing variation on the two levels (country/time). In the specification shown, we have provided only the best final model. Results, not shown, are available upon request from the corresponding author.

of the studied area with a low computational cost and, more importantly in our context, much more efficiency.

3.4.- Inference

As known, the estimates of the parameters in random coefficient panel data models will be inconsistent, even for sufficiently large T and N (Hsiao and Pesaran, 2008), unless the initial levels of the dependent variables are fixed constants (Hsiao *et al.*, 1999) and the assumption of independence between the regressors and the random effects is fulfilled,. In dynamic panel data models, with the lagged dependent as the explanatory variable and, typically, with finite T, the assumption of independence does not hold (Nickell, 1981; Anderson and Hsiao, 1981, 1982). However, Hsiao *et al.* (1999) show that, even in this case, the use of a Bayesian approach performed fairly well. In this paper, we preferred, moreover, to relax the assumption of strict exogeneity, allowing a weak exogeneity of the lagged dependent variable, that is to say, that current shocks only affect future values of the dependent variable (Moral-Benito, 2010). In doing this, we were able to obtain consistent estimates of the parameters of interest (even with fixed T).

It is important to point out that this relaxation involves two requirements; first, a large N, i.e. obtained in our case by considering regional data; second, identically and independently distributed error terms. This can only be achieved by the space-time adjustment explained above, imposing a certain structure on the original disturbance term.

In our case, inferences were performed using a Bayesian framework. This approach was considered the most suitable for accounting model uncertainty, both in the parameters and in the specification of the models. Furthermore, only under the Bayesian approach was it possible to model both spatial (heterogeneity and spatial dependence) and temporal extra variability, with relatively sparse data in some cases. Finally, within the Bayesian approach, it is easy to specify a hierarchical structure on the (observable) data and (unobservable) parameters, all considered random quantities. Within the (pure) Bayesian framework, we followed the Integrated Nested Laplace Approximation (INLA) approach (Rue *et al.*, 2009). In fact, in Maynou and Saez (2013), we show how the greater flexibility of the INLA estimation, consequence of its hierarchical strategy, and as it is a Bayesian approach this leads to better control of the biases associated with dynamic panel data models. With this control we have obtained estimates of the parameter of interest with less bias and greater efficiency than other estimators commonly used in dynamic panel data models (in particular, GMM estimates).

All analyses have been done with the free software R (version 2.14.0) (R Development Core Team, 2012), though the INLA library (The R-INLA project, 2012; Rue *et al.*, 2009).

4.- Results

The results of estimating the models are shown in Tables 1 and 2. As stated above, the coefficients of interests in this analysis were β, the coefficient associated with the lagged gross domestic product, and γ_1, the effect of structural and cohesion funds. We have found significant convergence among eurozone countries, as β was negative, -1.6, and statistically significant (the 95% credible interval did not contain the zero). We also found a (statistically) significant positive effect of the structural and cohesion funds, 0.896. That is to say, if the regional funds increased by 1%, the GDPPC growth of the eurozone grows by 0.9%.

The remaining explanatory variables with a (statistically) significant positive effect on the GDPPC growth rate were: population density, 0.226%, gross fixed capital formation, 0.212, and female employment rate, 0.636. In contrast, the unemployment rate had a negative effect on growth (equal to -0.438).

In Table 2, we show the mean and the 95% credibility intervals for the random effects of our model. Note that β varied over time. The years which showed (statistically) significant variation were 1997, 2003, 2009 and 2010. From 2003 onwards, a reduction of disparities between countries can be seen, as they have moved towards the path of convergence. With respect to the effect of structural and cohesion funds, we did not find any (statistically) significant variation between countries.

Figures 1 to 6 show the evolution of the Structural and Cohesion funds, and private and public debt (% GDP). As can be seen in Figure 2, while the higher levels of regional funds have been given to the poorer countries as expected (Portugal, Greece, Spain, and Ireland), from 1993 to 2005, these funds have decreased in all countries. By looking at private and public debt (Figures 3 and 4), it can be said that private debt has increased in all countries, but the highest levels can be seen in the relatively poorer ones countries. This could be explained through the low interest rates that the eurozone has had during recent years, which in turn has contributed to an increase in debt. In terms of public debt, the countries with highest public debt (% GDP) are not only the poorer ones but richer countries as well, as we also see countries like Germany and Belgium at the top. In order to further consider the relationship between public and private debt and the Structural and Cohesion Funds, we have constructed Figures 5 and 6. In both graphs, we can see a positive relationship between these variables.

5.- Discussion

Our results indicate that there is (statistically) significant economic convergence amongst the eurozone countries for the studied period. This means that, during the last twenty years, disparities between the eurozone countries have been reduced. Moreover, EU funds have positively contributed to the GDPPC growth of the countries which received them.

Even if the existing literature agrees on the positive contribution of the Structurals and Cohesion funds, it is not conclusive, at least in regards to direct econometric estimations. Our findings follow the same line. The recipient countries are mostly those with lower GDPPC and the main objective was that they would be able to grow at the same rate as the rest of eurozone countries. Accordingly, these funds have favoured the less developed countries in the eurozone, which has in turn increased their GDPPC and allowed them to reach (conditional) convergence. However, from the random effects results, it can be seen that convergence is mainly reached at the end of the period studied.

In terms of the random effects, we did not find a significant variation of structural and cohesion funds across countries. In other words, we did not found differential effects based on the thresholds defined by Kyriacou and Roca (2012) or Becker *et al* (2010). In fact, we can not conclude, as Becker (2012) did, that the differential effect of the funds, mainly on Convergence Objective regions, is a consequence of the differing abilities of regions at converting transfers into additional growth. Regions with low levels of education and poor governance fail to make good use of EU transfers (Becker, 2012). Marzinotto (2012) went further with her analysis and concludes that EU funds contribute to convergence, as we also find in our study, however with three conditions: i) if used in a supportive institutional environment; ii) in the presence of industrial structure and some R&D intensity and; iii) when used for soft (i.e. R+D) and not just hard environment.

The evidence provided in the previous section indicates that that both public and private debt has increased over the past twenty years. Our preliminary examination suggests a positive relationship between the debts and the Structural and Cohesion funds. As previously explained, this can easily happen because of the principles partnership and additionality which are inherent to Fund absorption were needed. While we can corroborate our hypothesis, it must be said that predominantly the less favoured countries were those characterized by an increase in private debt, while the others had higher public debt. This said, further empirical work is required to systematically examine the link between the Structural and Cohesion funds and the levels of public and private debt across countries.

Conflicts of Interest

There are no conflicts of interest for any of the authors. All authors disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organisations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

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Table 1.- Results of estimating the model

Dependent variable: Annual rate of variation GDPPC	
Fixed effects:	**Mean (95% credibility interval)**
Intercept, α	15.006(-0.806,29.662)
Coefficients of interest	
Lagged Gross Domestic Product PPS per capita, b	-1.600(-2.264,-0.936)
Structural and Cohesion Funds, γ_1	0.896(0.451,1.341)
Other explanatory variables	
Density	0.226(0.104,0.347)
High-tech employment	-0.119(-0.247,0.028)
Secondary students	-0.100(-0.282,0.082)
University students	-0.106(-0.342,0.129)
Gross fixed capital formation	0.212(0.082,0.345)
Unemployment	-0.438(-0.829,-0.045)
Young unemployment	0.159(-0.159,0.476)
Female employment rate	0.636(0.346,0.926)
Exports	-2.064(-5.315,1.109)
Imports	2.517(-0.680,5.796)
External balance (goods)	0.037(-0.042,0.121)
Public expenditure	-0.077(-0.838,0.682)
Random effects	**Standard errors**[1]
Heterogeneity (α_j) - country	2.5733(0.0387)
Coefficients of interest	
Lagged Gross Domestic Product PPS per capita (β_t) –time	0.2748(0.0571)
Structural and Cohesion Funds (γ_{1j}) – country	0.0107(0.0061)
Other coefficients	
High-tech employment - country	0.1493(0.0629)
Gross fixed capital formation - country	0.2092(0.0512)
Exports - country	0.0104(0.0063)
Imports - country	0.0102(0.0065)
Public expenditure – country	0.0106(0.0061)

DIC	11563.10
Effective number of parameters	57.09
-log(mean(cpo))	2.3815

[1] Mean (standard deviation). *Shaded, the 95% credible interval did not contain zero.*

Source: own construction

Table 2. Random effects

Mean (95% credibility interval)	
Lagged Gross Domestic Product PPS per capita (β_t) –time	1997 0.3107(0.0450,0.5790) 2003 -0.3268(-0.5905,-0.0649) 2009 -0.9245(-1.1989,-0.6543) 2010 -0.9245(-1.5250,-0.3285) Other years NS
Structural and Cohesion Funds (γ_{1j}) – country	NS
High technology employment – country	NS
Gross fixed formation – country	Estonia 0.3872(0.1079,0.6608) Greece -0.2614(-0.4643,-0.0734) Ireland 0.4427(0.2334,0.6717) Italy -0.1612(-0.3085,-0.0148) Other countries NS
Exports – country	NS
Imports – country	NS
Public expenditure – country	NS

Source: own construction

Figure 1a. Structural and Cohesion funds 1993-1996

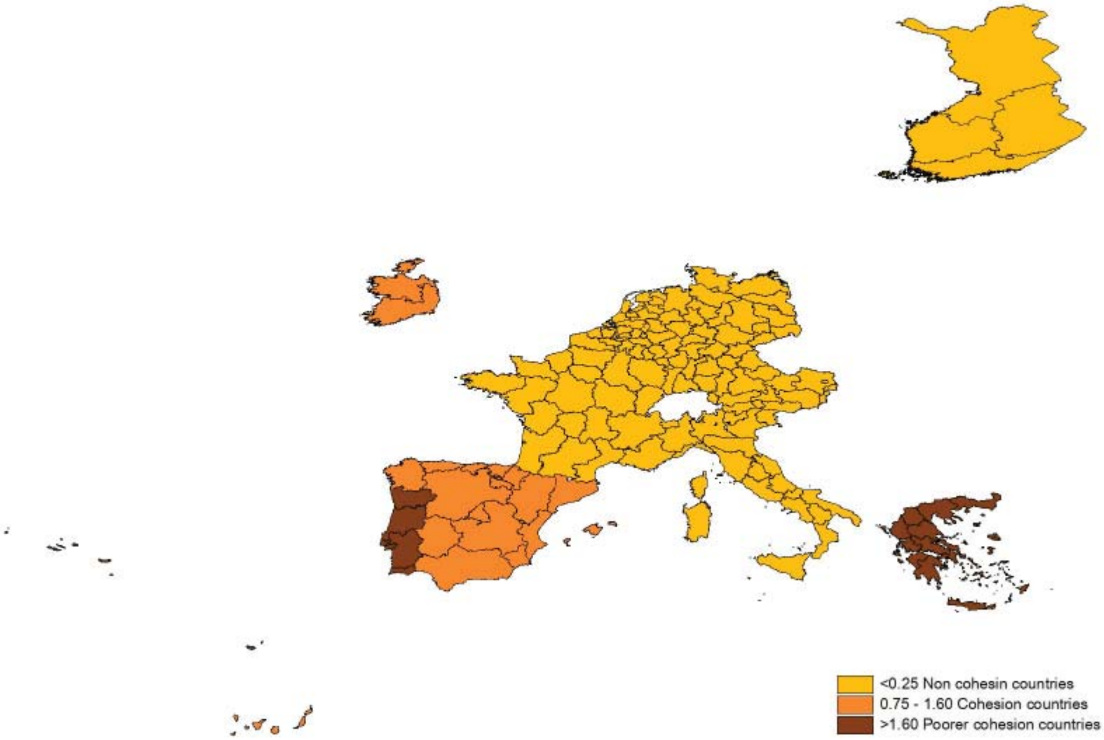


Figure 1b. Structural and Cohesion funds 1997-2000

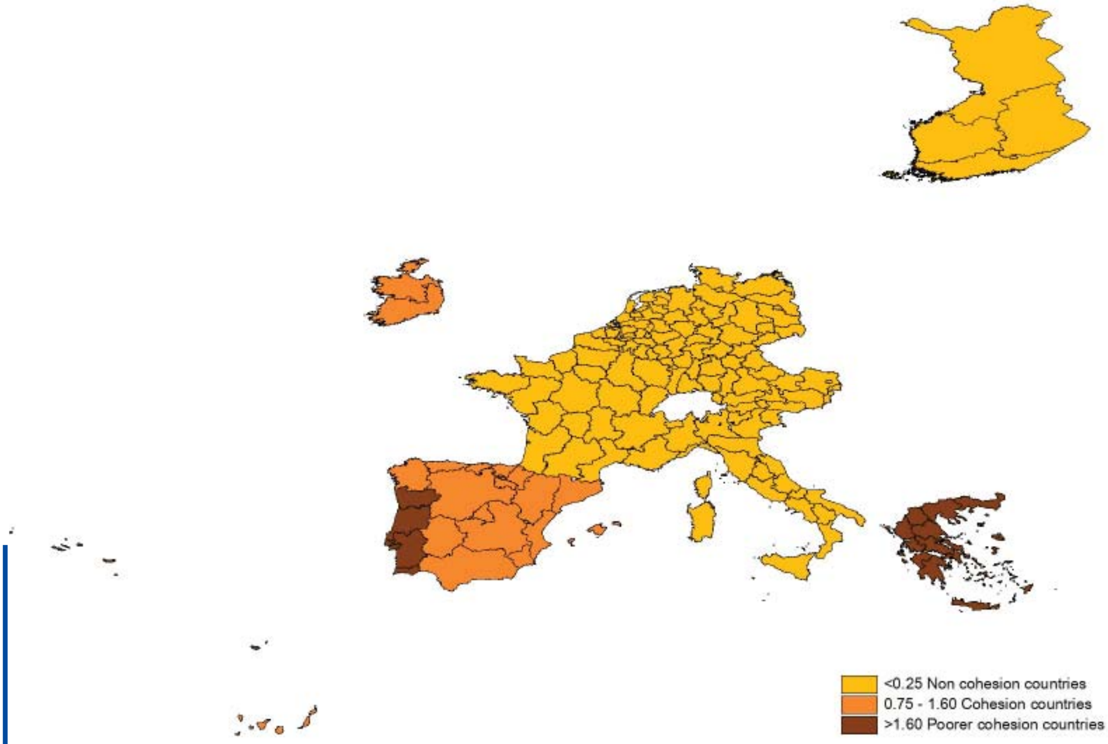


Figure 1c. Structural and Cohesion funds 2001-2005

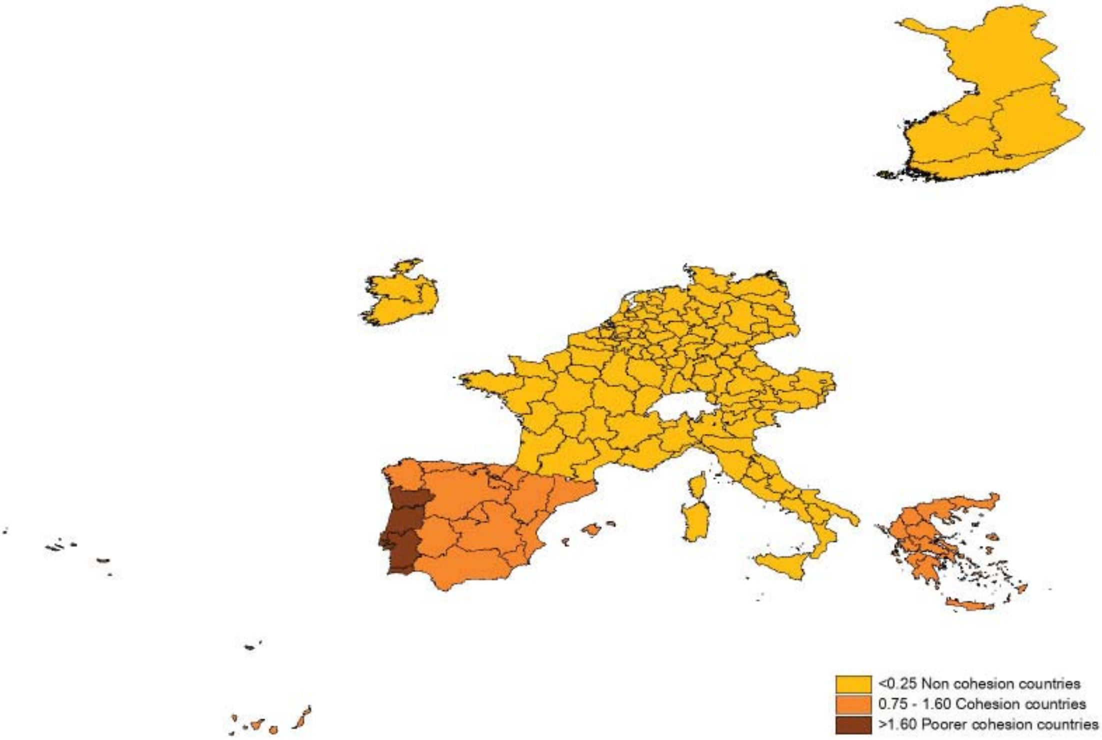


Figure 2. Evolution of Structural and Cohesion funds 1993-2005

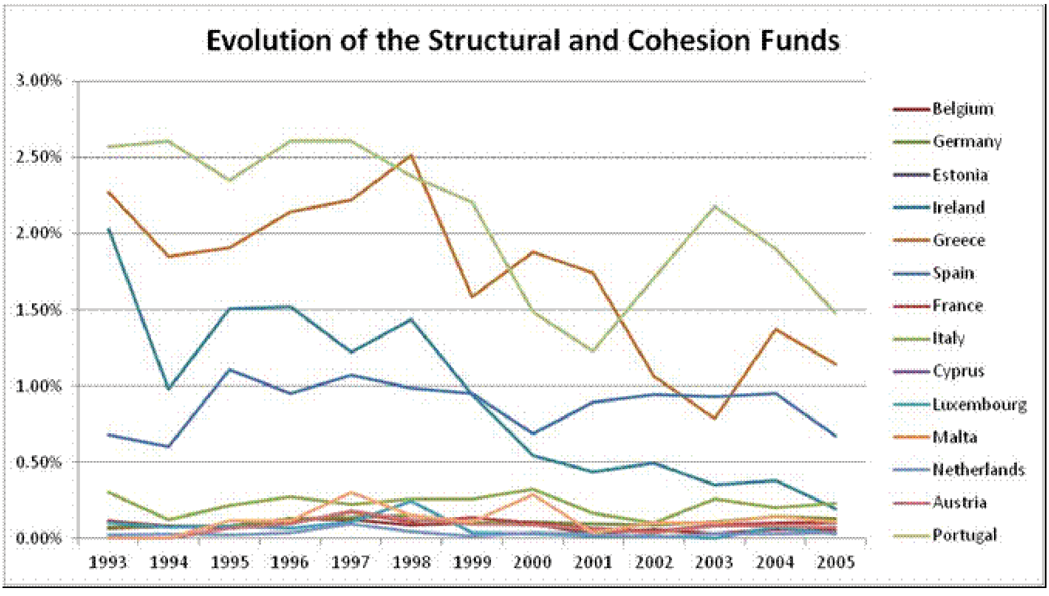


Figure 3. Evolution of private debt (% GDP) 1990-2010.

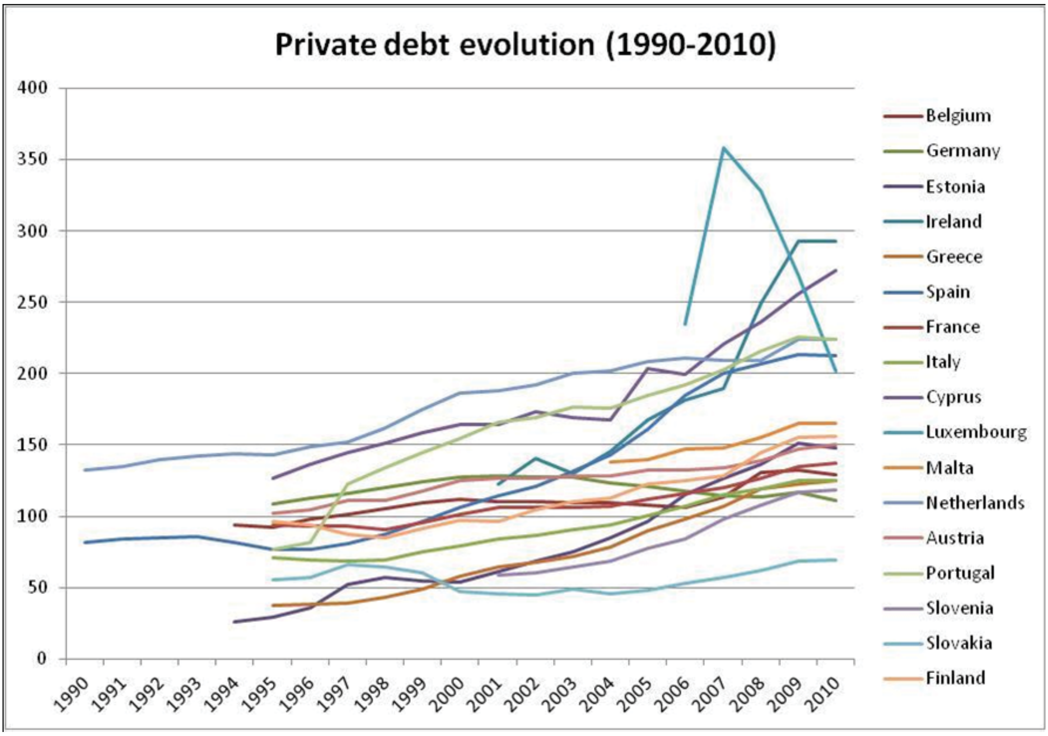


Figure 4. Evolution of public debt (% GDP) 1995-2010.

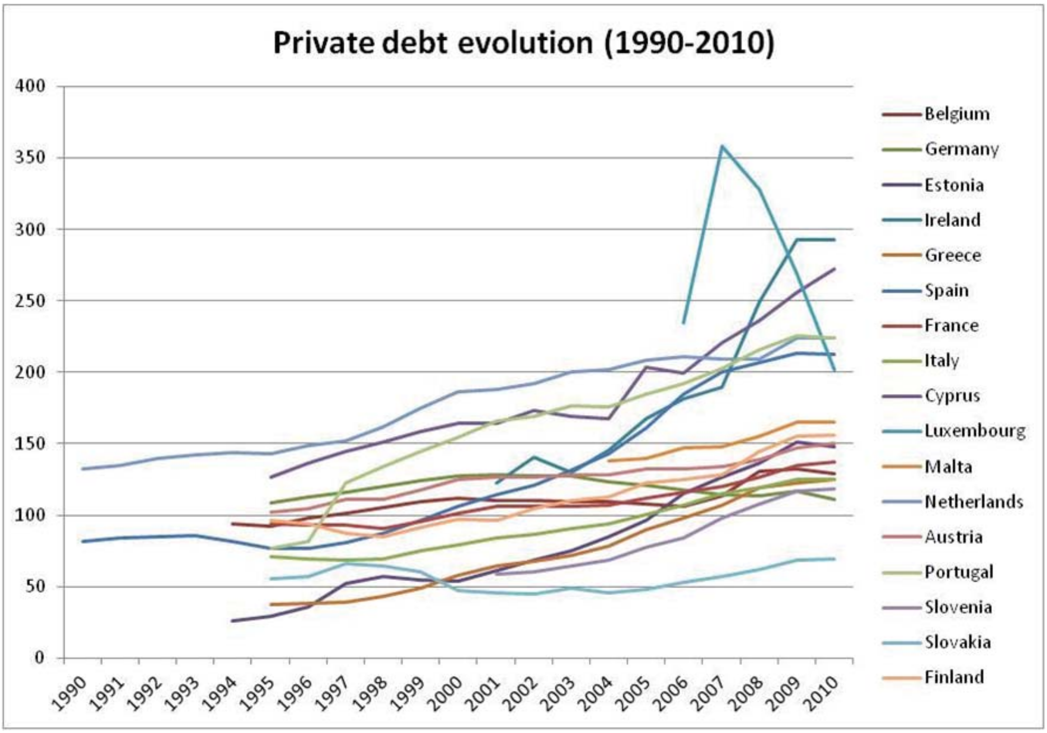


Figure 5. Private debt (% GDP) vs. Structural and Cohesion Funds (% GDP)

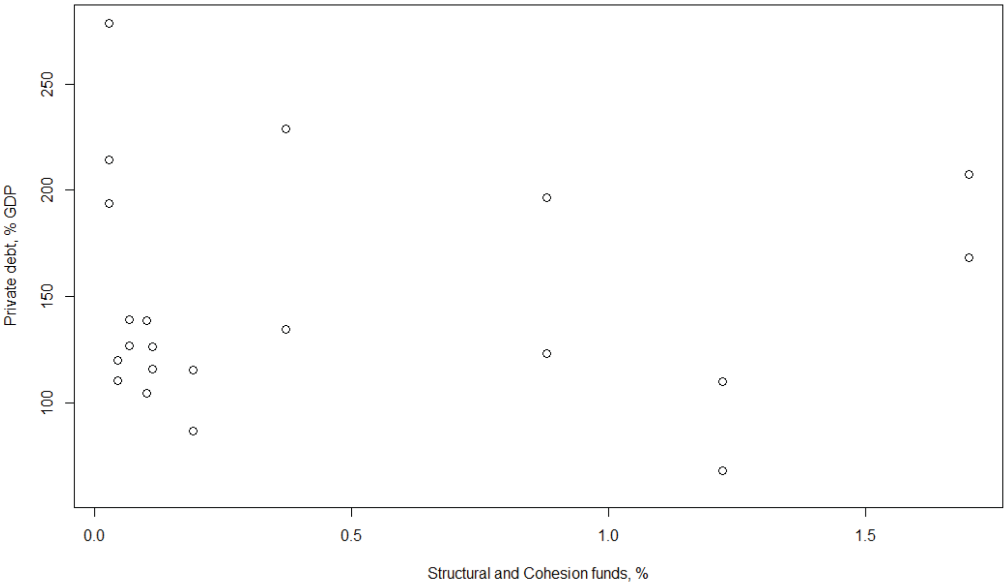
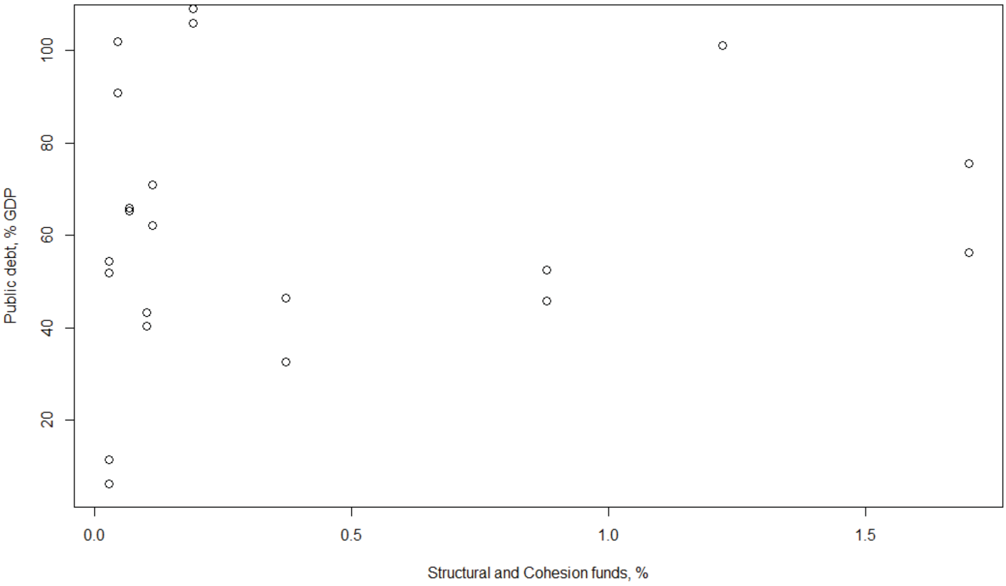


Figure 6. Public debt (% GDP) vs. Structural and Cohesion Funds (% GDP)



4.3. Convergence dynamics of core-periphery: empirical evidence from the eurozone 1990-2009

Paper 3. Maynou, L., Saez, M. and Bacaria, J. (2013) ‘Convergence dynamics of core-periphery: empirical evidence from the eurozone 1990-2009’ *Journal of International Economics* (under revision).

> *“My dear, here we must run as fast as we can, just to stay in place. And if you wish to go anywhere you must run twice as fast as that.”*
>
> *Lewis Carroll, Alice in Wonderland.*

Convergence dynamics of core-periphery: empirical evidence from the eurozone 1990-2009

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Abstract

Core-periphery countries are defined based on GDP growth, productivity and population density, according to the main theories. We evaluate the convergence dynamics of the core-periphery among the eurozone countries between 1990-2009 using a spatio-temporal econometric framework. We identify distinct convergence patterns of core and periphery in terms of GDP per capita: although core and periphery countries converged before 2003, we unexpectedly find that from 2003 the core appears to have diverged from the eurozone average while periphery countries have kept converging. This implies that the disparity among GDP per capita growth levels is diminishing at a fast rate, hence the difference between core-periphery shrinks rapidly.

Key words: Core-periphery, convergence, β-convergence, dynamic random coefficients panel data models, Bayesian models, INLA

JEL codes: F15, F60, E60, C01, C31, C11

1.- Introduction

It was in 1999, after different attempts inside the European Union (EU), that the Economic and Monetary Union (EMU) was officially born. In order to enter the EMU, the candidate countries had to comply with nominal convergence requisites, which were defined in the Maastricht Treaty (1992). These conditions were defined to guarantee that before entering the EMU, the countries had reached a certain level of economic (nominal) convergence. This requirement stems from the theory of the 'optimum currency areas', which states that the economic convergence is a prerequisite to have an effective Economic and Monetary Union (Mundell, 1961). However, after more than ten years of its creation, are the EMU countries converging? Europe has been popularly defined, from the late 80s, as the "two-speed Europe", in other words, the so called core-periphery countries. Are these two blocks of countries (core-periphery) converging among them? The answer of this question is the main interest of this paper.

Our main objective is to evaluate the convergence dynamics of the core-periphery among the eurozone countries. Our hypothesis is that, as a result of the policies implemented to establish the EMU, the eurozone countries began a process towards convergence, and as a consequence, the distance between core-periphery countries has been reduced during the last decade. However, we suppose that this convergence had not been the same for all countries and throughout all the period analyzed.

The concept of core-periphery has been extensively studied during the last century. However, even if the theory is widely understood, there are still some controversial opinions on its practical application. One of the earliest and best-known core-periphery concepts is Myrdal's 'cumulative causation' theory (Myrdal, 1957). According to this, one region (or country) will grow at the expense of another. Myrdal used the concept of the 'backwash effect', to explain the improvement in a 'core' region, as an agglomeration effect consisting of attracting capital and labour from other regions, with a negative effect on the latter.

Following Myrdal's agglomeration concept, Friedmann (1966) attributes core concentration to industrial and capital investment growth, which leads to an urbanization process and creates an agglomeration pole. At the same time, this creates dependence on the surrounding peripheral areas. On extending the concept of economic concentration, Keeble *et al.* (1988) introduced the problem of accessibility. Periphery is linked to remoteness from economic activity. Physical distance imposes costs and diminishes firms' attraction and interaction between areas. In fact, as they point out, the area of greatest attraction to industry will be the region with the lowest distance costs to all possible markets (Keeble *et al.*, 1988).

Krugman (1991) developed the 'New Economic Geography' (NEG) theory, which aims to explain the formation of economic agglomerations in certain geographical areas (see also Fujita and Krugman, 2004). Although agglomeration (concentration or clustering) of economic activity occurs on many geographical levels with a variety of compositions, the emergence of a core-periphery pattern will depend on transportation costs, economies of scale and the importance of non-agricultural food in total expenditure. When these three variables cross a critical threshold, the population will begin to concentrate in one region, making other regions become peripheral.

Apart from these last theories, the EU has also used a definition for core-periphery in order to determine the recipients of the Structural and Cohesion Funds. It has associated the term periphery with the definition of objective status (Gren, 2003), understood as the need to help those less developed regions (in the EU) through certain 'Funds'. With the focus on cohesion policy which began in 1988, EU objectives for 2007-2013 were classified as: Convergence (formerly Objective One), Regional Competitiveness and Employment (formerly Objective Two) and European Territorial Co-operation (formerly Objective Three) (Council Regulation (EC) No 1083/2006 of 11 July 2006, see Annex 1). However, the EU core-periphery concept does not seem to hugely differ from the main theories. As Mack and Jacobson (1996) point out that the regions covered by the Convergence Objective (formerly Objective One) might be considered the eurozone periphery.

Except Myrdal (1957), who introduced the concept of 'spread-out effect' to explain that, after agglomeration, positive spill over effects will stimulate growth in countries (regions) located in the periphery of the centre, most theories have a negative connotation, implying a clear trend towards a dualism in which the superiority of the core areas and the disadvantages of the peripheral areas tends to widen (Mack & Jacobson, 1996).

1.1.- Eurozone core-periphery

We can state that from a purely geographical point of view, the eurozone has a centre, comprising the countries in the middle of the continent, i.e. Austria, Belgium, Finland, France, Germany, Italy, Luxembourg and Netherlands; and then an area surrounding the centre, comprised of other countries like Ireland, Portugal, Spain, Greece, eastern European countries and island states (Cyprus, Malta). The latter are separated from the centre by natural geographical features such as seas, mountain ranges, rivers, etc., which impede easy access or complete interaction with the centre.

However, as we have described above, the core-periphery concept is not only based on the geographical location. Other aspects as agglomeration of economic activity and population density are also important to determine core-periphery countries. Several core-periphery theories point out that the agglomeration of economic activity takes place in areas of high technology, where there are specialized manufacturing processes, scale economies and low distance costs. These concentrated areas might be called 'core' countries and contrast with those we might call 'periphery': areas with low levels of specialization, based on low technology manufacturing and agriculture and which depend on imports from the core.

If we try to determine the core-periphery of the eurozone following this last approach, we should analyze the concentration of both, population density and economic activity, measured, at least, by GDP per capita and by productivity. However, as we can see in Figure 1, no clear pattern emerges from this. There exists a centre, formed by an imaginary axis which would join the Italian regions of Emilia-Romagna, Lombardia, Piemonte and Liguria in the south, with Dutch regions in the north. It is not easy to define exactly what regions of which countries could be considered periphery. However, in order to interpret our results, we will take as core-periphery countries the classification which is mainly used at the EU level: periphery (Greece, Ireland, Portugal and Spain) and core (Austria, Belgium, Finland, France, Germany, Italy, Luxmebourg and Netherlands). The rest of the eurozone countries out of this classification will be divided in two groups: Eastern European countries (Estonia, Slovakia and Slovenia) and State Islands (Cyprus and Malta).

Following this introduction, section two details the data setting and methods used. The results are explained in section three. Finally, discussion and concluding remarks are given in section four.

2.- Methods

2.1.- Data setting

As our interest is to evaluate convergence dynamics of the core-periphery among the eurozone, we only considered regions in the seventeen European Union countries that constitute the eurozone. In particular, we use the 174 regions (NUTS 2 level) of these 17 EU countries, from 1990 to 2009 (see Table 1, source: EUROSTAT).

Our reason for using regional data is twofold. First of all, it exist significant differences in terms of agglomeration and economic concentration among regions within countries. It is for this reason that we define core-periphery in terms of regions, rather than countries (see Figure 1). Second, as we will explain below, with limited time series (T), as in our case (i.e., 1990-2009, 20 years), in order to obtain consistent estimates of the parameters of interest we needed a large N (instead of only seventeen countries, one hundred seventy four regions).

2.2.- Econometric model

Models are specified based on the well-known beta-convergence hypothesis (Baumol, 1986; Barro and Sala-i-Martin 1991, 1992; Sala-i-Martin 1996), originally specified as a cross-section model:

$$g_T = \alpha + \beta y_0 + u \qquad u \sim N\left(0, \sigma_u^2 I\right) \qquad [1]$$

where g_T denoted the vector of (dependent variable) average growth rate in the period $(0,T)$; y_0 was the vector of (dependent variable) initial levels; u was a zero-mean and homoskedastic ($\sigma_u^2$was the constant variance) normally distributed disturbance term; and α and β denoted (unknown) parameters.

The absolute β-convergence hypothesis (equation [1]) rests on the assumption that there is a negative correlation between the initial level (of the dependent variable) and the growth rate (of such variable). Therefore, β–convergence exists if the estimated value for β, the coefficient of interest, is (statistically significant) negative. If this is true, poorer economies (periphery) grow faster than richer ones (core) and will catch them up in the long run.

However, it is more reasonable to assume that a negative correlation exists between growth rate and, rather than level, the distance the level of the dependent variable is from its steady state equilibrium. Therefore, poorer regions do not necessarily grow faster than richer regions, because the latter may be even further from their steady state equilibria (Baumont *et al* 2002). In this paper we therefore use the conditional specification of the β-convergence hypothesis:

$$g_T = \alpha + \beta y_0 + X\gamma + u \qquad u \sim N\left(0, \sigma_u^2 I\right) \qquad [2]$$

where X is a matrix of explanatory variables (of convergence); and γ the associated (unknown) parameters.

In line with core-periphery theories, we considered three possible dependent variables (vector *g* in equation [2]) two capturing economic concentration: i) Gross Domestic Product per inhabitant in PPS (*GDPPC*) (data from 1995 to 2009) and; ii) productivity (*product*), defined as the ratio of GDP to the active population (data from 1999 to 2009); and one capturing agglomeration: iii) population density (density), computed as inhabitants per km^2 (data from 1990 to 2010).

As explanatory variables we considered only real and not nominal variables. Once the country met the criteria of nominal convergence and adopted the Euro, changes in the price level would be (theoretically) temporary and would be controlled by the European Central Bank. Changes in price levels therefore would only distort the analysis. Due to the difficulty of obtaining some variables at regional level, we also considered a few variables at country level. We primarily use economic variables, but also use variables representing the level of education. In this way we try to characterize the most specific characteristics of the country or region[4].

Regional level

Gc: Gross fixed capital formation	This consisted of resident producers' acquisitions, fewer disposals of fixed assets during a given period plus certain additions to the value of non-produced assets realized by the productive activity of producer or institutional units (European System of Accounts). It was measured in millions of euro.
Unempl: Unemployment rate	Ratio of unemployed (both sexes) over active population.
Youngunempl: Young unemployment rate	Ratio of youth (15-24 years old) unemployed (both sexes) over youth active population.
Empf: Female employment rate	Ratio of female employed over active population.
Empht: High-tech employment	Employment in technology and knowledge-intensive sectors (thousands of employees).
Sec: Percentage of secondary students	Ratio of the sum of level 2 students (lower secondary or second stage of basic education), level 3 students (upper secondary education) and level 4 students (post-secondary non-tertiary education) over total population.
Univ: Percentage of university students	Ratio of the sum of level 5 and 6 students (tertiary education) over total population.

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[4] The explanatory variables were the ones of the best final model. We tried more variables in other models, but applying the Deviance Information Criterion (DIC), these were the ones which gave a better goodness-of-fit.

Country level

Exports: Export rate	Ratio of the value of exported goods and services over the country's GDP.
Imports: Import rate	Ratio of the value of imported goods and services over the country's GDP.
Bpg: External balance	The ratio of exported goods minus imported goods over the country's GDP.
Pubexp: Public expenditure rate	Ratio of goods and services bought by the State over the country's GDP.

By contrast with more standard studies, we do not specify cross-section but spatio-temporal models, i.e. dynamic panel data, from a Bayesian approach. In fact, we want to explicitly consider the time dimension in our data. As we argued, our hypothesis state that, as a result of the policies implemented to establish the European Monetary Union (from 1999 onwards), the Eurozone countries began a process towards convergence. In addition, the convergence rate may have been different for each country and/or have varied during the period under analysis. Furthermore, with small T, we need a large N in order to obtain consistent estimates.

In particular, we specify the following three dynamic panel data models:

Gross Domestic Product per inhabitant, in PPS (GDPPC)

$$\frac{GDPPC_{ijt}-GDPPC_{ijt-1}}{GDPPC_{ijt-1}}=\alpha_j+\beta_t\log(GDPPC_{ijt-1})+\gamma_1\log(density_{ijt})+\gamma_{2j}\log(empht_{ijt})+\gamma_3\log(\sec_{ijt})+$$
$$\gamma_4\log(univ_{ijt})+\gamma_5\log(unempl_{ijt})+\gamma_{6j}\log(g_{ijt})+\gamma_7\log(youngunempl_{ijt})+$$
$$\gamma_8\log(empf_{ijt})+\gamma_{9j}\log(\text{exports}_{jt})+\gamma_{10j}\log(\text{imports}_{jt})+\gamma_{11j}\log(pub\exp_{jt})+\gamma_{12}\log(bpg_{jt})+u_{ijt}$$

[3a]

Productivity (product)

$$\log(product_{ijt})=\alpha_j+\beta_{jt}\log(product_{ijt-1})+\gamma_1\log(density_{ijt})+\gamma_{2j}\log(empht_{ijt})+\gamma_3\log(\sec_{ijt})+$$
$$\gamma_4\log(univ_{ijt})+\gamma_5\log(unempl_{ijt})+\gamma_6\log(g_{ijt})+\gamma_7\log(youngunempl_{ijt})+$$
$$\gamma_8\log(empf_{ijt})+\gamma_{9j}\log(\text{exports}_{jt})+\gamma_{10}\log(\text{imports}_{jt})+\gamma_{11}\log(pub\exp_{jt})+\gamma_{12}\log(bpg_{jt})+u_{ijt}$$

[3b]

Density (density)

$$\log(density_{ijt})=\alpha_j+\beta_t\log(density_{ijt-1})+\gamma_1\log(GDPPC_{ijt})+\gamma_2\log(product_{ijt})+\gamma_{3j}\log(empht_{ijt})+\gamma_4\log(\sec_{ijt})+$$
$$\gamma_5\log(univ_{ijt})+\gamma_6\log(unempl_{ijt})+\gamma_7\log(g_{ijt})+\gamma_8\log(youngunempl_{ijt})+$$
$$\gamma_9\log(empf_{ijt})+\gamma_{10}\log(\text{exports}_{jt})+\gamma_{11j}\log(\text{imports}_{jt})+\gamma_{11j}\log(pub\exp_{jt})+\gamma_{12}\log(bpg_{jt})+u_{ijt}$$

[3c]

In all three equations, i denotes region *(i=1,…,174)*; j country *(j=1,…,17)*; t year (for instance, *t=1995 1996,…, 2009* for GDP); α, β and γ denotes unknown parameters; and u, the normally distributed disturbance term.

Note that in the models corresponding to Gross Domestic Product per inhabitant in PPS [3a] and productivity [3b] we included density as explanatory variable, and in the model corresponding to density [3c] we included Domestic Product per inhabitant in PPS and productivity.

Some of the coefficients, and in particular the coefficient of interest, β, have subscripts. In fact, we specify (dynamic) random coefficient panel data models (Hsiao and Pesaran, 2008) or, in mixed models terminology, we allow (some of the) coefficients to be random effects (Pinheiro and Bates, 2000). In other words, we have allowed them to be different for the various levels we have considered. Thus, for example, the coefficient of interest, β, varies per year in the three models [3a to 3c],

$$\beta_t = \beta + \nu_t$$

and also per country when productivity is the dependent variable [3b].

$$\beta_j = \beta + \upsilon_j$$

With respect to the other explanatory variables, the random effects are associated with different levels depending on the final model[5].

When the random effects vary by country we assume they are identical and independent Gaussian random variables with constant variance, i.e. $\upsilon_j \sim N\left(0, \sigma_\upsilon^2\right)$. When the random effects vary by year, we assume a random walk of order 1 (i.e. independent increments) for the Gaussian random effects vector (although we also assume a constant variance) (R INLA, 2013).

$$\Delta\upsilon_j = \upsilon_j - \upsilon_{j+1} \qquad \Delta\upsilon_j \sim N\left(0, \sigma_\upsilon^2\right)$$

2.3.- Spatio-temporal adjustment

In all three models, the disturbance terms, although Gaussian, are not identically and independently distributed. In fact, with spatial data, as it is in our case, it is necessary to distinguish between two sources of extra variability (Lawson *et al.*, 2003, Barceló *et al.*, 2009). Firstly, the largest source is usually named 'spatial dependence', or clustering, and is a consequence of the correlation between the spatial unit and the neighbouring spatial units, generally the adjacent geographical areas. The closer areas are much more similar than the more distant ones. Part of this dependence is not really a structural dependence, but mainly due to variables (with a spatial behaviour too) that are not included in the analysis. The second source is independent, spatially uncorrelated

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[5] We have a preliminary estimation of all three models allowing variation on three levels (country/region/time) for all the coefficients. In the specification shown, we have provided only the best final models. Results not shown can be requested. from the authors.

extra variability, called uncorrelated or non-spatial heterogeneity, which is due to unobserved non-spatial variables that could influence the dependent variable (Lawson *et al.*, 2003, Barceló *et al.*, 2009). In our case, as we had the time dimension in our data, there was also temporal dependency (i.e. serial autocorrelation). Again, maybe not result of a dynamic behaviour of the dependent variable per se, but to the omission of time-varying explanatory variables.

To take into account this spatio-temporal extra-variability, we introduce some structure in the model. Heterogeneity is captured using the random effect associated with the intercept (α_j) (varying at a country level *j*). Temporal dependency is approximated through the random walk of order 1, linked to the random effect associated with the parameter of interest, β_t (varying at a year level, *t*).

For spatial dependency we follow the recent work of Lindgren *et al.* (2011) and specify a Matèrn structure (Stein, 1999). In short, we use a representation of the Gaussian Markov Random Field (GMRF) explicitly constructed through stochastic partial differential equations (SPDE) which has as a solution a Gaussian Field (GF) with a Matérn covariance function (Lindgren *et al.*, 2011). To sum up, instead of using the Matérn in a regular lattice, which is the usual practice and would imply an estimation with a high computational cost and, also, one that would be weak in terms of efficiency (Lindgren *et al.*, 2011), we specify the structure of the spatial Matérn covariance in a triangulation (Delaunay triangulation – Hjelle and Daehlen, 2006) of the studied area (Figure 2) with a low computational cost and, more importantly in our context, much more efficiency.

2.4.- Inference

It is known that in random coefficient panel data models, unless the initial levels of the dependent variables are fixed constants[6] (Hsiao *et al.*, 1999), or, in other words, the assumption of independence between the regressors and the random effects is fulfilled, the estimates of the parameters will be inconsistent, even for T and N sufficiently large (Hsiao and Pesaran, 2008). In dynamic panel data models, with the lagged dependent as explanatory variable and, typically, with finite T, the assumption of independence does not hold (Nickell, 1981; Anderson and Hsiao, 1981, 1982). However, Tsiao *et al.* (1999) show that, even in this case, the use of a Bayesian approach performed fairly well. In this paper, we preferred, moreover, to relax the assumption of strict exogeneity, allowing a weak exogeneity of the lagged dependent variable, this is to say, that current shocks only affect future values of the dependent variable (Moral-Benito, 2010). By doing this, we could obtain consistent estimates of the parameters of interest (even with fixed T).

It is important to point out that this relaxation involves two requirements; first, a large N, i.e. obtained in our case considering regional data; second, identically and independently distributed error terms. This can only be achieved by the spatio-temporal adjustment explained above, imposing a certain structure on the original disturbance term.

In our case inferences were performed using a Bayesian framework. This approach (more or less pure), was considered the more suitable to accounting model uncertainty, both in the parameters and in the specification of the models, either in cross-sectional studies (Raftery, 1985; Fernández *et al.*, 2001; and Sala-i-Martin *et al.*, 2004) or in panel data models (Hsiao *et al.*, 1999; Hsiao and Pesaran, 2008; Moral-Benito, 2010; Redon, 2012; among others). Furthermore, only under the Bayesian approach was possible to model both spatial (heterogeneity and spatial

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[6] Note that only in the case of the density this hypothesis may be true.

dependence) and temporal extra variability, with relative sparse data in some cases (see Table 1). Finally, within the Bayesian approach, it is easy to specify a hierarchical structure on the (observable) data and (unobservable) parameters, all considered random quantities.

Within the (pure) Bayesian framework, we followed the Integrated Nested Laplace (INLA) approach (Rue *et al.*, 2009). In particular, our problem could be specified modelling the mean (of the dependent variable) for the ijt-th unit, $\mu_{ijt} = E(g_{ijt})$, by means of an additive linear predictor, defined on the identity scale (we had Gaussian data) (Blangiardo *et al.*, 2013),

$$\mu_{ijt} = \alpha + \sum \beta_m x_{m,ijt} + \sum f_l(z_{l,ijt})$$

where α denotes the intercept; β the 'fixed' effects; and f a collection of functions defined in terms of a set of explanatory variables z. Varying the form of f it is possible to accommodate both, random effects and space-temporal adjustment (Rue *et al.*, 2009). The vector of parameters is represented by $\theta = \{\alpha, \beta, f\}$. Note that all parameters are treated as random.

Following Schrödle and Held (2011), the spatio-temporal models are built as Bayesian two-stage hierarchical models. The first stage is the observational model, $p(y|\theta)$, where y denotes the vector of observations of both, the dependent and the explanatory variables, and θ are the unknown parameters. We assumed a Gaussian Markov random field (GMRF) prior on θ, $p(\theta|\psi)$, with mean 0 and a precision (inverse of the variance) matrix Q. The second stage is given by the 'hyperparameters' ψ and their respective prior distribution $p(\psi)$.

We are interested in the posterior marginals of the GMRF, i.e. $p(\theta_i|y) = \int_\psi p(\theta_i|\psi, y)p(\psi|y)d\psi$, that we approximate using the following finite sum

$$\tilde{p}(\theta_i|y) = \sum_k \tilde{p}(\theta_i|\psi_k, y)\tilde{p}(\psi_k|y)\Delta_k \qquad [4]$$

where $\tilde{p}(\theta_i|\psi_k, y)$ and $\tilde{p}(\psi_k|y)$ denotes approximations of $p(\theta_i|\psi, y)$ and $p(\psi|y)$, respectively. The finite sum [4] is evaluated at support points ψ_k using appropriate weights Δ_k.

The posterior marginal $p(\psi|y)$ of the hyperparameters is approximated using a Laplace approximation (Tierney and Kadane, 1986).

$$p(\psi|y) = \frac{p(\theta,\psi|y)}{p(\theta|\psi,y)} \propto \frac{p(\psi)p(\theta|\psi)p(y|\theta)}{p(\theta|\psi,y)} \approx \left.\frac{p(\psi)p(\theta|\psi)p(y|\theta)}{\tilde{p}(\theta|\psi,y)}\right|_{\theta=\theta^*(\psi)} = \tilde{p}(\psi|y)$$

where the denominator $\tilde{p}(\theta|\psi, y)$ denotes the Gaussian approximation of $p(\theta|\psi, y)$ and $\theta^*(\psi)$ is the mode of the full conditional $p(\theta|\psi, y)$ (Rue and Held, 2005).

According to Rue *et al.* (2009), it is sufficient to "numerically explore" this approximate posterior density using suitable support points Δ_k in [4]. In this paper, these points are defined in the h-dimensional space, using the strategy known as 'central composite design'. Centre points are augmented with a group of star points which allow the curvature of $\tilde{p}(\psi|y)$ to be estimated (Rue *et al.*, 2009).

To approximate the first component of [4], we use a 'simplified Laplace approximation', less expensive from a computational point of view with only a slight loss of accuracy (Schrödle and

Held, 2011; Rue *et al.*, 2009; Martino and Rue, 2010). Finally, we specify minimally informative priors on the log of the precision of all hyperparameters, i.e. logGamma (1,0.0005).

All analyses have been done with the free software R (version 2.15.2) (R Development Core Team, 2012), though the INLA library (The R-INLA project, 2012; Rue *et al.*, 2009).

3.- Results

3.1.- Descriptive

In Table 2, we provide some descriptive data for the three dependent variables. Table 2a shows the growth of the GDPPC in the eurozone from 1990 to 2009. The average growth for this period was 4.13% (standard deviation -sd- 3.18%; median 4.20%; first quartile -Q1- 2.30%; third quartile –Q3- 5.80%). However, this growth was not homogenous in time. It was higher until 2000 and then fell at more or less the same rate until 2009. Moreover, GDPPC growth was also not homogenous between countries. From 1990 to 2009, Estonia had the highest GDPPC growth, followed by Slovakia. Italy had the lowest growth, followed by Belgium, Malta, Germany, France and Austria. Concluding, the behaviour of the GDPPC rate during the three five-year periods was very heterogeneous. Some countries followed the eurozone's behaviour, while others followed a totally different path.

In Table 2b, we have collected the descriptive data for productivity. The mean level of productivity in the eurozone from 1990-2009 was 50.252 (sd: 14.183; median: 48.605; Q1: 42.444; Q3: 56.125). From 1996 to 2009, the level of productivity rose to 54.103 in the eurozone countries. However, similar to the GDPPC rate, we find heterogeneity among the eurozone countries. The countries with higher levels of productivity over the last twenty years were Belgium, Ireland and Austria, while Estonia, Luxembourg and Slovakia had the lowest level of productivity of the eurozone. We must take into account, however, that even if some countries had lower levels, the productivity of all eurozone countries grew from 1990 to 2009.

Descriptive data for the density variable are presented in Table 2c. The mean population density of the eurozone from 1990 to 2010 was 345.09 (sd: 783.44; median: 134.52; Q1: 71.29; Q3: 293.49). Different levels of population density existed across the eurozone countries, with countries like Malta and Belgium having the highest levels during the period 1990-2010, and Finland, Estonia and Ireland having the lowest levels. Regarding the evolution of population density in all countries, we can state that the population has generally remained almost stable, although some significant changes can be seen in Spain and Malta, where population density has increased in the last twenty years.

3.2.- Results of the estimation

The results of estimating the models are shown in Tables 3 and 4. As stated above, the coefficient of interest in this analysis is β. For the model corresponding to (annual variation of) Gross Domestic Product per capita in PPS, we find significant convergence among eurozone countries, as the coefficient is negative, -1.57%, and statistically significant (the 95% credible interval did not contain the zero). In the models corresponding to productivity and population density, however, we found a (statistically) significant divergence between the countries of 4.14%

and 4.33%, respectively, as the coefficient of interest is positive and statistically significant.

In Table 4, we show the mean and the 95% credibility intervals of the random effects of each model. The table shows countries where there was significant variation and the years where this took place. For our coefficient of interest, β, we had three possible levels of variation: country, region and time. For the GDPPC rate model, we allow the β to vary only across time, as it was not significant for the other two levels. For this case, the years which show (statistically) significant variation are 1996 to 2001, 2003 to 2005, and 2007 to 2008. For the productivity model, we allow the β to vary per country and year. The countries that show significant variation in this model are Estonia, Germany, Greece, Italy and Malta, and the years which also showed variation were 1999 to 2002, and 2005 to 2008. For the third model, population density, we allowed the β to vary only for time. In this case, the years which had a significant variation were 1990 to 1994, and 1999 to 2008.

In Figure 3 we show the results of the model estimation. The graphs collect the coefficient of interest (β) for the peripheral (Greece, Ireland, Portugal and Spain), for the core (Austria, Belgium, Finland, France, Germany, Italy, Luxembourg and Netherlands), for the Eastern countries (Estonia, Slovakia and Slovenia) and for the Islands (Cyprus and Malta). With respect to GDPPC model (Figure 3a), it can be observed that a common trend existed with regard to convergence from 1996 to 2003 for the core, periphery and eastern European countries, while the Islands diverged. Focusing on the core and periphery countries, we can see that both converged (negative β) until 2003, however, from 2004 some differences arose and the core countries started to diverge (positive β), while the peripheral continued to converge. This implies that the disparity among GDPPC growth levels diminished at a fast rate, hence the distance between core-periphery shrunk rapidly. Nevertheless, this distance reduction was done at a faster rate by the peripheral countries as the graph shows. Moreover, the Eastern European countries followed the same path of the core countries, as they sharply diverged from 2001, while the Islands followed a convergence from 2000 to 2004, to end up diverging too.

With respect to the productivity model (Figure 3b), we see that up until 2001-2002, the four groups of countries converged with regard to the rate of productivity. However, from that point on there was a common trend towards divergence. So, we cannot see a distance reduction in terms of productivity. In Figure 3c, we show the results of estimating the density model. In this case, we see a common trend of divergence for the core and periphery countries until 2003. From that point, the periphery countries continued diverging, while the core countries started a slow process of convergence. As we can see in the graph, there was not a distance reduction bewteen periphery and core countries in terms of population density. In relation to the Islands and the Eastern European countries, we can see that the former kept stable until 2003 to then follow a path of divergence, while the Islands converged until 2001 and from2004, after some years of divergence.

To provide additional evidence, in Figure 4 we have represented the coefficient of variation of GDP per capita (Figure 4a) and productivity (Figure 4b). As it is known, the coefficient of variation is the most frequently used summary measures of σ-convergence (Quah, 1993). We find σ-convergence when there is a decrease in the cross-sectional dispersion over time. In addition, β-convergence is a necessary but not sufficient condition for sigma-convergence to occur (Barro and Sala-i-Martin 1991; Salai-i-Martin 1996; Bernard and Durlauf, 1996; Quah 1996; Paas, 2007). We represent the temporal evolution of the coefficient of variation average for each group of countries. In terms of GDP per capita, there was an increase of dispersion for the core, the eastern European countries and the islands for the studied period. However, for the peripheral countries there was a decrease in dispersion between 2000 and 2005, followed by an increase until 2008, and a decrease in 2009 (see Figure 4a). Note that, in the case of the productivity, the evolution of the coefficient of variation show a decrease of dispersion until 2004 for all the countries. However, from that point on, all the countries showed an increase of dispersion in terms of productivity. For the eastern European countries this increase is follow by a decrease in 2005, which continued until the end of the period. The islands follow a similar path, in 2005 there was a decrease in dispersion, follow by an increase in 2007. From 2007, the periphery countries showed a reduction of dispersion which continued until the end of the period (see Figure 4b).

Although in this paper we were not interested in the coefficients of the variables that conditioned the convergence, note that their estimates varied significantly between the three models, both in terms of its significance, its sign or magnitude. Note also that this variation occurred in both the fixed (Table 3) and the random effects (Table 4). In this sense, the female employment rate was found to be (statistically significant) positively associated with the growth of GDP PPS per capita. By contrast, it was found negatively associated with the growth of productivity and of population density. The ratio of secondary students was estimated negative for the growth of population density and negative for the growth of GDP PPS per capita. The effect of high-tech employment was found to be positive in the growth of productivity and negative in the growth of population density. The same happens for the ratio of university students, gross fixed capital formation and external balance (only of goods). Unemployment was the only variable that had the same sign (negative) in all three cases (although it was not statistically significant for the growth of GDP PPS per capita). Public expenditure rate was only found statistically significant (with a positive sign) for the growth of GDP PPS per capita. In the case of random effects this variability is repeated, enlarged if possible, since, by definition, these varied between countries and during the period under study.

4.- Discussion

Although we allow random effects to vary regionally, we found no evidence for in any case. It seems, therefore, that the country would be the relevant level to the convergence. This last statement could be consequences of the policies relevant for this convergence are taken at a country and not at a regional level. This could involve a very small effect of EU policies at the regional level, i.e. the Cohesion and the Structural funds. However, explicitly analyze the effect of such funds, if any, goes far beyond this work and certainly requires further research.

We also found both, spatial dependency and heterogeneity. In our case, this spatial heterogeneity was expressed both as structural instability, i.e. the estimates of the coefficients varied in space, and as groupwise heteroskedasticity, the covariance matrix of the error term varied across observations. Monfort (2008) point out that spatial heterogeneity is related to the concept of convergence clubs, that is, the possibility of multiple, locally stable, steady-state equilibrium to which similar economies converge (Durlauf and Johnson, 1995). In fact, this is precisely what we have found in this paper. However, a detailed analysis of club convergence is far from the objectives of our paper. Certainly, this requires further research.

The work could have several limitations. Let us discuss that in the same hierarchy used in the estimation of our models. First, in the area of growth models, Ciccone and Jarocinski (2010) point out that its results are sensitive to the GDP data used in the estimation. However, in an analysis of sensibility which uses GDP data from three versions of the Penn World Table and GDP data reported in the World Development Indicators 2005, Moral-Benito (2010) concludes that it is the number of explanatory variables and the number of observations what is relevant. He points out that the fewer the regressors and the more the number of observations, the smaller the sensitivity of the results to the GDP data used. But, on the other hand, data from a regional GDP for all EU countries can only be obtained from Eurostat, the data source we used.

Second, the consistency of the estimates is totally dependent on the fulfillment of the hypothesis of weak exogeneity. This, in turn, depends, at least, on one of their requirements. Once we did the spatio-temporal adjustment, the error terms should be identically and independently distributed. In this sense, we checked the absence of autocorrelation, or spatial or temporal, in the standardized residuals of all three models. In addition, using cross-correlation functions we also checked the absence of (contemporary) correlation between the error terms and each of the regressors, including lagged dependent variables in particular.

Third, as in any Bayesian analysis, the choice of the prior may have a considerable impact on the results. In the second stage of the hierarchy we used, we allowed variation on the different levels for all coefficients, i.e. we allowed all the coefficients were random effects. We tested, then, that the variance of the effects was equal to zero, i.e. the effects were actually fixed. Only when we reject this null hypothesis we maintained the coefficient as a random effect. Furthermore, regarding the third stage in the hierarchy, increasing the precision (lowering the variance) we performed sensitivity analyses to asses how the prior on the hyperparameters influences the estimation. We found no significant differences.

We opted to use a Matérn for the spatial covariance function, instead of functions with exponential decay (i.e. exponential or autoregressive) because is more flexible than the alternatives, producing smoother representations of the actual spatial covariance. As an alternative structure for the spatial dependence would be the non-parametric approximation, conditional autoregressive model, CAR, either in its intrinsic (Besag, 1974) (the between-area covariance matrix is not positive definite) or proper (Cressie, 1993) (matrix positive definite) versions. To use this approach, areas (regions in our case) have taken to be neighbors if they share a common boundary. This approach provides good results if all regions are of similar size and are arranged in a regular pattern but results are not promising in another case (Kelsall and Wakefield, 2002). In fact, as Simpson *et al.* (2011) point out, CAR relies heavily on the regularity of the lattice and it is quite difficult to construct a CAR on an irregular lattice that is resolution consistent (Rue and Held, 2005). This is the main reason we chose to follow the SPDE approach in our work. As we wrote above, instead of relying on a regular lattice, we specified the structure of the spatial Matérn covariance in a triangulation of the studied area, implying a low computational cost and much more efficiency.

4.1.- Conclusions

Although we have found (statistically) significant convergence in Gross Domestic Product per capita in PPS among eurozone countries, we could not find such convergence in productivity or density. In this case we have estimated a statistically significant divergence.

In fact, we found that convergence existed in Gross Domestic Product per capita in PPS but only until 2003. It was from 2004 when differences appeared and, while core countries begin to diverge, the periphery countries continue their convergence. It seems, therefore, that our hypothesis is fulfilled. Eurozone membership has spurred the growth of the periphery countries, leading to convergence. However, the core countries growth slowed, leading to a divergence from the rest of the eurozone countries. As a result, we found that the distance between core-periphery has been reduced during the last years (mainly from 2004), as the core diverged while the periphery converged.

This result was not expected, as some economists attribute the divergence to the peripheral countries. However, we must take into account that in some of the core countries (e.g. Germany, France) important labour reforms were done at the beginning of the 21st century (mainly in 2003 as our data shows). These reforms were mainly based on deregulation and an increase of flexibility in the markets. These reforms led to a rise in unemployment in these countries (Davidson, 2011). This fact might explain the change richer countries experienced in terms of convergence from 2003 onwards. These countries had to implement market reforms to make their economies more flexible, as they were stuck in a rut. Due to these changes, the convergence tendency stopped and most of the richer countries started to diverge.

Even if our interest falls on the core-periphery countries, we can briefly analyse the two the other groups of countries mentioned in the paper. Out of our results, these countries are mainly diverging in terms of GDPPC, productivity and population density. The speed of divergence is higher than the core countries. As a result, they are increasing the distance with the eurozone average. We would have expected these countries to behave like the periphery, because they have also started from low levels of growth and the eurozone policies should have boosted their convergence. But, it seems that these policies did not work for the Eastern European and the Islands of the eurozone, as it did for the periphery.

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Conflicts of Interest

There are no conflicts of interest for any of the authors. All authors disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

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Table 1.- Eurozone countries and regions

AUSTRIA (9 regions) Burgenland (A) Niederösterreich Wien Kärnten Steiermark Oberösterreich Salzburg Tirol Vorarlberg **BELGIUM (11 regions)** Région de Bruxelles Capitale Prov. Antwerpen Prov. Limburg (B) Prov. Oost,Vlaanderen Prov. Vlaams,Brabant Prov. West,Vlaanderen Prov. Brabant Wallon Prov. Hainaut Prov. Liège Prov. Luxembourg (B) Prov. Namur **CYPRUS (1 region)** Cyprus **ESTONIA (1 region)** Eesti **FINLAND (5 regions)** Itä,Suomi Etelä,Suomi Länsi,Suomi Pohjois,Suomi Åland	**FRANCE (26 regions)** Île de France Champagne,Ardenne Picardie Haute,Normandie Centre Basse,Normandie Bourgogne Nord , Pas,de,Calais Lorraine Alsace Franche,Comté Pays de la Loire Bretagne Poitou,Charentes Aquitaine Midi,Pyrénées Limousin Rhône,Alpes Auvergne Languedoc,Roussillon Provence,Alpes,Côte d'Azur Corse Guadeloupe (FR) Martinique (FR) Guyane (FR) Réunion (FR)	**GERMANY (39 regions)** Stuttgart Karlsruhe Freiburg Tübingen Oberbayern Niederbayern Oberpfalz Oberfranken Mittelfranken Unterfranken Schwaben Berlin Brandenburg, Nordost Brandenburg, Südwest Bremen Hamburg Darmstadt Gießen Kassel Mecklenburg,Vorpommern Braunschweig Hannover Lüneburg Weser,Ems Düsseldorf Köln Münster Detmold Arnsberg Koblenz Trier Rheinhessen,Pfalz Saarland Chemnitz Dresden Leipzig Sachsen,Anhalt Schleswig,Holstein Thüringen
GREECE (13 regions) Anatoliki Makedonia, Thraki Kentriki Makedonia Dytiki Makedonia Thessalia Ipeiros Ionia Nisia Dytiki Ellada Sterea Ellada Peloponnisos Attiki Voreio Aigaio Notio Aigaio Kriti **IRELAND (2 regions)** Border, Midland and Western Southern and Eastern **ITALY (21 regions)** Piemonte Valle d'Aosta Liguria Lombardia Provincia Autonoma Bolzano Provincia Autonoma Trento Veneto Friuli,Venezia Giulia Emilia,Romagna Toscana Umbria Marche Lazio	Abruzzo Molise Campania Puglia Basilicata Calabria Sicilia Sardegna **LUXEMBOURG (1 region)** Luxembourg **MALTA (1 region)** Malta **NETHERLANDS (12 regions)** Groningen Friesland (NL) Drenthe Overijssel Gelderland Flevoland Utrecht Noord,Holland Zuid,Holland Zeeland Noord,Brabant Limburg (NL) **PORTUGAL (7 regions)** Norte Algarve Centro (P) Lisboa Alentejo Região Autónoma dos Açores Região Autónoma da Madeira	**SLOVAKIA (4 regions)** Bratislavský kraj Západné Slovensko Stredné Slovensko Východné Slovensko **SLOVENIA (2 regions)** Vzhodna Slovenija Zahodna Slovenija **SPAIN (19 regions)** Galicia Principado de Asturias Cantabria País Vasco Comunidad Foral de Navarra La Rioja Aragón Comunidad de Madrid Castilla y León Castilla,La Mancha Extremadura Cataluña Comunidad Valenciana Illes Balears Andalucía Región de Murcia Ciudad Autónoma de Ceuta Ciudad Autónoma de Melilla Canarias

Source: Eurostat and own construction

Table 2a.- Descriptive data for the dependent variable: annual rate of Gross Domestic Product per capita in PPS GDPPC (percentage).

Countries	1996-2000	2001-2005	2006-2010	***1990-2010***
EURO ZONE (17)	0.049(0.0245)[1] 0.047(0.034,0.062)[2]	0.039(0.0357) 0.037(0.018,0.058)	0.038(0.0317) 0.041(0.018,0.055)	*0.0413(0.0318)* *0.042(0.023,0.058)*
AUSTRIA	0.044(0.0093) 0.046(0.039,0.050)	0.035(0.0308) 0.044(0.014,0.060)	0.031(0.0205) 0.030(0.013,0.049)	*0.0368(0.2323)* *0.04(0.022,0.08)*
BELGIUM	0.038(0.0188) 0.039(0.024,0.056)	0.037(0.0358) 0.027(0.011,0.059)	0.024(0.021) 0.028(0.013,0.040)	*0.0335(0.0277)* *0.031(0.019,0.049)*
CYPRUS	0.047(0.015) 0.047(0.034,0.059)	0.047(0.034) 0.065(0.017,0.065)	0.056(0.017) 0.053(0.045,0.068)	*0.0499(0.023)* *0.056(0.034,0.065)*
ESTONIA	0.085(0.036) 0.075(0.057,0.112)	0.103(0.022) 0.108(0.097,0.109)	0.084(0.068) 0.111(0.046,0.122)	*0.0915(0.04174)* *0.108(0.064,0.122)*
FINLAND	0.064(0.033) 0.063(0.044,0.092)	0.046(0.0461) 0.030(0.020,0.082)	0.038(0.032) 0.034(0.016,0.053)	*0.0489(0.0392)* *0.044(0.02,0.0825)*
FRANCE	0.046(0.018) 0.045(0.036,0.058)	0.032(0.0396) 0.039(0.019,0.057)	0.028(0.0276) 0.035(0.012,0.048)	*0.035(0.0314)* *0.04(0.027,0.054)*
GERMANY	0.036(0.017) 0.036(0.024,0.046)	0.031(0.0173) 0.031(0.020,0.042)	0.037(0.023) 0.043(0.021,0.051)	*0.0343(0.01916)* *0.035(0.022,0.047)*
GREECE	0.054(0.035) 0.046(0.034,0.074)	0.057(0.047) 0.052(0.036,0.082)	0.035(0.033) 0.030(0.014,0.053)	*0.0492(0.0402)* *0.045(0.026,0.074)*
IRELAND	0.101(0.022) 0.102(0.084,0.117)	0.068(0.035) 0.049(0.044,0.095)	0.021(0.068) 0.051(-0.021,0.064)	*0.0635(0.0541)* *0.066(0.046,0.102)*
ITALY	0.043(0.0174) 0.046(0.033,0.054)	0.019(0.034) 0.014(-0.007,0.052)	0.032(0.022) 0.033(0.013,0.049)	*0.0304(0.0279)* *0.037(0.007,0.051)*
LUXEMBOURG	0.069(0.053) 0.051(0.035,0.103)	0.053(0.040) 0.063(0.043,0.068)	0.064(0.041) 0.059(0.033,0.094)	*0.061(0.0413)* *0.06(0.035,0.0854)*
MALTA	0.033(0.050) 0.048(0.003,0.062)	0.031(0.053) 0.031(-0.006,0.058)	0.040(0.0213) 0.046(0.024,0.055)	*0.0343(0.04114)* *0.046(0.002,0.058)*
NETHERLANDS	0.060(0.024) 0.063(0.045,0.077)	0.039(0.0403) 0.035(0.017,0.064)	0.051(0.0409) 0.051(0.025,0.069)	*0.0488(0.03713)* *0.049(0.024,0.074)*
PORTUGAL	0.068(0.026) 0.061(0.049,0.082)	0.040(0.0494) 0.027(0.014,0.057)	0.043(0.031) 0.045(0.023,0.066)	*0.0493(0.0396)* *0.048(0.023,0.067)*
SLOVAKIA	0.067(0.0359) 0.071(0.047,0.095)	0.067(0.0235) 0.067(0.055,0.081)	0.100(0.0438) 0.100(0.063,0.132)	*0.077(0.0373)* *0.071(0.058,0.100)*
SLOVENIA	0.072(0.0117) 0.071(0.063,0.080)	0.054(0.0217) 0.055(0.040,0.069)	0.050(0.0134) 0.050(0.044,0.060)	*0.0583(0.01865)* *0.059(0.048,0.071)*
SPAIN	0.060(0.015) 0.061(0.050,0.072)	0.051(0.024) 0.049(0.032,0.073)	0.047(0.035) 0.058(0.024,0.074)	*0.0527(0.0263)* *0.055(0.04,0.073)*

[1] *mean (standard deviation);* [2] *median (Q1, Q3)*

Source: Eurostat and own construction

Table 2b.- Descriptive data for the dependent variable: productivity (Gross Domestic Product/active population).

Countries	1996-2000	2001-2005	2006-2010	*1990-2010*
EURO ZONE (17)	44.074(12.5997)[1] 42.881(37.801,48.293)[2]	48.266(13.459) 46.901(41.260,53.457)	54.103(14.401) 52.319(46.103,60.228)	*50.252(14.183)* *48.605 (42.444,56.125)*
AUSTRIA	47.368(9.281) 47.164(43.049,50.896)	52.251(10.035) 51.182(46.519,57.140)	58.146(10.978) 57.725(50.914,62.949)	*54.121(10.8561)* *54.394(46.764,54.119)*
BELGIUM	49.691(19.953) 42.831(38.116,49.931)	57.144(22.313) 50.283(43.964,57.835)	61.261(21.926) 54.590(47.035,64.608)	*58.0457(22.0104)* *50.843(45.187,60.702)*
CYPRUS	39.064 39.064(39.064,39.064)	40.499(1.217) 40.227(40.169,40.885)	46.516(2.882) 46.325(44.332,48.699)	*42.762(3.7488)* *41.581(39.893,45.833)*
ESTONIA	16.345 16.345(16.345,16.345)	22.058(3.273) 22.028(19.579,23.994)	32.474(2.547) 32.849(30.478,34.470)	*25.653(6.664)* *25.193(19.258,32.282)*
FINLAND	42.423(10.517) 38.025(35.715,46.254)	47.236(8.692) 43.897(40.732,52.161)	55.080(7.741) 54.296(48.886,63.928)	*49.8422(9.4632)* *49.439(42.112,57.263)*
FRANCE	43.754(5.309) 42.791(40.537,4.301)	48.115(9.987) 46.513(43.638,50.155)	52.135(8.415) 51.237(47.498,54.112)	*49.3932(9.3708)* *47.876(44.295,52.054)*
GERMANY	48.558(12.760) 46.014(43.087,51.790)	49.913(11.930) 48.737(44.533,54.741)	54.313(12.442) 54.560(45.495,59.549)	*51.6563(12.409)* *50.203(44.487,57.398)*
GREECE	35.469(6.170) 34.367(31.808,38.394)	41.760(6.231) 40.424(37.302,45.789)	49.357(7.284) 47.726(44.115,53.603)	*44.1699(8.0733)* *43.655(38.236,49.921)*
IRELAND	46.638(11.681) 46.638(38.379,54.898)	54.776(11.681) 53.635(43.754,66.563)	63.566(13.761) 63.158(50.630,75.186)	*57.478(13.1682)* *54.036(46.02,70.337)*
ITALY	49.852(8.781) 52.152(40.157,57.171)	53.401(9.023) 56.384(43.694,60.894)	58.238(9.146) 60.974(49.134,65.458)	*54.981(9.4487)* *56.522(46.238,62.312)*
LUXEMBOURG	101.703 101.703(101.703, 101.703)	115.877(7.364) 113.941(110.456,119.866)	148.970(12.813) 151.791(139.601,158.340)	*27.697(20.8005)* *23.216(109.98,149.72)*
MALTA		40.640(1.370) 40.842(40.730,40.947)	46.359(1.253) 46.699(45.396,47.322)	*43.182(3.258)* *42.236(40.786,46.699)*
NETHERLANDS	44.923(6.739) 43.074(39.074,49.910)	50.486(7.761) 49.239(44.521,56.434)	58.976(10.513) 56.237(51.876,65.443)	*53.325(10.0895)* *52.036(45.930,60.213)*
PORTUGAL	30.937(5.581) 30.126(25.625,33.675)	34.963(6.653) 34.188(28.106,38.978)	40.422(8.485) 38.750(32.303,48.076)	*36.7438(7.9505)* *35.304(30.589,40.858)*
SLOVAKIA	21.311(9.873) 17.118(15.401,27.221)	25.651(11.787) 19.698(18.420,31.049)	37.206(19.234) 28.688(24.622,47.414)	*29.839(16.006)* *22.956(19.035,35.465)*
SLOVENIA		36.210(7.036) 35.494(30.151,42.704)	43.258(8.578) 42.418(35.684,51.423)	*39.734(8.408)* *38.419(32.132,46.757)*
SPAIN	39.293(6.379) 38.168(34.333,45.627)	44.659(6.826) 45.365(38.900,50.462)	51.345(7.827) 51.587(44.178,57.104)	*46.797(8.224)* *46.500(40.606,52.709)*

[1] mean (standard deviation); [2] median (Q1, Q3)

Source: Eurostat and own construction

Table 2c.- Descriptive data for the dependent variable: population density (population/km^2).

Countries	**1990-1995**	**1996-2000**	**2001-2005**	**2006-2010**	***1990-2010***
EURO ZONE (17)	334.18(751.55) 135.87(68.37,292.31)	343.01(775.16) 131.90(71.29,292.02)	346.91(786.95) 134.56(72.24,291.52)	354.80(814.55) 138.10(72.53,295.34)	*345.09(783.44)* *134.52(71.29,293.49)*
AUSTRIA	478.84(1140.53) 72.07(67.20,113.165	484.87(1157.93) 72.27(69.84,113.98)	495.03(1181.31) 72.56(69.65,115.39)	521.63(1249.73) 73.69(70.39,117.73)	*496.07(1176.24)* *73.02(68.83,116.64)*
BELGIUM	831.19(1630.40) 339.30(262.74,461.06)	834.99(1629.89) 339.03(263.47,475.76)	854.40(1674.07) 338.36(265.63,483.57)	899.97(1786.29) 345.30(274.48,495.79)	*857.09(1675.84)* *340.75(267.74,476.33)*
CYPRUS	65.95(2.99) 66.07(63.48,68.43)	72.45(1.24) 72.52(71.50,73.41)	76.52(1.69) 76.27(75.41,77.31)	84.39(2.18) 84.75(82.86,86.15)	*74.98(7.56)* *74.65(69.10,81.92)*
ESTONIA	34.82(1.17) 35.08(33.80,35.88)	32.06(0.45) 32.03(31.72,32.40)	31.16(0.19) 31.15(31.03,31.28)	29.86(0.48) 29.67(29.64,29.73)	*32.01(2.09)* *31.40(30.28,33.47)*
FINLAND	20.30(17.38) 16.06(8.30,20.29)	20.79(18.27) 16.32(8.15,20.37)	21.16(18.84) 16.76(7.89,20.44)	21.62(19.44) 17.13(7.68,20.84)	*20.97(18.24)* *16.56(7.82,20.59)*
FRANCE	132.41(178.57) 79.46(54.45,124.81)	138.13(180.093) 81.80(55.73,135.02)	150.88(180.93) 92.95(58.26,147.44)	148.77(187.90) 93.06(52.31,148.69)	*143.15(181.97)* *83.68(55.22,142.20)*
GERMANY	456.16(732.52) 207.31(151.24,370.58)	432.70(698.24) 220.87(153.82,373.73)	435.41(692.45) 215.95(153.47,378.36)	433.05(696.95) 208.29(149.70,379.47)	*439.65(704.41)* *211.81(152.30,378.42)*
GREECE	122.61(242.89) 52.30(37.26,66.96)	128.04(255.49) 53.18(38.24,70.10)	130.79(261.18) 53.33(38.64,71.85)	134.47(270.42) 52.53(38.42,73.03)	*128.98(256.34)* *52.75(38.19,72.21)*
IRELAND		51.86(24.65) 51.53(29.35,74.37)	54.76(25.02) 54.21(31.04,78.47)	60.75(27.08) 59.31(35.08,87.30)	*56.70(25.18)* *54.85(31.82,80.54)*
ITALY	169.18(103.88) 152.20(74.25,209.16)	169.23(104.21) 149.91(74.10,209.46)	170.01(104.38) 151.89(76.42,208.28)	176.11(108.43) 157.57(80.95,210.75)	*171.37(105.06)* *152.45(74.39,210.20)*
LUXEMBOURG	151.71(3.81) 151.65(148.65,154.75)	162.21(2.62) 162.20(160.18,164.23)	171.69(3.19) 171.71(169.76,173.36)	185.99(5.90) 185.61(181.39,190.84)	*168.26(14.22)* *167.67(155.8,179.88)*
MALTA	1144.25(20.35) 1144.68 (1127.73,1161.06)	1188.533(9.78) 1188.96 (1180.88,1196.18)	1244.25(24.24) 1250.45 (1240.23,1258.86)	1294.99(14.01) 1295.28 (1283.29,1308.89)	*1219.56(63.54)* *1204.64* *(1165.85,1279.58)*
NETHERLANDS	381.02(264.70) 328.94 (150.20,549.86)	391.78(270.52) 338.93 (148.83,561.92)	404.04(277.01) 348.40 (162.24,568.98)	413.13(282.73) 357.15 (170.58,574.87)	*397.73(272.65)* *340.59 (161.73,570.55)*
PORTUGAL	230.35(277.40) 103.61(71.02,318.26)	235.72(287.08) 102.84(73.43,303.20)	240.61(296.67) 102.60(79.84,291.37)	246.56(302.36) 104.87(84.44,296.13)	*239.04(288.97)* *103.57(80.70,296.50)*
SLOVAKIA		151.77(90.45) 111.58(90.12,213.02)	150.16(86.39) 111.86(90.94,208.41)	151.23(87.48) 112.50(91.41,208.72)	*151.02(86.41)* *112.50(86.80,250.05)*
SLOVENIA	100.58(11.17) 100.36(89.94,111.40)	100.34(12.65) 100.33(88.51,112.27)	100.84(13.13) 100.54(88.39,113.39)	102.33(14.59) 101.46(88.43,115.64)	*101.10(12.51)* *100.36(88.50,112.74)*
SPAIN	421.67(1047.14) 99.15(50.52,189.93)	572.01(1297.80) 99.46(52.05,211.83)	594.56(1346.38) 100.53(53.50,232.87)	611.47(1358.54) 106.57(58.35,262.30)	*546.98(1261.76)* *100.15(52.21,215.99)*

[1] mean (standard deviation); [2] median (Q1, Q3)

Source: Eurostat and own construction

Table 3.- Results of estimating the models

Dependent variables	Annual rate of variation GDPPC	Productivity	Population density
A	-0.5334(-0.8327,-0.2474)[1]	2.8468(1.5536,4.0718)	4.6385(4.1813,5.0830)
β	-0.0157(-0.0222,-0.0093)	0.0414(0.0191,0.0652)	0.0433(0.0326,0.0540)
Fixed effects:			
GDPPC			-0.0091(-0.0163,-0.0021)
Product			0.0443(0.0231,0.0651)
Density	-0.0021(0.0007,0.0035)	0.1821(0.1622,0.2021)	
Empht	-0.0011(-0.0038,0.0015)	2.8468(1.5536,4.0718)	-0.0232(-0.0319,-0.0145)
Sec	-0.0023(-0.0043,-0.0003)	-0.0002(-0.0082,0.0078)	0.0232(0.0065,0.0399)
Univ	0.0020(-0.0005,0.0045)	0.0171(0.0059,0.0283)	-0.0400(-0.0645,-0.0156)
Unemploy	-0.0007(-0.0047,0.0034)	-0.0617(-0.0804,-0.0429)	-0.0682(-0.1004,-0.0359)
Gc	0.0004(-0.0019,0.0026)	0.0025(0.0012,0.0025)	-0.0063(-0.0097,-0.0029)
Youngunemploy	-0.0023(-0.0056,0.0010)	-0.0071(-0.0159,0.0017)	0.0509(0.0273,0.0745)
Empf	0.0054(0.0025,0.0084)	-0.0896(-0.1687,-0.0105)	-0.0422(-0.0654,-0.0229)
Exports	0.0808(-0.0447,0.2039)	-0.0979(-0.3349,0.1456)	0.6318(0.3253,0.9392)
Imports	0.1075(-0.0133,0.2359)	-0.1586(-0.0058,0.3224)	-0.6428(-0.9707,-0.3160)
Bpg	0.0019(-0.0004,0.0042)	0.0077(0.0028,0.0125)	-0.0097(-0.0191,-0.0003)
Pub exp	0.0430(0.0024,0.0848)	0.0022(-0.0339,0.0381)	0.0413(-0.0351,0.1153)
Standard deviation of random effects:			
Heterogeneity			
α_j	0.0209032993(0.0006675972)[2]	0.0469668492(0.0009528549)	0.201500948(0.002533386)
β_j	0.4774387(0.1000336)	1.2234852(0.3004686)	0.010671378(0.006383554)
β_t		0.040083504(0.009507109)	
γ empht	0.0034388799(0.0006947215)	0.006059552(0.002127383)	0.007955706(0.001822723)
γ gc	0.0046789896(0.0009948779)	0.13700072(0.03897657)	0.009271115(0.002329941)
γ exports	0.0041333270(0.0008392519)		
γ imports	0.15718721(0.04703617)	0.3473476(0.0767247)	
γ pub exp	0.14982484(0.05178227)		0.19080928(0.04807111)
γ Year	0.06971477(0.01713860)	0.04385554(0.01292793)	0.11990071(0.02721914)
DIC	-10808.42	-5339.69	-1061.46
Effective number of parameters	189.56	236.05	232.70
-log(mean(cpo))	-2.3795	-1.7153	-0.4811

[1] *mean (95% credible interval);* [2] *mean (standard deviation); the 95% credible interval did not contain the zero (statistically significant).*

Source : own contruction

Table 4. Random effects

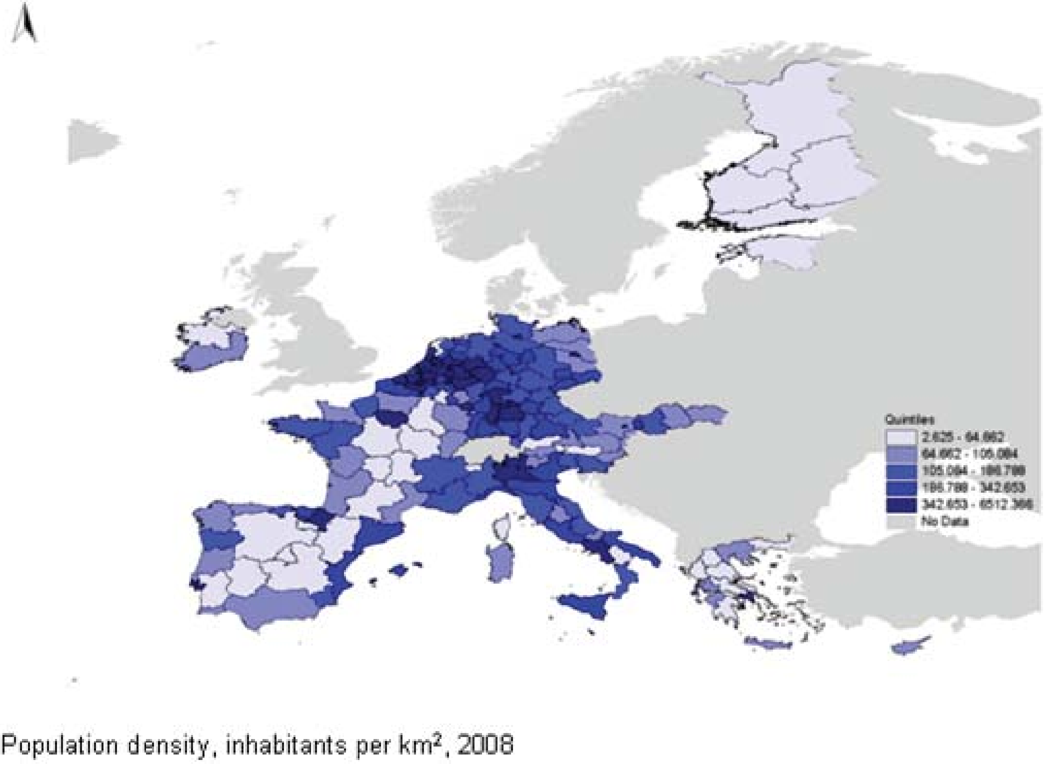
Standard deviation of random effects	Annual rate of variation GDPPC	Productivity	Population density
α_j	Belgium -0.4763(-0.8427,-0.1177)[1] Finland -0.5679(-1.1275, -0.0497) Germany 0.4969(0.2182,0.7847) Greece 0.7217(0.4456,1.0109) Ireland 0.6789(0.4010,0.9700) Italy -0.4528(-0.7791,-0.1289) Slovakia -0.7472(-1.2136,-0.2952)	Belgium 1.6423(0.4044,2.9743) Italy 0.9314(0.0282,1.8683) Slovakia -3.2098(-4.7928,-1.7650)	
β_j		Estonia 0.0902(0.0559,0.1262) Germany -0.0243(-0.0463,-0.0037) Greece 0.1062(0.0488,0.1696) Italy -0.0251(-0.0471,-0.0042) Malta -0.0548(-0.090,-0.0211)	
β_t	1996 0.0036(0.0024,4.7740e-03) 1997 0.0037(0.0026,4.7418e-03) 1998 0.0028(0.0018,3.7972e-03) 1999 0.0018(0.0012,2.3029e-03) 2000 0.0015(0.0011,2.0231e-03) 2001 -0.0014(-0.0018,-9.3367e-04) 2003 -0.0030(-0.0035,-2.5458e-03) 2004 -0.0005(-0.0010,-4.5609e-05) 2005 -0.0010(-0.0015,-4.4147e-04) 2007 -0.0009(-0.0016,-2.2869e-04) 2008 -0.0058(-0.0067,-4.9152e-03)		1990 -0.03615(-0.0551,-0.0185) 1991 -0.03614(-0.0471,-0.0254) 1992 -0.0317(-0.0422,-0.0214) 1993 -0.0307(0.0054, -0.0202) 1994 -0.0108(-0.0207,-0.0009) 1999 0.0095(0.0029,0.0164) 2000 0.0121(0.0053,0.0191) 2001 0.0127(0.0058,0.0199) 2002 0.01444(0.0072,0.0219) 2003 0.0159(0.0086,0.0234) 2004 0.0168(0.0095,0.0243) 2005 0.0172(0.0100,0.0246) 2006 0.0177(0.0105,0.0250) 2007 0.0169(0.0096,0.0244) 2008 0.0109(0.0035,0.0185)
γ empht	Cyprus 6.8142e-03(0.0018,0.0121) Portugal -7.4714e-03(-0.0126,-0.0025) Slovakia -7.3270e-03(-0.0117,-0.0031)	Estonia 0.2742(0.0294,0.5904) France -0.2984(-0.4247,-0.1849) Slovenia 0.1234(0.03182,0.2081)	France -0.0210(-0.0319,-0.0107) Germany 0.0085(0.0003,0.0168)
γ gc	Estonia 5.5815e-03(0.0004,0.0110) Greece -3.1816e-03(-0.0060,-0.0004) Ireland 8.0204e-03(0.0044,0.0117)		
γ exports	Greece -1.8860e-01(-0.3239,-0.0578) Italy 2.3766e-01(0.1030,0.3788) Portugal -2.0305e-01(-0.3889,-0.0297)	Belgium -3.8779e-01(-0.7001,-0.0936) Estonia -6.3984e-01(-1.0344,-0.2751) France 3.7785e-01(0.1222,0.6355) Luxembourg 3.9219e-01(0.0360,0.7749) Slovakia 7.9599e-01(0.4609,1.1546)	
γ imports	Austria -2.4529e-01(-0.4838,-0.0394) Germany -1.2680e-01(-0.2554,-0.0064) Portugal 1.6332e-01(0.0181,0.3200) Slovakia 3.0977e-01(0.0998,0.5410)		France -4.7651e-01(-0.6651,-0.2971) Spain 3.3391e-01(0.1545,0.5257)
γ pub exp	Belgium 7.9667e-02(0.0136,0.1479) Finland 1.1057e-01(0.0158,0.2151) Germany -6.1238e-02(-0.1238,-0.0010) Italy 1.0397e-01(0.0534,0.1555) Netherlands -9.2697e-02(-0.1693,-0.0196)		France 3.1883e-01(0.2320,0.4111)

	Portugal -7.0754e-02(-0.1271,-0.0161)		
γ Year		1999 -0.0426(-0.0812,-0.0046) 2000 -0.1169(-0.1712,-0.0710) 2001 -0.0701(-0.1121,-0.0307) 2002 -0.0400(-0.0798,-0.0016) 2005 0.0500(0.0063,0.0976) 2006 0.0914(0.0435,0.1437) 2007 0.1290(0.0761,0.1861) 2008 0.1424(0.0332,0.2102)	

[1] mean (95% credible interval)

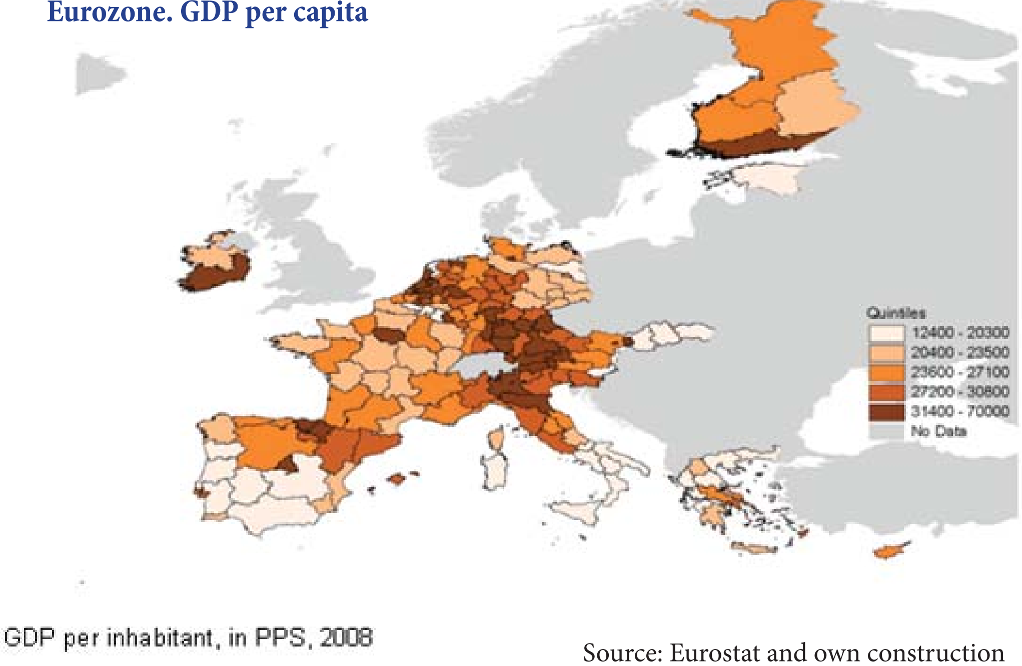
Source: own construction

Figure 1a.- Geographical distribution of some variables by NUTS 2 regions, Eurozone. Population density



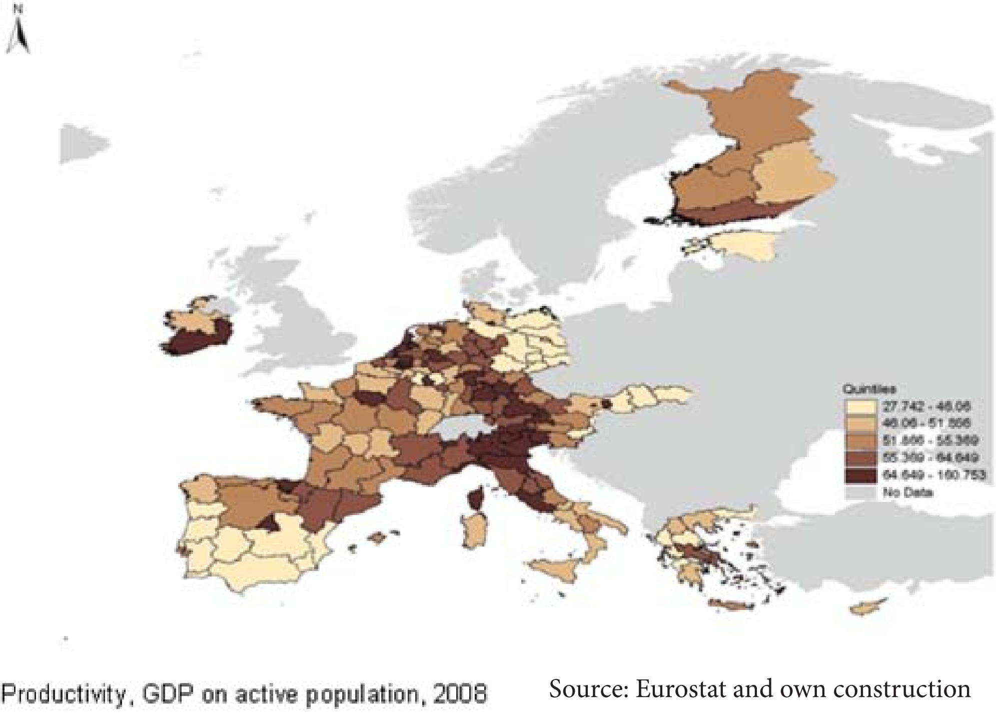
Source: Eurostat and own construction

Figure 1b.- Geographical distribution of some variables by NUTS 2 regions, Eurozone. GDP per capita



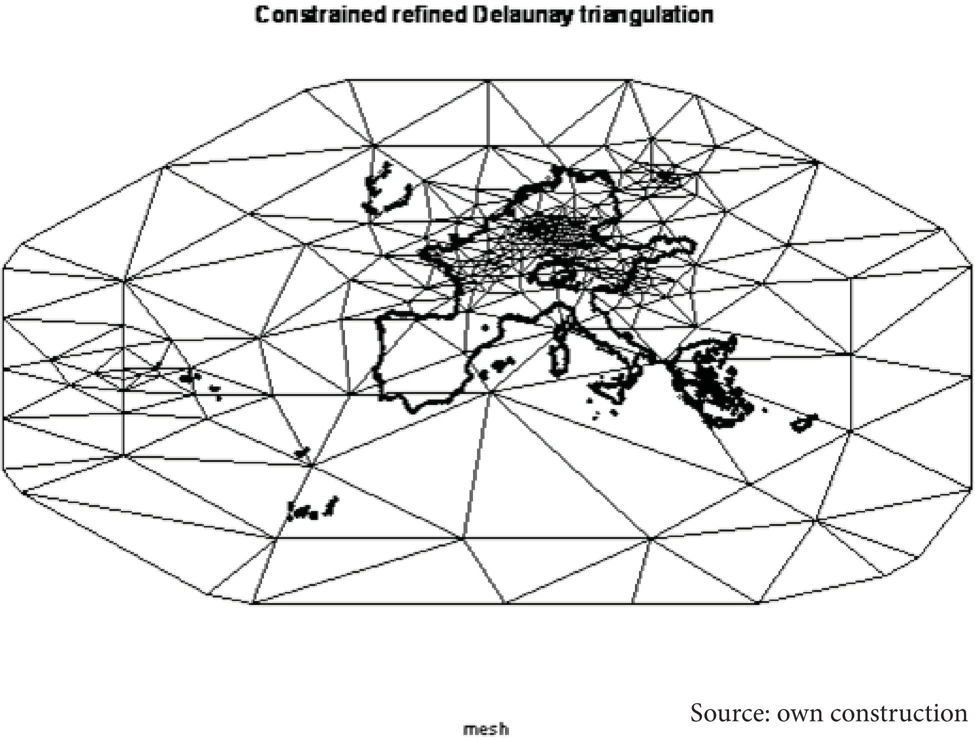
Source: Eurostat and own construction

Figure 1c.- Geographical distribution of some variables by NUTS 2 regions, Eurozone. GDP on active population



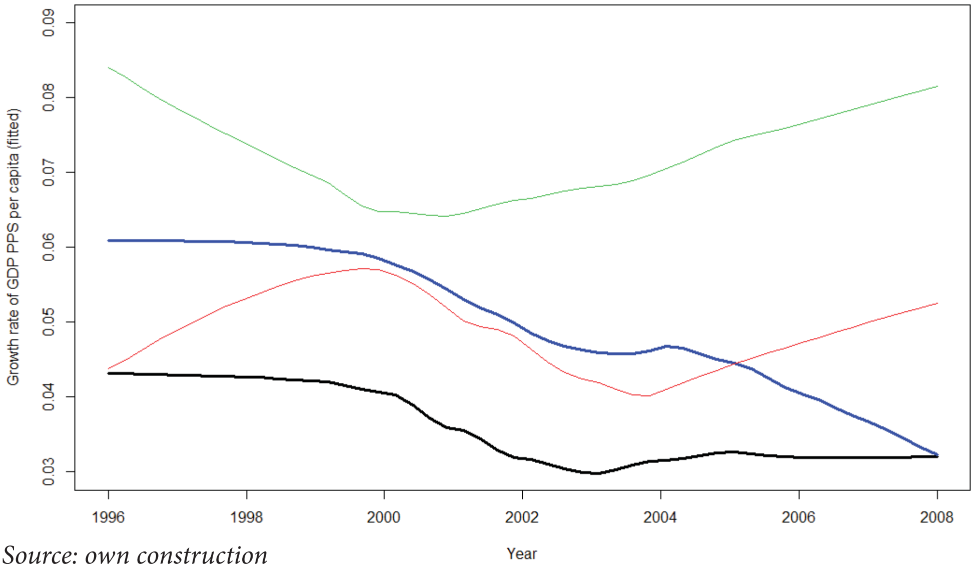
Source: Eurostat and own construction

Figure 2.- Triangulation of the area under study (Eurozone)



Source: own construction

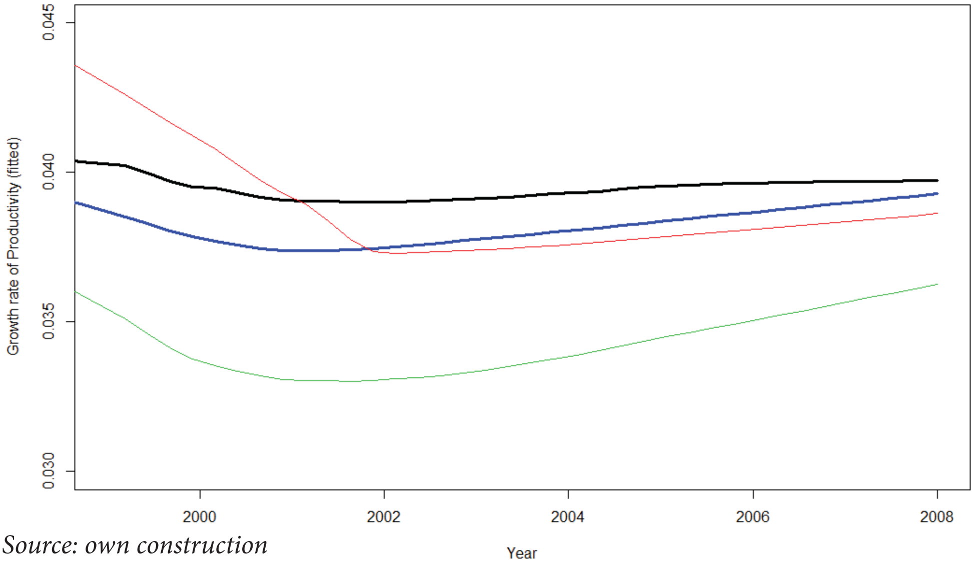
Figure 3a.- Evolution of the annual variation of GDP PPS per capita (fitted values).



Source: own construction

Black – Core countries (Austria, Belgium, Finland, France, Germany, Italy, Luxembourg and Netherlands)
Blue – Periphery countries (Greece, Ireland, Portugal, Spain)
Green – Eastern European countries (Estonia, Slovakia, Slovenia)
Red – Islands (Cyprus, Malta)

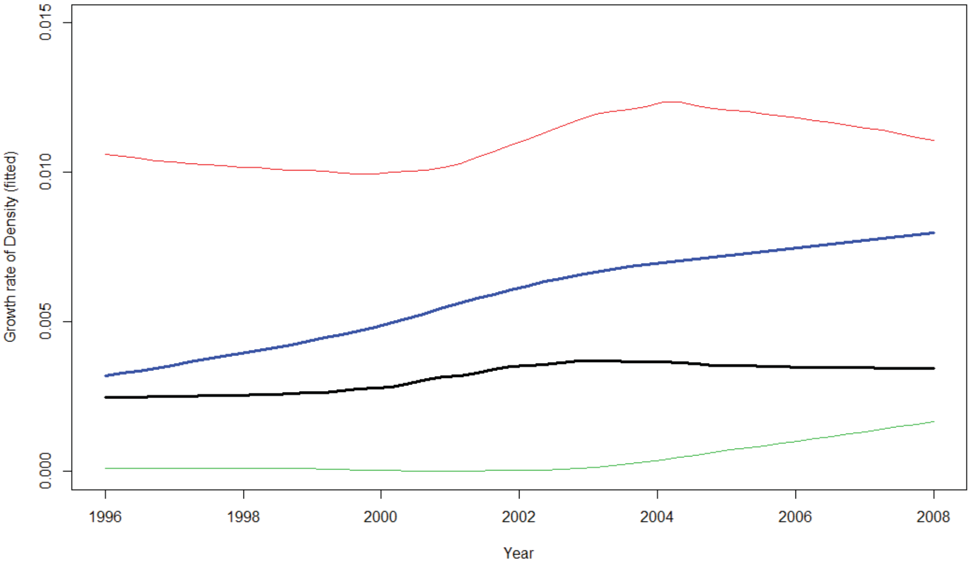
Figure 3b.- Evolution of the annual variation of productivity (fitted values.



Source: own construction

Black – Core countries (Austria, Belgium, Finland, France, Germany, Italy, Luxembourg and Netherlands)
Blue – Periphery countries (Greece, Ireland, Portugal, Spain)
Green – Eastern European countries (Estonia, Slovakia, Slovenia)
Red – Islands (Cyprus, Malta)

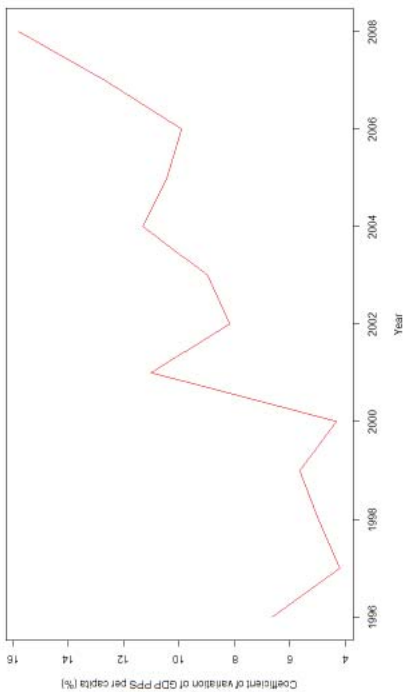
Figure 3c.- Evolution of the annual variation of density (fitted values).



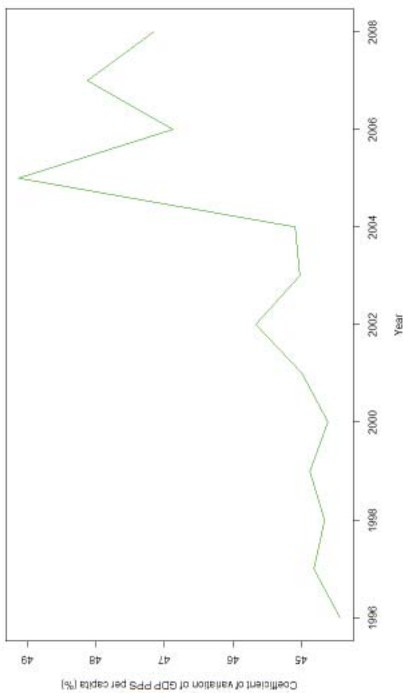
Source: own construction

Black – Core countries (Austria, Belgium, Finland, France, Germany, Italy, Luxembourg and Netherlands)
Blue – Periphery countries (Greece, Ireland, Portugal, Spain)
Green – Eastern European countries (Estonia, Slovakia, Slovenia)
Red – Islands (Cyprus, Malta)

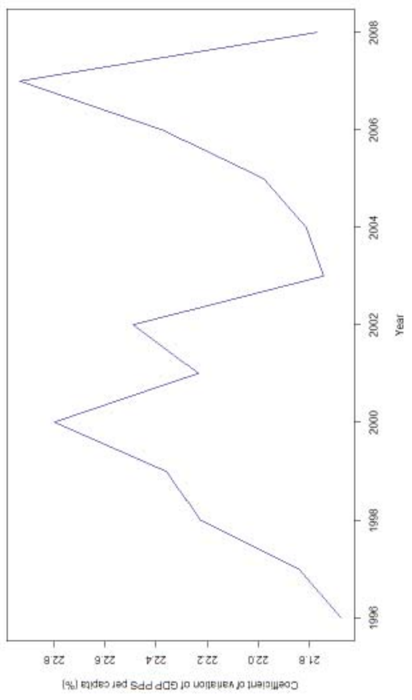
Figure 4a.- Evolution of the coefficient of variation of GDP per capita



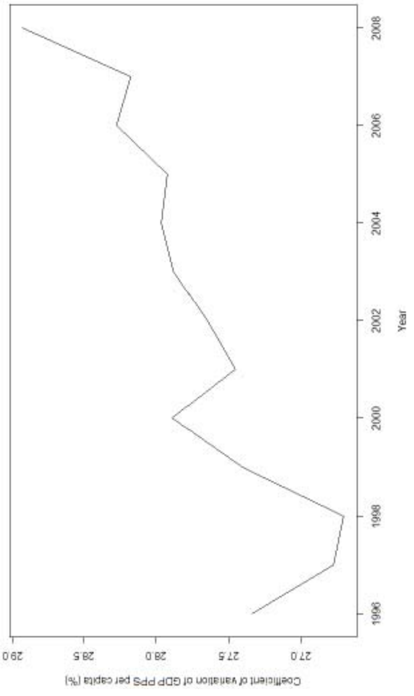
Islands: Cyprus, Malta



Eastern European countries: Estonia, Slovakia, Slovenia



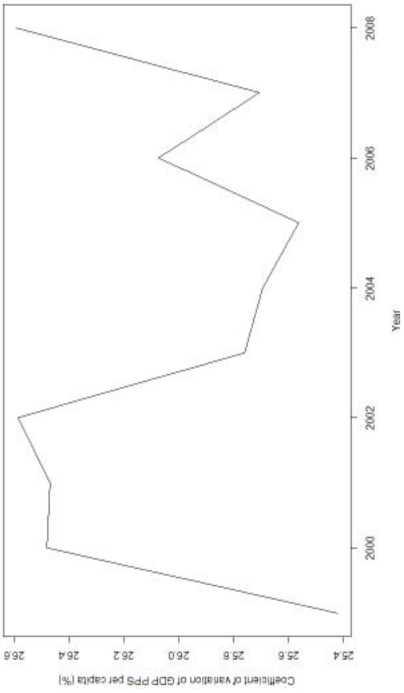
Periphery countries: Greece, Ireland, Portugal, Spain

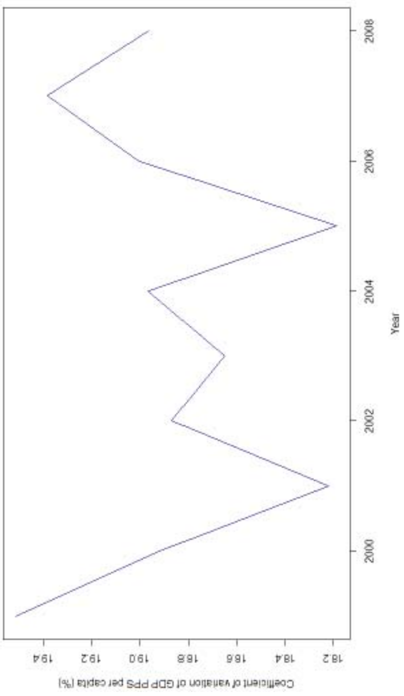


Core countries: Austria, Belgium, Finland, France, Germany, Italy, Luxembourg and Netherlands

Source: own construction

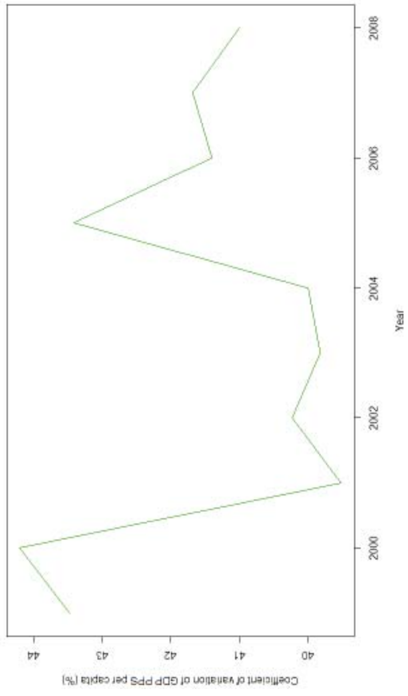
Figure 4b.- Evolution of the coefficient of variation of productivity

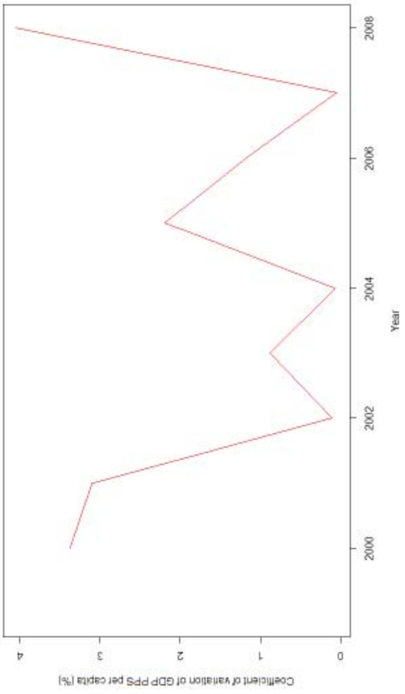




Core countries: Austria, Belgium, Finland, France, Germany, Italy, Luxembourg and Netherlands

Periphery countries: Greece, Ireland, Portugal, Spain





Eastern European countries: Estonia, Slovakia, Slovenia

Islands: Cyprus, Malta

Source: own construction

Annex 1.- Classification of cohesion policy objectives (Council Regulation (EC) No 1083/2006 of 11 July 2006)

- *Convergence (formerly Objective One)*: regions corresponding to the Nomenclature of Territorial Units for Statistics (NUTS), level II, which have a per capita Gross Domestic Product (GDP) of less than 75% of the EU average. The basic idea is to reduce regional disparities. Two groups exist under this objective, those regions covered by the Convergence Objective and those receiving phasing-out assistance[7]. The Convergence Objective is financed by the European Regional Development Fund (ERDF), the European Social Fund (ESF) and the Cohesion Fund.

- *Bulgaria:* the whole country.

- *Czech Republic:* Střední Čechy, Jihozápad, Severozápad, Severovýchod, Jihovýchod, Střední Morava, Moravskoslezsko.

- *Germany:* Brandenburg-Nordost, Mecklenburg,Vorpommern, Chemnitz, Dresden, Dessau, Magdeburg, Thüringen. *Phasing-out regions*: Brandenburg-Südwest, Lüneburg, Leipzig, Halle.

- *Estonia:* Esti.

- *Greece:* Anatoliki Makedonia, Thraki, Thessalia, Ipeiros, Ionia Nisia, Dytiki Ellada, Peloponnisos, Voreio Aigaio, Kriti. *Phasing-out regions*: Kentriki Makedonia, Dytiki Makedonia, Attiki.

- *Spain:* Andalucía, Castilla, La Mancha, Extremadura, Galicia. *Phasing-out regions:* Ciudad Autónoma de Ceuta, Ciudad Autónoma de Melilla, Principado de Asturias, Región de Murcia.

- *France :* Guadeloupe, Guyane, Martinique, Réunion.

- *Hungary:* Közép-Dunántúl, Nyugat-Dunántúl, Dél-Dunántúl, Észak, Magyarország, Észak-Alföld, Dél-Alföld.

- *Italy:* Calabria, Campania, Puglia, Sicilia. Phasing-out regions: Basilicata.

- *Latvia:* the whole country.

- *Lithuania:* the whole country.

- *Malta:* Malta.

- *Portugal:* Norte, Centro, Alentejo, Região Autónoma dos Açores. *Phasing-out regions:* Algarve.

- *Poland:* the whole country.

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[7] Ten new countries have joined the EU since 2004, all poorer than existing member countries. Due to this, the regional rankings were changed and the status of sixteen regions that had previously fallen under this objective prior to enlargement was changed to phasing-out assistance. This is known as statistical effect and does not mean that these sixteen regions were better off, rather simply a change in ranking due to the entry of poorer countries.

- *Romania:* the whole country.
- *Slovenia:* Vzhodna Slovenija, Zahodna Slovenija.
- *Slovakia:* Západné Slovensko, Stredné Slovensko, Východné Slovensko.
- *United Kingdom:* Cornwall and Isles of Scilly, West Wales and the Valleys.
- *Belgium (phasing-out regions)*: Province du Hainaut.
- *Austria (phasing-out regions)*: Burgenland.

- *Regional Competitiveness and Employment (formerly Objective Two)*: regions not covered by the Convergence Objective or receiving phasing-out assistance. This has the aim of creating jobs and making regions more attractive for investors. The regions covered under this objective receive phasing-in assistance. It is financed by the European Regional Development Fund (ERDF) and the European Social Fund (ESF).

- *Ireland:* Border, Midland and Western.
- *Greece:* Sterea Ellada, Notio Aigaio.
- *Spain:* Canarias, Castilla y León, Comunidad Valenciana.
- *Italy:* Sardegna.
- *Cyprus:* the whole country.
- *Hungary:* Közép-Magyarország.
- *Portugal:* Região Autónoma da Madeira.
- *Finland:* Itä-Suomi.
- *United Kingdom:* Merseyside, South Yorkshire.

- *European Territorial Co-operation (formerly Objective Three)*: this objective is basically designed to fund cross-border co-operation (between countries or regions) among EU Member States. The European Territorial Co-operation objective is financed by the European Regional Development Fund (ERDF) and supports cross-border, transnational and interregional co-operation programmes.

4.4. Health inequalities in the European Union: An empirical analysis of the dynamics of regional differences

Paper 4. Maynou, L., Saez, M., Bacaria, J. and López-Casasnovas, G. (2013) ‘Health inequalities in the European Union: An empirical analysis of the dynamics of regional differences’ *European Journal of Health Economics* (under revision).

> *“No society can surely be flourishing and happy, of which the far greater part of the members are poor and miserable.”*
>
> *Adam Smith.*

Health inequalities in the European Union: An empirical analysis of the dynamics of regional differences

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Abstract

In a panel setting, we analyse the speed of (beta) convergence of (cause-specific) mortality and life expectancy at birth in EU countries between 1995-2009. Our contribution is threefold. First, in contrast to earlier literature, we allow the convergence rate to vary and thereby uncover significant differences in the speed of convergence across time and regions. Second, we control for spatial correlations across regions. Third, we estimate convergence among regions, rather than countries, and thereby highlight noteworthy variations within a country. Although we find (beta) convergence on average, we also identify significant differences in the catching-up process both across time and regions. Moreover, we use the coefficient of variation to measure the dynamics of dispersion levels of mortality and life expectancy (sigma convergence) and, surprisingly, find no reduction on average in dispersion levels. Consequently, if the reduction of dispersion is the ultimate measure of convergence then, to the best of our knowledge, our study is the first that shows a lack of convergence in health across EU regions.

Key words: health convergence, beta-convergence, sigma-convergence, catching-up, spatio-temporal modelling, Bayesian models, INLA.

Highlights

- There was a catching-up process, in health, between the EU-27 regions between 1995 and 2009.

- However, there were significant differences in the catching-up process both across time and regions.

- Moreover, we were unable to estimate a reduction in heath disparities between the EU-27 regions.

JEL: I14, I15, C33, C11

1.- Introduction

Numerous previous studies have analysed economic convergence, i.e. the reduction of disparities in GDP per capita and productivity, and its determinants (for a survey, see Durlauf *et al.*, 2005). Economic convergence, however, can only give a partial picture of the dynamics of inequalities across countries (e.g. Kenny 2005). Well-being is multifaceted and typically involves many aspects beyond income. Therefore, to analyse the reduction of disparities in well-being across countries, it would appear that simple income measures are insufficient. It is of course impossible to directly control for all the dimensions of life quality. However, it is possible to employ summary measures that encompass a wider range of factors of well-being (Sen 1998, 1999). In this paper, in an effort to look beyond income, we analyse convergence using life expectancy and (cause-specific) mortality in the EU-27 regions from 1995 to 2009.

Both life expectancy and mortality have been suggested as valid measures for the quality of life. Sen (1999) and Maslow (1943) argue, for instance, that one of our most basic needs is to prevent diseases and premature death. Furthermore, Becker *et al.* (2003) propose longevity (i.e. life expectancy at birth) as not only a quantity but also a quality measure of well-being. Mayer (2003) also proposes life expectancy as a suitable measure, arguing that it is the best indicator of population welfare available. Similarly, Sen (1998) advocates mortality as an indicator of social ill-being. Mortality is directly and naturally related to many factors that determine quality of life. For instance, mortality can be taken as a summary measure of the availability of health care, social services and orderliness of urban living, among others.

Our contribution is threefold. First, we look beyond economic convergence and use life expectancy and mortality to capture a wider set of dimensions for the quality of life. Second, in contrast to earlier literature, we allow the convergence rate to vary and thereby uncover significant differences in the speed of convergence across time and space. Third, our dataset is more disaggregated because it comprises of regions rather than countries, and allows us to develop a more detailed picture of disparity dynamics.

The paper is organised as follows. In section two, we develop the concept of convergence and how it can be applied to health. We explain the methodology and the results of the model in sections three and four, respectively. Finally, in section five we discuss our findings and conclude in section six.

2.- Convergence and Health

The concept of convergence, in its most general sense, is the reduction or equalising of disparities (Paas *et al*, 2007). Convergence is a real and long-term phenomenon directly related to growth processes; that is, convergence exists when two or more countries' levels of wellbeing or development tend towards one another over time (Barro and Sala-i-Martín, 1991).

There are two well-known convergence hypotheses; the absolute and the conditional convergence hypothesis. In the former, the per capita income of countries or regions converges in the long term without taking into account initial conditions. Poorer countries and regions tend to grow faster than richer ones and there is a negative relationship between average growth rates and initial levels of income. It is assumed that all economies converge to the same stationary state (Sala-i-Martin, 1996a).

On the other hand, the conditional convergence hypothesis assumes that the per capita income of countries and regions converge in the long term provided that their structural characteristics (i.e. technology, human capital, institutions, population growth rates, preferences) are the same (Sala-i-Martin, 1996a and 1996b). With absolute convergence, the initial conditions are irrelevant. However, with conditional convergence, the equilibrium in each economy varies and each tends toward its own equilibrium.

Beta and sigma convergence

The customary and most widely used instrument for measuring convergence is beta-convergence analysis. This began with the studies conducted by Baumol (1986) and steadily grew in popularity (Barro and Sala-i-Martín, 1991, 1992; Sala-i-Martín, 1996a; Fischer and Stirböck, 2004). Beta-convergence is defined as the negative relationship between the initial level of income and the subsequent income growth.

Another instrument used to measure convergence, which became popular with the work of Quah (1993), is sigma-convergence. This author showed that the traditional relationship in initial growth level did not give a clear answer for convergence, as it tended to be negative if differences in income were not reduced. According to his theory, there is sigma-convergence if the dispersion and inequalities between countries are reduced over time. Sigma-convergence can be calculated using different dispersion measures (variance, standard deviation or coefficient of variation).

Health convergence

Life expectancy and mortality, instead of GDP, have both been suggested as valid measures for the quality of life. In a cross-country study comprising of virtually the entire world, Preston (1975) showed that while keeping income constant, the change in the longevity-income profile represented gains of fifteen years in life expectancy. In fact, macroeconomic studies of economic growth, such as Barro (1991), have already found that life expectancy is a key predictor of economic growth. Pritchett and Summers (1996) corroborated by using instrumental variables that countries with higher incomes enjoy greater health, suggesting, as did Anand and Ravallion (1993), that the main reason for this relationship is the income levels of the poor in addition to public expenditure on healthcare. Wilson (2001) studied the world distribution of life expectancy and found a decrease in its dispersion (i.e. sigma-convergence). Becker *et al.* (2003), also in a worldwide study examining whether there is a positive correlation between longevity and income per capita, showed that convergence exists with longevity, while it does not with income. Glei *et al.* (2010) find that there is no sigma-convergence for life expectancy at older ages in high-income countries. Edwards (2011) points out that there is beta-convergence but not sigma-convergence in life expectancy at birth across countries (although he finds sigma-convergence within countries). Clark (2011), however, does not find beta-convergence, but rather that improvements in life expectancy have been greater for developing countries. Similarly, Eggleston and Fuchs (2012), studying life expectancy in industrialised countries, point out that most gains in life expectancy have occurred in adult mortality, in particular for those over 65.

In terms of mortality, Edwards and Tuljapurkar (2005) examining differences in the age pattern of mortality between countries over time (for practically the whole world), show that there is no sigma-convergence in mortality in industrialised countries. In the study previously referred to, Clark (2011) finds that reductions in infant mortality are greater in high-income countries (i.e.

there is no beta-convergence in infant mortality). Edwards (2011) did not find (beta) convergence in adult mortality either, particularly in developed countries. Finally, d'Albis *et al.* (2012) did not find (beta and sigma) convergence across countries when they considered the entire sample of industrialised countries, but they do provide some evidence of (sigma) convergence among a subset of countries.

Earlier literature does not give conclusive results for the use of these variables as measures of well-being. The main reason is that these variables have little variation in the short run. Significant changes are needed in social, health and demographic factors to provoke sufficient variation in mortality and life expectancy. However, in the long run, mortality and life expectancy variables can be more sensitive to changes than GDP (Sen, 1998). Our first hypothesis is that by analysing regions instead of countries we can observe sufficient variability in the health variables of interest to estimate the (dis)similarity of their distribution over time.

EU-27 convergence

Our interest in the regions of the twenty-seven countries of the European Union (EU-27) lies specifically in one of the main priorities of the Treaty establishing the European Community: specifically economic and social cohesion. In keeping with Monfort (2008), Article 158 of the Treaty (and its updated version Article 174) states, 'In particular, the Community shall aim at reducing the disparities between the levels of development of the various regions and the backwardness of the least favoured regions or islands, including rural areas.' Although it is true that the purpose of the cohesion policy goes far beyond mere economic convergence, the reduction of regional disparities has been measured as the convergence of regional levels of GDP per capita. In fact, pure economic convergence has become a major aspect in assessing the effectiveness of the European Cohesion Policy (Monfort, 2008).

In respect of this, and adhering to Eckey and Türk (2006), despite differences in model specification and observations, most studies on convergence in regional GDP per capita estimated (beta) convergence among EU countries, at both EU-15 and EU-27 level. However, the speed of convergence is not constant, neither in time nor between regions (Montfort, 2008; Maynou *et al.*, 2013). With regards to sigma-convergence, Monfort (2008) shows that convergence between EU-15 regions was strong up until the mid-90s and stabilised thereafter (his analysis ends in 2005). However, as he found that disparities continued to decrease rapidly for the EU-27 regions, he concluded that the poorest regions in the new Member States were catching up with the Union's richer territories.

Since, at least at the aggregate level, there is much evidence of a positive association between income and health, our second hypothesis is that, when considering the time period at the end of the economic boom (i.e. 2005-2009), there will be beta-convergence in health between the EU-27 regions, but not sigma-convergence. Our third hypothesis is that, like economic convergence, the speed of health convergence is neither constant in time nor between regions.

3.- Methods

Data setting

We used data from 271 regions of the 27 EU member countries from 1995 to 2009. Data were obtained from EUROSTAT.

Our rationale for using regional data is twofold. First, it is the regions, rather than the countries, which are the subject of cohesion policies. Second, as we will explain below, with limited time series (T), as in our case (i.e., 1995-2009, 15 years), in order to obtain consistent estimates of the parameters of interest we needed a large N (thus instead of only seventeen countries, we have two hundred seventy-one regions).

Econometric model

Models are specified based on the well-known beta-convergence hypothesis (Baumol, 1986; Barro and Sala-i-Martin 1991, 1992; Sala-i-Martin 1996a and 1996b), originally specified as a cross-section model:

$$g_T = \alpha + \beta y_0 + u \qquad u \sim N\left(0, \sigma_u^2 I\right) \qquad [1]$$

where g_T denoted the vector of (dependent variable) average growth rate in the period *(0,T)*; y_0 was the vector of (dependent variable) initial levels; u was a zero-mean and homoskedastic (σ_u^2 was the constant variance) normally distributed disturbance term; and α and β denoted (unknown) parameters.

The absolute β-convergence hypothesis (equation [1]) rests on the assumption that there is a negative correlation between the initial level (of the dependent variable) and the growth rate (of such a variable). Therefore, β–convergence exists if the estimated value for β, the coefficient of interest, is (statistically significant) negative. If this is true, poorer economies (periphery) grow faster than richer ones (core) and will catch them up in the long run.

However, it is more reasonable to assume that a negative correlation exists between growth rate and, rather than level, the distance the level of the dependent variable is from its steady state equilibrium. Therefore, poorer regions do not necessarily grow faster than richer regions, because the latter may be even further from their steady state equilibria (Baumont *et al* 2002). As a consequence, in this paper we use the conditional specification of the β-convergence hypothesis:

$$g_T = \alpha + \beta y_0 + X\gamma + u \qquad u \sim N\left(0, \sigma_u^2 I\right) \qquad [2]$$

where X is a matrix of explanatory variables (of convergence); and γ the associated (unknown) parameters.

In contrast to more standard studies, we do not specify cross-section, but rather spatio-temporal models, i.e. dynamic panel data, from a Bayesian approach. In fact, we want to explicitly consider the time dimension in our data. As we have argued, the convergence rate may have been different for each country and/or have varied during the period under analysis. Furthermore, with small T, we need a large N in order to obtain consistent estimates.

In particular, we have specified the following model:

$$\begin{aligned}
&\log(y_{ijt}) = \alpha_j + \beta_{jt} \log(y_{ijt-1}) + \gamma_{1jt} \log(gdppc_{jt}) + \gamma_2 \log(gdppc_{jt-1}) + \\
&\gamma_3 \log(gdppc_{jt-2}) + \gamma_4 \log(gdppc\ rate_{jt-1}) + \gamma_5 \log(gdppc\ rate_{jt-2}) + \gamma_{6jt} \log(Gini_{jt}) + \\
&\gamma_7 \log(\mathrm{sec}_{ijt}) + \gamma_8 \log(univ_{ijt}) + \gamma_9 \log(pub\,\mathrm{exp}_{jt}) + \gamma_{10} \log(umy_{ijt}) + \gamma_{11} \log(ufy_{ijt}) + \\
&\gamma_{12} \log(\mathrm{bpg}_{jt}) + S_i + u_{ijt}
\end{aligned} \qquad [3]$$

Where *y* denoted one of the four dependent variables we chose. First, as in most previous studies on health (in concurrence with the seminal paper of Sen, 1999), we used life expectancy at birth (in years). However, instead of using total mortality, we preferred to use here (several) cause-specific mortality. Total mortality is actually a combination of many phenomena that could undermine this variable as an indicator of social ill-being (Sen, 1998). In particular, we chose those causes of mortality most associated with socioeconomic deprivation in the literature (Borrell *et al*., 2010; Puigpinós-Riera *et al*., 2011; Salcedo *et al*., 2012): ischemic heart disease mortality; cancer mortality; and larynx, trachea, bronchus and lung cancer mortality (cause-specific mortality was standardised as death rate per 100,000 inhabitants, 3-year average).

The subscript *i* denoted region *(i=1,…,271)*; *j* country *(j=1,…,27)*; *t* year *(t=1995 1996,…, 2009)*; α, β and γ denoted unknown parameters; *S* denoted spatial random effects (see below); and *u* normally distributed disturbance term.

The main explanatory variables of the growth rate of the dependent variables were the GDP per capita *(gdppc)* (data available regionally), and the Gini index *(Gini)* (data available only at country level). We believe that the growth rate of the dependent variables was determined not only by the level of GDP per capita in absolute terms but also by its growth rate *(gdppcrate)*. Note that we assumed that the effects, if any, of GDP per capita (both in levels and as rates) on health convergence, were distributed in time. Hence, we included the current level *(t)* and two lags (*t*-1 and *t*-2) of GDP per capita and two lags (*t*-1 and *t*-2) of GDP per capita rate.

According to the EUROSTAT, the Gini index is defined as the relationship of cumulative shares of the population arranged according to the level of equivalised disposable income, to the cumulative share of the equivalised total disposable income received by them. The Gini coefficient ranges between 0 and 1, with 0 signifying complete income equality and 1 signifying complete inequality. In a meta-analysis of multilevel studies, involving a total of more than 61 million subjects, Kondo *et al.* (2009) concluded that people living in regions with high income inequality (a higher Gini coefficient) had an increased risk of premature death, regardless of individual socioeconomic status, age, or gender. In particular, the mortality risk increased 8% per 0.05 increase in the Gini coefficient. Furthermore, these authors also seem to confirm a theoretical 'threshold effect' (a Gini coefficient equal to 0.3) above which disparities in health outcomes are observed.

Moreover, we considered additional variables that may secondarily contribute to health convergence. These variables were available both at the regional and country level.

Regional level:

Umy: Youth male unemployment rate.	Youth male unemployment rate (15-24 years old).
Ufy: Youth female unemployment rate	Youth female unemployment rate (15-24 years old).
Sec: Percentage of secondary students	Ratio of the sum of level 2 students (lower secondary or second stage of basic education), level 3 students (upper secondary education) and level 4 students (post-secondary non-tertiary education) over total population.
Univ: Percentage of university students	Ratio of the sum of level 5 and 6 students (tertiary education) over total population.

Country level:

Bpg: External balance	The ratio of exported goods minus imported goods over the country's GDP.
Pubexp: Public expenditure rate	Ratio of goods and services bought by the State over the country's GDP.

There were two reasons that led us to include these variables. First, since the main explanatory variable was the convergence of GDP per capita and given that in a previous study we found them to be associated with economic convergence in the EU (see details in Maynou *et al.*, 2013), these additional variables might influence, at least, the initial situation prior to convergence. Second, some of these variables could be clearly associated with socioeconomic deprivation, e.g. unemployment and percentage of secondary and tertiary students (Salcedo *et al.*, 2012).

Some of the coefficients, and in particular the coefficient of interest, β, have subscripts. In fact, we specify (dynamic) random coefficient panel data models (Hsiao and Pesaran, 2008) or, in mixed models terminology, we allow (some of the) coefficients to be random effects (Pinheiro and Bates, 2000). In other words, we have allowed them to be different for the various levels we have considered. Thus, for example, the coefficient of interest, β, varies per year,

$$\beta_t = \beta + \nu_t$$

and also per country,

$$\beta_j = \beta + \upsilon_j$$

With respect to the other explanatory variables, the random effects are associated with different levels depending on the final model[8].

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[8] We have a preliminary estimation of all models allowing variation on the two levels (country/time) for all coefficients. In the specification shown, we have provided only the best final models. Results not shown can be requested from the authors.

When the random effects vary by country, we assume they are identical and independent Gaussian random variables with constant variance, i.e. $\upsilon_{j} \sim N\left(0,\sigma_{\upsilon}^{2}\right)$. When the random effects vary by year, we assume a random walk of order 1 (i.e. independent increments) for the Gaussian random effects vector (although we also assume a constant variance) (R INLA, 2013).

$$\Delta\upsilon_{jt} = \upsilon_{j} - \upsilon_{j+1} \qquad \Delta\upsilon_{j} \sim N\left(0,\sigma_{\upsilon}^{2}\right)$$

Spatio-temporal adjustment

In all models, the disturbance terms, although Gaussian, are not identically and independently distributed. In fact, with spatial data, as is in our case, it is necessary to distinguish between two sources of extra variability (Lawson *et al.*, 2003, Barceló *et al.*, 2009). First, the largest source is usually named 'spatial dependence', or clustering, and is a consequence of the correlation between the spatial unit and the neighbouring spatial units, generally the adjacent geographical areas. The closer areas are much more similar than the more distant ones. Part of this dependence is not really a structural dependence, but mainly due to variables (with a spatial behaviour too) that are not included in the analysis. The second source is independent, spatially uncorrelated extra variability, called uncorrelated or non-spatial heterogeneity, which is due to unobserved non-spatial variables that could influence the dependent variable (Lawson *et al.*, 2003, Barceló *et al.*, 2009). In our case, as we had the time dimension in our data, there was also temporal dependency (i.e. serial autocorrelation). Again, maybe not results of a dynamic behaviour of the dependent variable per se, but rather the omission of time-varying explanatory variables.

To take into account this spatio-temporal extra-variability, we introduced some structure into the model. Heterogeneity is captured by using the random effect associated with the intercept (α_j) (varying at a country level *j*). Temporal dependency is approximated through the random walk of order 1, and linked to the random effect associated with the parameter of interest, β_t (varying at a year level, *t*).

For spatial dependency, we follow the recent work of Lindgren *et al.* (2011), and specify a Matérn structure (Stein, 1999). In short, we use a representation of the Gaussian Markov Random Field (GMRF) explicitly constructed through stochastic partial differential equations (SPDE) which has as a solution a Gaussian Field (GF) with a Matérn covariance function (Lindgren *et al.*, 2011). To sum up, instead of using the Matérn in a regular lattice, which is the usual practice and would imply an estimation with a high computational cost as well as one that would be weak in terms of efficiency (Lindgren *et al.*, 2011), we specify the structure of the spatial Matérn covariance in a triangulation (Delaunay triangulation – Hjelle and Daehlen, 2006) of the studied area with a low computational cost and, more importantly in our context, much greater efficiency.

Inference

As is well-known in random coefficient panel data models that unless the initial levels of the dependent variables are fixed constants (Hsiao *et al.*, 1999), or the assumption of independence between the regressors and the random effects is fulfilled, the estimates of the parameters will be inconsistent, even for sufficiently large T and N (Hsiao and Pesaran, 2008). In dynamic panel data models, with the lagged dependent as the explanatory variable and, typically, with finite T, the assumption of independence does not hold (Nickell, 1981; Anderson and Hsiao, 1981, 1982). However, Hsiao *et al.* (1999) show that, even in this case, the use of a Bayesian approach performed fairly well. Under the Bayesian perspective, Zhang and Small (2006), building on the Hsiao *et al.* (1999) estimator, allow the initial values to be correlated with the unit-specific coefficients and imposing stationarity on the unit-specific AR(1) coefficients. Their approach provides good estimates even when T is small. In Maynou and Saez (2013), we show how the greater flexibility of the Bayesian estimation, a consequence of its hierarchical strategy, leads to better control of the biases associated to dynamic panel data models. This control had allowed us to obtain estimates of the parameter of interest with less bias and greater efficiency than other estimators commonly used in dynamic panel data models (in particular, GMM estimates).

Here inferences were performed using a Bayesian framework. This approach (more or less pure), was considered the most suitable for accounting model uncertainty, both in the parameters and in the specification of the models, either in cross-sectional studies (Raftery, 1985; Fernández *et al.*, 2001; and Sala-i-Martin *et al.*, 2004) or in panel data models (Hsiao *et al.*, 1999; Hsiao and Pesaran, 2008; Moral-Benito, 2010; Rendon, 2012; among others). Furthermore, only under the Bayesian approach was it possible to model both spatial (heterogeneity and spatial dependence) and temporal extra variability, with relatively sparse data in some cases (see Table 1). Finally, within the Bayesian approach, it is easy to specify a hierarchical structure on the (observable) data and (unobservable) parameters, all considered random quantities.

Moreover, in this paper we preferred to relax the assumption of strict exogeneity, allowing a weak exogeneity of the lagged dependent variable, that is to say, that current shocks only affect future values of the dependent variable (Moral-Benito, 2010). By doing this, we were able to obtain consistent estimates of the parameters of interest (even with fixed T). It is important to point out that this relaxation involves two requirements; first, a large N; i.e. obtained in our case by considering regional data; second, identically and independently distributed error terms. This can only be achieved by the space-time adjustment explained above, imposing a certain structure on the original disturbance term.

Within the (pure) Bayesian framework, we followed the Integrated Nested Laplace Approximation (INLA) approach (Rue *et al.*, 2009). In particular, our problem could be specified modelling the mean (of the dependent variable) for the ijt-th unit, $\mu_{ijt} = E(g_{ijt})$, by means of an additive linear predictor, defined on the identity scale (we had Gaussian data) (Blangiardo *et al.*, 2013),

$$\mu_{ijt} = \alpha + \sum \beta_m x_{m,ijt} + \sum f_l(z_{l,ijt})$$

where α denotes the intercept; β the 'fixed' effects; and f a collection of functions defined in terms of a set of explanatory variables z. Varying the form of f, it is possible to accommodate both random effects and spatio-temporal adjustment (Rue *et al.*, 2009). The vector of parameters is represented by $\theta = \{\alpha, \beta, f\}$. Note that all parameters are treated as random.

Following Schrödle and Held (2011), the spatio-temporal models are built as Bayesian two-stage hierarchical models. The first stage is the observational model, $p(y|\theta)$, where y denotes the vector of observations of both the dependent and the explanatory variables, and θ are the unknown parameters. We assumed a Gaussian Markov random field (GMRF) prior on θ, $p(\theta|\psi)$, with mean 0 and a precision (inverse of the variance) matrix Q. The second stage is given by the 'hyperparameters' ψ and their respective prior distribution $p(\psi)$.

We are interested in the posterior marginals of the GMRF, i.e. $p(\theta_i|y) = \int_\psi p(\theta_i|\psi, y)p(\psi|y)d\psi$ that we approximate using the following finite sum

$$\tilde{p}(\theta_i|y) = \sum_k \tilde{p}(\theta_i|\psi_k, y)\tilde{p}(\psi_k|y)\Delta_k \qquad [4]$$

where $\tilde{p}(\theta_i|\psi_k, y)$ and $\tilde{p}(\psi_k|y)$ denote approximations of $p(\theta_i|\psi, y)$ and $p(\psi|y)$, respectively. The finite sum [4] is evaluated at support points ψ_k using appropriate weights Δ_k .

The posterior marginal $p(\psi|y)$ of the hyperparameters is approximated using a Laplace approximation (Tierney and Kadane, 1986).

$$p(\psi|y) = \frac{p(\theta, \psi|y)}{p(\theta|\psi, y)} \propto \frac{p(\psi)p(\theta|\psi)p(y|\theta)}{p(\theta|\psi, y)} \approx \left.\frac{p(\psi)p(\theta|\psi)p(y|\theta)}{\tilde{p}(\theta|\psi, y)}\right|_{\theta=\theta^*(\psi)} = \tilde{p}(\psi|y)$$

where the denominator $\tilde{p}(\theta|\psi, y)$ denotes the Gaussian approximation of $p(\theta|\psi, y)$ and $\theta^*(\psi)$ is the mode of the full conditional (Rue and Held, 2005).

According to Rue *et al.* (2009), it is sufficient to "numerically explore" this approximate posterior density using suitable support points Δ_k in [4]. In this paper, these points are defined in the h-dimensional space, using the strategy known as 'central composite design'. Centre points are augmented with a group of star points which allow the curvature of $\tilde{p}(\psi|y)$ to be estimated (Rue *et al.*, 2009).

To approximate the first component of [4], we use a 'simplified Laplace approximation', less expensive from a computational point of view and with only a slight loss in accuracy (Schrödle and Held, 2011; Rue *et al.*, 2009; Martino and Rue, 2010). Finally, we specify minimally informative priors on the log of the precision of all hyperparameters, i.e. logGamma (1,0.0005).

All analyses have been made with the free software R (version 2.15.3) (R Development Core Team, 2012), though the INLA library (The R-INLA project, 2012; Rue *et al.*, 2009).

4.- Results

Descriptive

In Tables 1 to 6 we provide some descriptive data. In Table 1, we can see the descriptive data for life expectancy at birth. We find heterogeneity between EU countries, in terms of life expectancy during the last fifteen years, ranging from Latvia (mean: 71.413) to Italy (mean: 80.317). However, the trend of this variable in all countries has been a gradual increase. The countries with higher life expectancy over the past fifteen years were Italy, Sweden and Spain, while Latvia, Lithuania and Estonia had the lowest life expectancy of the EU. In Figure 1, we can see the evolution of life expectancy over time and across regions. Changes in life expectancy are seen in the long run. Although we only analyse fifteen years, we can see that regions are moving towards the upper levels of life expectancy.

Descriptive data for mortality due to ischemic heart disease are presented in Table 2. The trend for this variable in EU countries over the last fifteen years has been a gradual reduction. However, this rate has not been homogenous among the twenty-seven EU countries. Lithuania, Latvia and Estonia have had the highest rates of ischemic heart disease mortality, while France, Spain and Portugal have had the lowest. The map in Figure 2 shows that fewer and fewer regions suffer ischemic heart disease mortality. Eastern European countries are those with the higher rates, although these were falling.

In Table 3, we have collected the descriptive data for cancer mortality. The common EU trend has been a gradual decrease (except for Bulgaria, Cyprus, Greece and Romania). The countries with higher rates of cancer death were Hungary, the Czech Republic and Poland, while, Cyprus, Finland and Sweden had the lowest rates in the period studied, 1995 to 2009. The map in Figure 3 shows that there has been a reduction of cancer mortality in the EU, mainly in the centre and south, but not in the east.

The descriptive data for mortality due to lung cancer are collected in Table 4. For this standardised death rate, there was no common trend among the EU countries from 1995 to 2009. The EU countries with higher lung cancer death rates were Malta, Hungary and Poland, and those with lower rates were Lithuania, Sweden and Finland. In Figure 4, we observe that in all regions rates of lung cancer mortality have generally stayed the same or have increased (mainly in the centre of Europe).

Table 5 shows GDP per capita in the EU from 1995 to 2009. During the period studied, there was a common growth in GDP per capita among all EU countries. Luxembourg had the highest GDPPC, followed by Austria and Italy. Bulgaria had the lowest GDPPC, behind Portugal and Latvia. The map in Figure 5 does not show any sizeable changes in the EU regions in terms of GDPPC. However, while until 2005 some levels rose, after that date some central regions experienced a drop in their GDPPC.

The last table collects descriptive data for the Gini Index. During the past fifteen years, inequalities have increased or decreased in EU countries, with no common path. Portugal, Latvia and Estonia were the countries with higher inequalities, while Slovenia, Sweden and Denmark were more equal (Table 6). In Figure 6, we can see the representation of the Gini Index for the EU regions. The regions with more inequalities were in the east, while for the southern and central regions there has been a reduction in inequalities in last fifteen years.

Results of estimating health convergence models

The results of estimating the models are shown in Tables 7. As stated above, the coefficient of interest in this analysis was β, which shows whether convergence or divergence existed between countries. However, we are not only interested in the existence of convergence; we also want to see the rate/speed of convergence/divergence. For this reason, we use the formula proposed by Šlander and Ogorevc (2010[9] to compute the average speed of convergence.

In Table 7.1, we show the results of the estimations for the four models. For the variable corresponding to life expectancy, we found significant convergence between EU countries, as the coefficient was negative, -0.819%, and statistically significant (the 95% credible interval did not contain the zero). The only explanatory variable which had a (statistically) significant

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[9] $\frac{-\ln(1-\beta)}{T}*100$

effect on the convergence of life expectancy was external balance (0.0001%). For mortality due to ischemic heart disease, we also found convergence between EU countries, as the coefficient of interest was negative, -1.557%, and statistically significant. In this model the significant explanatory variables which have an effect on convergence were GDP rates, 0.1214% (lag 1) and 0.12% (lag 2), and public expenditure, -0.0045%. As for standardised cancer rates, the model also showed convergence, -1.934%. In this case, the explanatory variables which had an effect on the convergence of cancer mortality were secondary students, -0.00183%, university students, 0.00075%, and young unemployed male, -0.00047%. For lung cancer mortality, we also found significant convergence among EU countries, -0.744%. The explanatory variables which had an effect on the convergence of lung cancer mortality were GDPPC, -0.00429% (lag 1), secondary students, -0.00269%, university students, 0.00142% young unemployed female, -0.00051%, and external balance, 0.00205%.

Table 7.2 shows the results of estimating the random effects. Note that the coefficients of some variables that were not statistically significant as fixed effects were estimated as statistically significant when considering them random effects. This was the case with the Gini coefficient. Our interpretation, therefore, is that although the Gini coefficient had no effect on convergence in health on average, it did have an effect on health convergence for some countries and in some of the years. Note also that this effect was very heterogeneous.

Although there was average beta-convergence for the regions of the EU-27 in the four health variables considered (i.e., the coefficient of interest,β, was negative and statistically significant), there were discontinuities in both convergence and the speed of this convergence between countries and over time. While there was no divergence in any country, the rate of convergence in life expectancy at birth was less than average in Malta and higher in Portugal and the UK (in that order). As regards to mortality from ischemic heart disease, note that in Estonia, Luxembourg, Romania and Malta (in descending order) there was no convergence (because the coefficient associated, which was the sum of both the fixed and random effect for that country, was positive). Moreover, even with convergence (because in this case, the sum of both the fixed and random effect for that country, was still negative), it was not as fast as the average for the Netherlands but faster than Finland, Bulgaria and Greece. With regard to cancer mortality, France, Romania, and Ireland and, to a much lesser extent, Spain showed divergence. Moreover, the convergence rate was somewhat lower than average in the UK and higher in Greece, Finland, Portugal and Italy. Finally, with regard to mortality from lung cancer, we estimate a very slight divergence in Poland, Hungary and Austria. Among the converged countries, France and the United Kingdom converged at a slower rate and Greece at a much faster than average speed.

As regards to discontinuities in time, we estimated divergence only in cancer mortality for the year 2009. There were, however, differences in the rate of convergence for all variables. We estimated an above average rate for mortality from cancer (year 2008) and only slightly higher for lung cancer mortality (year 1999) and life expectancy (2003). Mortality from ischemic heart disease (2009) and lung cancer (2008 and 2009) were below average.

In order to analyse sigma convergence, we used the coefficient of variation for each health variable (Figure 7). Note that sigma convergence did not occur in all cases. Only in life expectancy and lung cancer mortality were disparities reduced among the regions of the EU-27 for 1995-2009. However, the greatest reductions in disparities in life expectancy at birth occurred between 1995 and 2003, before increasing and then remaining stable from 2005 onwards. In the case of lung cancer mortality, disparities were reduced in 1999, before increasing until 2008 and then falling in the final year considered.

5.– Discussion

Our results indicate that there was (statistically) significant beta-convergence in life expectancy and mortality (ischemic heart disease, lung cancer and cancer) among the EU-27 regions for the studied period. In particular, the speed of the beta-convergence was, on average -1.934% per year (cancer mortality); -1.557% per year (mortality for ischemic heart disease); -0.819% per year (life expectancy); and -0.819% (mortality for lung cancer).

This means that, in terms of health, there was a catching-up process between the EU-27 regions between 1995 and 2009. Given the association (in the aggregate) between income and health variables, it might be reasonable to suppose that this catching-up process reflected the same process followed by economic convergence. The lower rate in beta-convergence in most of the health variables analysed for 2008 and 2009, two years after the start of the economic crisis, might exemplify this.

Although we find (beta) convergence on average, we also identify significant differences in the catching-up process both across time and regions. This spatio-temporal heterogeneity is not only different from those found for the European regions in economic convergence analysis (Eckey and Türk, 2006. for EU-15 and EU-27; Monfort, 2008 for EU-27; Maynou *et al*., 2013, for the Eurozone) but also from the health convergence analysis between countries (d'Albis *et al*., 2012), suggesting that beta-convergence in health may be the result of different phenomena than those affecting economic convergence. In this respect, for instance, following their entry into the EU in 2004, eastern European countries benefited from the EU cohesion policies that had boosted economic convergence; although in view of the results it is not clear that these policies also promote health convergence, at any rate for all of these countries and for all of the health variables. This can perhaps be attributed to the fact that prior to 2004 the health system in these countries had already reached quite high standards.

Using the coefficient of variation as a summary measure of sigma-convergence, we were unable to estimate a reduction in disparities between EU-27 regions over the fifteen years. As Sala-i-Martin (1996a) states, beta and sigma convergence do not always show up together because they capture different aspects. Sigma convergence analyses whether the cross-country distribution of the (health, in our case) variable shrinks over time or not, while beta convergence relates to mobility within the given variable distribution. Therefore, we have estimated mobility within the distribution but the distribution itself has remained unchanged. In summary, if, as Quah (1993) and other authors suggest, the concept of sigma-convergence is that which best reveals the reality of convergence, we cannot conclude that there was convergence in health among the regions of the EU-27 between 1995 and 2009.

Although we allowed the parameters, and in particular those of interest, to vary regionally, we were only able to estimate heterogeneity at a country-level. In a previous work on economic convergence between European regions, albeit in a smaller geographic area (the Eurozone), we were not able to estimate a spatial heterogeneity at the regional level either (Maynou *et al*., 2013). We believe that this is a consequence of how European policies are implemented, which, even if they have a regional dimension, are operational on a country level.

The effect of unequal income distribution, measured by means of the Gini index, on health convergence was very heterogeneous both between countries and between years. We believe this was because that in some countries and/or years the Gini coefficient did not exceed the threshold (equal to 0.3) above which disparities in health were seen (Kondo *et al*., 2009).

The work could have several limitations. Let us discuss that in the same hierarchy used in the estimation of our models. First, we might have chosen other variables that would have explained the growth rate of the health dependent variables. We considered this possibility, but they could not be included due to a lack of data. In this respect, data for some variables are available at country level up to a maximum of three years, such as the abortion rate in the case of life expectancy, lifestyle as a percentage of smokers or drinkers, or the prevalence of obesity in cause-specific mortality. Other variables, such as immigrants from developing countries, are available at a country level for very few countries throughout the entire period considered in our paper (1995-2009). We preferred to include the Gini index as a proxy for income inequality and not include other variables such as poverty and social exclusion because of a lack of conclusive evidence regarding these variables, at least compared to the high position in the hierarchy of evidence provided by the study of Kondo *et al.* (2009).

Second, the consistency of the estimates is totally dependent on the fulfilment of the hypothesis of weak exogeneity. This, in turn, depends on, at least one of their requirements. Once we made the spatio-temporal adjustment, the error terms should be identically and independently distributed. In this sense, we checked the absence of autocorrelation, or spatial or temporal, in the standardized residuals of all three models. In addition, using cross-correlation functions, we also checked the absence of (contemporary) correlation between the error terms and each of the regressors, including lagged dependent variables in particular.

Third, as in any Bayesian analysis, the choice of the prior may have a considerable impact on the results. In the second stage of the hierarchy we used, we allowed variation on the different levels for all coefficients, i.e. we allowed all the coefficients to be random effects. Then, we tested that the variance of the effects was equal to zero, i.e. the effects were actually fixed. Only when we rejected this null hypothesis, did we maintain the coefficient as a random effect. Furthermore, as regards to the third stage in the hierarchy, by increasing the precision (lowering the variance) we performed sensitivity analyses to assess how the prior on the hyperparameters influences the estimation. We found no significant differences.

An alternative structure for the spatial dependence would be the non-parametric approximation, conditional autoregressive model, CAR, either in its intrinsic (Besag, 1974) (the between-area covariance matrix is not positive definite) or proper (Cressie, 1993) (matrix positive definite) versions. To use this approach, areas (regions in our case) are taken to be neighbours if they share a common boundary. This approach provides good results if all regions are of a similar size and are arranged in a regular pattern, but results are not promising in other sets of circumstances (Kelsall and Wakefield, 2002). In fact, as Simpson *et al.* (2011) point out, CAR relies heavily on the regularity of the lattice and it is quite difficult to construct a CAR on an irregular lattice that is resolution consistent (Rue and Held, 2005). This is the main reason we chose to follow the SPDE approach in our work. As we mentioned earlier, instead of relying on a regular lattice, we specified the structure of the spatial Matérn covariance in a triangulation of the studied area, implying a low computational cost and much greater efficiency.

6.- Conclusions

Our main objective was to analyse the speed of convergence (beta) of (cause-specific) mortality and life expectancy at birth in EU regions between 1995-2009. Our results show that, in terms of health, there has been a catching-up process among the EU regions. Although we found (beta) convergence on average, we also identified significant differences in the catching-up process both across time and regions. This last finding differs from other studies done for the EU regions. Moreover, by using the coefficient of variation to measure the dynamics of dispersion levels of mortality and life expectancy (sigma convergence), we, surprisingly, find no reduction on average in dispersion levels. Consequently, if the reduction of dispersion is the ultimate measure of convergence, as various authors have agreed (e.g. Quah, 1993), then our study shows a lack of convergence of health across EU regions.

Conflicts of Interest

There are no conflicts of interest for any of the authors. All authors freely disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organisations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

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Table 1.- Descriptive data for the dependent variable: Life expectancy at birth, males and females- Years.

Countries	**1995-2000**	**2001-2005**	**2005-2009**	***1995-2009***
AUSTRIA	78.091(0.856) 78.100(77.400,78.800)	79.316(0.714) 79.300(78.850,79.800)	80.644(0.747) 80.750(80.025,81.300)	*79.258(1.280)* *79.250(78.400,80.100)*
BELGIUM	77.368(1.111) 77.600(76.300,78.400)	78.393(1.213) 78.800(77.400,79.300)	79.686(1.258) 80.050(78.600,80.800)	*78.328(1.502)* *78.400(77.400,79.225)*
BULGARIA	71.017(0.779) 71.050(70.450,71.475)	72.160(0.606) 72.100(71.600,72.600)	73.033(0.701) 73.050(72.525,73.550)	*72.077(1.051)* *72.100(71.400,72.800)*
CYPRUS	77.567(0.288) 77.550(77.400,77.700)	78.980(0.192) 79.000(78.850,79.125)	80.575(0.457) 80.550(80.150,81.025)	*78.840(1.283)* *78.900(77.700,80.100)*
CZECH REPUBLIC	74.287(1.110) 74.200(73.525,75.100)	75.583(0.993) 75.650(74.950,76.175)	77.087(1.017) 77.200(76.300,77.675)	*75.466(1.533)* *75.500(74.300,76.600)*
DENMARK			78.687(0.538) 78.700(78.300,79.000)	*78.687(0.538)* *78.700(78.300,79.000)*
ESTONIA	69.767(1.084) 70.000(69.700,70.400)	71.680(0.870) 71.700(70.975,72.350)	73.925(1.021) 73.700(73.100,74.975)	*71.513(1.959)* *71.100(70.100,73.100)*
FINLAND	77.483(1.208) 77.250(76.800,77.900)	78.928(1.125) 78.800(78.200,79.425)	80.055(1.066) 79.850(79.400,80.350)	*78.651(1.545)* *78.500(77.400,79.700)*
FRANCE	78.495(0.989) 78.600(78.000,79.200)	79.518(1.085) 79.600(79.000,80.300)	80.985(1.145) 81.200(80.300,81.800)	*79.529(1.457)* *79.500(78.500,80.500)*
GERMANY		78.980(0.796) 79.000(78.425,79.400)	80.099(0.737) 80.100(79.600,80.475)	*79.540(0.945)* *79.500(78.800,80.100)*
GREECE	78.196(0.939) 78.200(77.600,79.000)	79.043(0.751) 79.100(78.675,79.525)	80.015(0.800) 80.000(79.600,80.500)	*78.964(1.114)* *79.100(78.300,79.700)*
HUNGARY	70.917(0.826) 70.950(70.400,71.400)	72.629(0.873) 72.500(72.000,73.300)	73.811(0.966) 73.850(73.125,74.450)	*72.259(1.477)* *72.200(71.175,73.300)*
IRELAND	76.188(0.242) 76.100(76.025,76.425)	78.350(0.781) 78.450(77.900,79.000)	79.775(0.275) 79.750(79.525,80.050)	*77.823(1.473)* *77.900(76.200,79.200)*
ITALY	79.231(0.855) 79.200(78.700,79.800)	80.699(0.777) 80.800(80.200,81.225)	81.851(0.632) 81.900(81.500,82.300)	*80.317(1.295)* *80.300(79.300,81.300)*
LATVIA		70.850(0.342) 70.900(70.500,71.150)	71.975(1.124) 71.850(70.975,73.100)	*71.413(0.976)* *71.100(70.825,72.175)*
LITHUANIA	70.983(1.127) 71.250(70.300,71.800)	71.820(0.311) 71.900(71.675,72.025)	71.800(1.049) 71.550(70.950,72.900)	*71.480(0.945)* *71.800(71.100,72.000)*
LUXEMBOURG	77.333(0.550) 77.200(76.800,78.000)	78.560(0.783) 78.100(77.975,79.300)	80.100(0.753) 80.100(79.425,80.775)	*78.480(1.312)* *78.000(77.300,79.500)*
MALTA	77.567(0.432) 77.450(77.300,77.600)	79.040(0.336) 78.900(78.775,79.400)	79.850(0.342) 79.800(79.550,80.200)	*78.667(1.045)* *78.800(77.500,79.500)*
NETHERLANDS		78.923(0.629) 78.900(78.425,79.400)	80.479(0.527) 80.500(80.125,80.800)	*79.615(0.971)* *79.600(78.725,80.400)*
POLAND	72.893(0.926) 72.800(72.325,73.500)	74.812(0.691) 74.700(74.325,75.300)	75.566(0.851) 75.400(75.000,76.175)	*74.205(1.443)* *74.400(73.025,75.275)*
PORTUGAL	75.000(1.549) 75.550(73.300,76.100)	76.494(1.902) 77.200(74.300,77.800)	78.093(1.848) 78.700(76.250,79.500)	*76.323(2.139)* *76.400(74.950,78.200)*
ROMANIA		72.019(0.856) 71.850(71.525,72.275)	73.247(0.763) 73.100(72.825,73.400)	*72.837(0.980)* *73.000(71.950,73.375)*
SLOVAKIA	73.256(0.767) 72.950(72.800,73.800)	74.125(0.809) 73.850(73.425,74.950)	75.087(1.004) 74.750(74.175,75.775)	*74.154(1.113)* *74.000(73.300,74.800)*
SLOVENIA		77.650(1.626) 77.650(76.500,78.800)	78.913(1.308) 79.000(77.575,80.225)	*78.660(1.381)* *78.600(77.400,79.700)*
SPAIN	78.682(1.118) 78.700(77.900,79.500)	80.039(1.033) 80.200(79.175,80.800)	81.315(1.035) 81.450(80.600,82.100)	*79.824(1.506)* *79.800(78.700,81.000)*
SWEDEN	79.313(0.492) 79.350(78.925,79.700)	80.175(0.524) 80.200(79.725,80.650)	81.047(0.514) 81.150(80.625,81.300)	*80.063(0.864)* *79.900(79.500,80.700)*
UNITED KINGDOM	77.940(1.098) 77.900(77.100,78.900)	78.727(1.245) 78.900(77.800,79.700)	79.959(1.296) 80.000(79.000,81.000)	*79.043(1.448)* *79.100(78.100,80.000)*

In each cell, first line: mean (standard deviation); second line: median (Q1.Q3).

Source: Eurostat and own construction

Table 2.- Descriptive data for the dependent variable: Ischemic Heart Disease mortality, males and females. Standardised death rate per 100,000 inhabitants – 3 year average

Countries	**1995-2000**	**2001-2005**	**2005-2009**	***1995-2009***
AUSTRIA	137.694(19.646) 139.100(125.875,153.025)	116.140(19.926) 114.500(102.675,127.575)	100.011(15.682) 96.600(87.500,112.100)	*119.293(23.587)* *116.400(100.375,137.825)*
BELGIUM	78.391(16.049) 82.450(76.600,86.500)	70.175(7.329) 67.450(64.025,77.275)		*76.652(14.225)* *79.450(64.950,83.925)*
BULGARIA		164.033(29.812) 156.500(143.000,195.025)	145.029(30.764) 134.600(118.850,166.625)	*151.364(31.366)* *150.400(124.350,169.250)*
CYPRUS		80.967(1.069) 80.400(80.300,82.200)	86.150(12.983) 81.400(77.350,99.700)	*83.929(9.609)* *80.400(79.600,83.200)*
CZECH REPUBLIC	212.184(33.383) 209.400(187.975,232.100)	176.223(21.446) 179.400(159.550,191.375)	198.116(43.406) 183.100(170.350,213.425)	*194.024(36.157)* *186.950(169.475,209.500)*
DENMARK				
ESTONIA	364.975(33.758) 354.050(341.225,399.650)	301.960(25.975) 305.700(281.175,323.800)	236.900(14.671) 237.800(221.800,251.100)	*306.700(56.295)* *313.750(254.925,348.475)*
FINLAND	167.385(41.689) 163.900(133.625,205.725)	153.208(30.923) 154.800(132.850,180.075)	129.360(30.247) 128.300(120.200,154.500)	*149.936(35.946)* *147.800(124.575,174.775)*
FRANCE	48.341(8.313) 48.300(42.950,54.550)	43.913(9.270) 44.800(40.500,49.300)	35.492(7.489) 36.600(31.800,39.700)	*42.998(9.824)* *43.350(37.400,49.375)*
GERMANY	188.900(67.035) 179.400(147.050,210.325)	116.870(23.687) 111.800(100.700,130.600)	96.442(28.235) 93.100(79.675,106.325)	*115.898(40.540)* *106.900(92.125,126.575)*
GREECE	79.738(14.411) 78.450(65.975,91.525)	78.768(12.067) 76.100(69.150,86.225)	72.640(16.607) 68.300(59.325,82.050)	*77.181(14.547)* *75.100(65.650,86.125)*
HUNGARY	245.100(18.416) 243.100(234.325,252.250)	237.877(26.425) 229.300(218.200,253.900)	235.195(29.082) 223.400(212.900,258.950)	*239.116(25.280)* *234.600(219.450,254.875)*
IRELAND	176.983(11.061) 178.050(166.700,182.900)	135.060(14.350) 134.650(123.500,147.400)	107.625(5.946) 108.000(102.225,112.025)	*136.396(28.920)* *128.450(111.675,161.700)*
ITALY	78.055(10.438) 76.450(69.700,85.600)	72.174(8.241) 71.100(65.000,77.700)	60.162(6.402) 59.700(55.400,64.300)	*72.040(11.595)* *70.750(63.500,80.000)*
LATVIA	332.967(13.133) 336.600(318.400,343.900)	294.580(8.071) 292.600(288.975,299.850)	274.050(14.044) 276.100(259.650,286.400)	*297.333(25.607)* *291.300(281.775,315.525)*
LITHUANIA	342.525(37.532) 329.400(315.875,382.300)	334.560(6.675) 333.800(329.925,339.075)	334.400(12.674) 335.300(321.300,346.600)	*337.175(21.100)* *334.550(322.575,343.300)*
LUXEMBOURG	84.950(9.284) 82.300(77.900,94.650)	75.580(3.099) 76.600(73.425,77.950)	58.300(8.515) 58.900(49.950,66.050)	*73.146(12.855)* *76.600(66.050,78.950)*
MALTA	177.050(3.701) 177.650(173.250,180.250)	148.420(8.037) 143.900(142.950,154.900)	124.400(10.013) 123.250(115.375,134.575)	*149.838(22.658)* *143.900(134.575,173.250)*
NETHERLANDS	97.527(12.411,94.950) 87.100(104.575,70.987)	70.987(9.945) 70.500(63.050,77.375)	51.353(5.138) 51.000(47.675,55.000)	*74.925(20.390)* *73.300(57.100,89.100)*
POLAND	135.006(26.625) 143.650(114.050,156.300)	116.229(27.412) 115.550(90.050,135.225)	102.647(22.941) 100.100(85.875,121.625)	*115.180(27.738)* *113.250(89.600,134.400)*
PORTUGAL	75.000(36.869) 66.800(44.925,99.400)	72.463(29.715) 64.800(45.400,86.900)	56.700(22.837) 52.450(33.300,72.000)	*70.519(31.803)* *63.600(45.375,87.925)*
ROMANIA	244.425(74.412) 208.500(188.700,306.000)	232.707(67.597) 198.300(185.600,299.325)	204.900(56.876) 182.650(161.075,258.800)	*222.756(65.135)* *193.300(177.125,287.425)*
SLOVAKIA	189.800(34.959) 190.700(154.400,224.300)	283.867(27.559) 295.600(252.425,309.200)	275.467(11.669) 275.400(269.300,282.250)	*266.829(39.175)* *275.200(252.425,294.325)*
SLOVENIA				
SPAIN	67.568(14.603) 62.500(56.900,75.700)	58.684(13.195) 54.800(48.100,68.300)	48.576(10.425) 45.950(39.700,57.550)	*58.308(14.849)* *55.900(47.300,67.500)*
SWEDEN	140.366(15.582) 137.800(129.950,149.675)	114.190(11.184) 114.050(106.575,123.175)	95.421(7.880) 96.000(89.950,100.500)	*118.223(21.189)* *115.800(101.000,132.375)*
UNITED KINGDOM	153.869(24.113) 153.050(134.400,168.700)	119.903(17.789) 118.700(106.975,132.100)	91.505(13.186) 92.000(81.800,100.500)	*126.641(29.900)* *124.300(104.475,145.300)*

In each cell, first line: mean (standard deviation); second line: median (Q1.Q3)

Source: Eurostat and own construction

Table 3.- Descriptive data for the dependent variable: Cancer mortality, males and females. Standardised death rate per 100,000 inhabitants - 3 year average

Countries	**1995-2000**	**2001-2005**	**2005-2009**	***1995-2009***
AUSTRIA	177.558(10.322) 175.850(168.050,186.625)	168.104(9.145) 165.400(160.675,175.400)	158.781(10.411) 157.000(151.600,166.300)	*168.925(12.120)* *167.050(159.925,176.375)*
BELGIUM	184.072(33.828) 191.050(178.700,203.325)	175.113(9.586) 176.800(166.225,181.575)		*181.085(28.325)* *183.150(169.075,197.600)*
BULGARIA		161.650(11.776) 163.700(150.875,170.475)	187.025(36.658) 176.000(162.850,211.100)	*178.567(32.769)* *170.100(157.300,183.650)*
CYPRUS		108.100(12.265) 108.800(95.500,120.000)	136.425(31.137) 121.400(119.950,167.925)	*124.286(27.643)* *120.000(108.800,122.400)*
CZECH REPUBLIC	242.528(18.894) 245.000(224.075,252.325)	231.252(18.297) 226.500(217.650,242.600)	230.797(45.043) 212.750(199.150,266.575)	*234.582(29.550)* *228.650(215.675,246.175)*
DENMARK				
ESTONIA	202.300(2.396) 203.250(199.775,203.875)	197.960(1.322) 197.700(197.250,198.525)	193.500(2.982) 194.000(190.300,196.200)	*198.292(3.996)* *197.850(196.275,202.050)*
FINLAND	146.192(28.518) 149.900(132.625,161.575)	146.568(9.752) 146.800(139.225,149.225)	140.473(11.578) 139.200(133.500,145.500)	*144.751(16.585)* *144.100(137.975,150.025)*
FRANCE	176.590(29.062) 182.400(163.300,195.950)	177.339(19.791) 177.500(168.800,187.700)	164.756(19.973) 165.550(156.800,176.100)	*173.752(23.580)* *176.550(162.725,187.650)*
GERMANY	205.172(44.075) 194.450(185.125,201.675)	172.710(10.735) 173.200(165.075,180.150)	166.520(31.368) 164.600(156.900,171.275)	*174.224(27.764)* *171.250(163.000,180.300)*
GREECE	155.279(12.437) 151.450(144.875,166.200)	156.469(11.376) 153.300(147.000,164.600)	171.319(35.844) 154.600(145.325,191.450)	*160.672(23.178)* *153.500(145.375,168.350)*
HUNGARY	272.933(10.336) 274.300(266.500,281.900)	257.503(11.035) 257.400(249.300,265.000)	240.538(9.582) 238.600(234.050,248.050)	*257.084(15.871)* *257.400(245.350,269.425)*
IRELAND	201.350(4.206) 200.400(198.100,205.100)	189.220(5.771) 189.750(184.300,192.800,)	179.300(6.261) 180.300(173.350,185.350)	*188.946(10.067)* *187.850(182.000,197.800)*
ITALY	175.317(21.814) 177.800(158.400,189.700)	170.750(18.325) 176.450(158.100,182.100)	157.569(13.359) 160.800(148.400,166.500)	*169.671(20.367)* *170.100(153.000,183.000)*
LATVIA	196.567(0.473) 196.400(196.200,197.100)	194.400(0.903) 194.300(193.575,195.150)	194.250(1.370) 194.100(193.050,195.600)	*194.892(1.369)* *195.000(193.525,196.100)*
LITHUANIA	197.600(2.357) 196.550(196.200,200.050)	195.580(1.199) 195.100(194.850,196.300)	195.067(0.929) 195.500(194.000,195.700)	*196.125(1.851)* *195.800(195.052,196.725)*
LUXEMBOURG	188.450(9.551) 186.800(180.425,198.125)	167.820(7.364) 168.000(162.275,173.650)	158.825(1.173) 158.900(157.675,159.900)	*171.400(14.006)* *168.000(159.250,180.425)*
MALTA	179.600(9.949) 177.300(171.725,189.775)	157.300(6.138) 157.600(151.350,162.025)	154.350(1.760) 154.450(152.600,156.000)	*163.254(12.975)* *157.600(153.400,171.725)*
NETHERLANDS	203.775(7.456) 203.400(200.000,207.600)	192.307(6.970) 191.750(188.525,196.100)	184.708(5.162) 184.850(182.775,187.150)	*194.230(9.990)* *192.700(186.450,201.950)*
POLAND	214.588(18.765) 218.400(201.325,228.125)	213.911(17.132) 217.950(200.525,227.850)	208.366(18.386) 210.150(193.575,222.325)	*212.609(17.686)* *216.500(199.575,226.675)*
PORTUGAL	161.179(52.177) 158.750(140.325,181.575)	167.517(20.544) 159.100(153.400,179.300)	162.236(18.673) 156.200(150.100,176.900)	*164.252(34.997)* *158.100(150.325,179.325)*
ROMANIA	174.963(23.354) 172.950(159.675,188.950)	179.510(21.564) 181.250(164.675,191.675)	181.422(18.973) 184.800(167.325,192.650)	*179.820(20.558)* *183.500(165.150,192.075)*
SLOVAKIA	151.350(4.238) 151.000(147.450,155.600)	209.658(5.780) 208.150(205.650,213.750)	202.350(7.490) 201.950(196.925,209.175)	*198.196(20.728)* *205.200(196.925,211.025)*
SLOVENIA				
SPAIN	173.232(9.107) 173.600(167.450,178.875)	164.641(8.080) 164.400(160.400,170.000)	154.950(10.090) 155.200(150.100,161.025)	*164.302(11.531)* *164.500(156.800,172.000)*
SWEDEN	158.209(5.664) 157.850(153.125,161.875)	154.688(5.646) 154.650(151.125,158.675)	148.596(6.001) 148.800(144.525,151.425)	*154.339(6.761)* *154.000(150.200,159.250)*
UNITED KINGDOM	193.371(16.204) 192.150(180.700,201.500)	185.613(14.269) 184.200(173.175,193.800)	175.561(13.758) 173.900(164.200,185.000)	*186.493(16.1118)* *184.200(173.800,195.425)*

In each cell, first line: mean (standard deviation); second line: median (Q1.Q3)

Source: Eurostat and own construction

Table 4.- Descriptive data for the dependent variable: Lung cancer mortality, males and females. Standardised death rate per 100,000 inhabitants – 3 year average

Countries	**1995-2000**	**2001-2005**	**2005-2009**	***1995-2009***
AUSTRIA	38.447(8.239) 33.950(31.650,42.800)	36.633(8.051) 32.400(30.850,42.025)	35.930(9.342) 31.900(29.400,42.500)	*37.062(8.433)* *32.900(30.900,42.450)*
BELGIUM	47.400(10.579) 48.850(41.050,54.125)	45.944(4.427) 46.500(42.075,49.700)		*46.915(8.975)* *47.900(42.075,52.200)*
BULGARIA		39.950(3.416) 35.100(34.125,41.275)	42.617(8.707) 40.050(36.100,48.325)	*40.728(7.799)* *37.750(35.025,42.725)*
CYPRUS	33.100(0.872) 33.300(32.200,33.800)	32.150(0.071) 32.150(32.100,32.200)	31.950(0.071) 31.950(31.900,32.000)	*32.575(0.805)* *32.150(32.000,33.550)*
CZECH REPUBLIC	52.694(8.731) 51.800(46.725,55.675)	48.745(8.146) 47.150(43.775,51.675)	49.075(11.994) 45.200(41.975,58.150)	*50.062(9.721)* *48.150(43.800,53.150)*
DENMARK				
ESTONIA	33.875(0.670) 33.950(33.200,34.475)	30.600(0.620) 30.300(30.175,31.000)	29.800(0.173) 29.900(29.600,29.900)	*31.492(1.864)* *30.550(29.950,33.600)*
FINLAND	27.250(5.015) 27.650(26.000,31.300)	30.938(7.174) 28.000(25.875,40.000)	30.887(7.111) 28.000(24.300,38.900)	*30.120(6.781)* *27.850(25.100,37.000)*
FRANCE	36.523(7.077) 36.800(33.200,40.025)	36.865(7.488) 37.500(34.900,39.875)	36.168(7.355) 36.650(35.125,39.825)	*36.573(7.307)* *36.950(34.725,39.950)*
GERMANY	42.956(9.658) 42.150(38.850,44.800)	35.107(6.092) 35.600(29.425,39.625)	34.975(8.848) 35.200(28.375,38.875)	*35.970(8.037)* *36.100(29.300,40.700)*
GREECE	40.320(4.276) 40.800(36.900,43.800)	40.343(3.463) 40.200(37.775,42.350)	43.879(9.610) 40.550(37.850,49.600)	*41.430(6.401)* *40.350(37.700,43.800)*
HUNGARY	59.648(13.425) 64.100(44.700,71.800)	58.817(13.656) 65.000(39.300,70.600)	56.450(14.556) 60.450(38.600,69.000)	*58.405(13.725)* *63.900(40.700,70.575)*
IRELAND	41.229(4.287) 42.700(37.200,45.200)	39.510(3.164) 39.100(37.200,42.800)	38.357(2.199) 37.900(36.800,41.000)	*39.675(3.354)* *38.450(37.125,42.775)*
ITALY	38.005(7.514) 40.000(31.500,43.900)	33.880(8.137) 34.150(27.800,41.600)	30.984(7.192) 31.050(25.950,37.075)	*34.965(8.125)* *35.950(28.025,41.800)*
LATVIA	38.600(1.637) 38.200(37.300,40.300)	37.850(0.636) 37.850(37.400,38.300)	33.400(0.283) 33.400(33.200,33.600)	*37.113(2.564)* *37.350(34.525,38.900)*
LITHUANIA		17.833(3.921) 18.300(13.700,21.500)	24.600(6.717) 21.650(20.600,31.550)	*21.700(6.385)* *20.900(18.300,22.400)*
LUXEMBOURG	40.933(0.252) 40.900(40.700,41.200)	39.840(0.483) 39.900(39.375,40.250)	38.375(1.170) 38.400(37.250,39.475)	*39.625(1.235)* *39.750(39.150,40.625)*
MALTA	82.800(1.179) 83.100(81.500,83.800)	80.340(1.205) 80.600(79.950,80.975)	80.233(1.650) 80.700(78.400,81.600)	*80.982(1.664)* *80.800(80.500,81.600)*
NETHERLANDS	48.945(7.858) 49.400(45.800,53.000)	47.453(8.738) 47.350(44.050,51.025)	45.643 (9.125) 45.500(42.850,47.550)	*47.475(8.597)* *47.500(44.050,50.675)*
POLAND	48.355(10.547) 51.000(38.400,55.900)	52.721(8.672) 53.700(49.925,58.075)	50.029(9.797) 51.100(45.200,56.100)	*51.342(9.370)* *52.750(46.375,57.575)*
PORTUGAL	27.409(14.264) 26.850(18.000,28.800)	36.900(18.576) 28.400(25.600,63.500)	37.279(18.986) 28.950(25.100,61.600)	*34.034(17.765)* *28.100(24.200,30.000)*
ROMANIA	39.821(10.754) 38.650(31.500,52.000)	41.772(7.278) 41.150(35.525,45.275)	42.175(5.473) 41.750(40.725,43.100)	*41.577(7.398)* *41.150(36.600,43.100)*
SLOVAKIA	30.800(3.111) 30.800(28.600,33.000)	39.217(2.240) 39.100(37.200,41.300)	37.667(2.841) 38.200(35.000,40.000)	*37.350(3.746)* *37.350(35.000,40.500)*
SLOVENIA	36.350(7.707) 36.350(30.900,41.800)	37.630(6.069) 36.950(32.000,43.400)	39.387(6.378) 39.050(33.575,45.325)	*38.205(6.057)* *37.900(32.100,44.100)*
SPAIN	38.954(4.599) 38.550(36.125,41.900)	38.646(4.121) 37.800(36.000,40.600)	37.751(5.108) 37.150(34.250,40.950)	*38.466(4.597)* *37.700(35.600,41.100)*
SWEDEN	25.814(3.886) 25.500(21.825,29.300)	26.548(3.169) 26.100(24.100,29.100)	27.471(3.162) 27.200(24.625,30.475)	*26.557(3.427)* *26.100(23.800,29.525)*
UNITED KINGDOM	43.660(11.042) 42.600(36.350,49.650)	40.689(9.757) 39.400(33.425,46.875)	39.074(9.472) 38.300(32.500,44.100)	*41.414(10.297)* *40.400(34.425,48.275)*

In each cell, first line: mean (standard deviation); second line: median (Q1.Q3)

Source: Eurostat and own construction

Table 5.- Descriptive data for the variable: Gross Domestic Product per capita in PPS.

Countries	**1995-2000**	**2001-2005**	**2005-2009**	***1995-2009***
AUSTRIA			29559.256(5626.535) 30500(25400,32900)	*29559.259(5626.535)* *30500(25400,32900)*
BELGIUM	20087.879(7944.975) 17800(15500,21200)	24794.545(9513.040) 22700(18300,26300)	27220.455(9681.283) 25450(20075,29625)	*23558.788(9399.397)* *20700(17675,26125)*
BULGARIA	4544.444(959.596) 4150(3800,5200)	6593.333(1852.851) 5850(5600,6900)	9070.833(3605.247) 7750(6950,8900)	*6434.444(2857.875)* *5800(4500,7100)*
CYPRUS	14450(1459.795) 14200(13300,15500)	18740(1040.673) 18200(18025,19550)	23175(1364.734) 23300(21825,24400)	*18206.667(3830.417)* *18100(14600,21400)*
CZECH REPUBLIC	12470.833(4008.181) 11100(10600,11850)	16217.5(6726.103) 13850(13125,15550)	19787.5(8557.651) 16750(15725,17800)	*15670.833(7002.681)* *13800(11300,16475)*
DENMARK	20713.333(3773.477) 20000(18000,22500)	24560(4144.675) 23700(22650,25150)	27645(4780.605) 27000(25575,28350)	*23844(5007.083)* *23600(20100,27000)*
ESTONIA	7200(1029.563) 7200(6550,7850)	11380(1806.11) 11300(9950,12750)	16325(1276.388) 16450(15075,17450)	*11300(3992.878)* *10750(7600,14900)*
FINLAND	18470(4646.478) 17600(14700,21300)	24084(5738.443) 22200(19700,29125)	27900(5942) 26200(22750,33850)	*22856(6587.155)* *22100(18100,26800)*
FRANCE	16364.103(3851.936) 16250(14525,17975)	20083.077(4404.246) 20150(18600,21400)	21986.538(5009.041) 21550(20350,23300)	*19103.077(4953.832)* *19200(15900,21400)*
GERMANY	19825.214(4793.200) 19500(16800,21900)	23462.051(5630.897) 22900(19600,25700)	27179.487(5987.015) 26700(22675,29425)	*22998.632(6163.492)* *22000(18950,26425)*
GREECE	13550(2717.273) 13250(11400,14700)	17767.692(2926.875) 17000(15575,19725)	19932.692(3985.499) 18700(17050,21225)	*16657.949(4135.598)* *16300(13600,19100)*
HUNGARY			13580.952(5455.696) 10800(10075,14625)	*13580.952(5455.696)* *10.800(10075,14625)*
IRELAND	18041.667(5219.798) 17250(13550,22375)	26700(6769.868) 26100(20100,32800)	30500(7711.216) 29450(24025,37900)	*24250(8228.368)* *22950(18400,31800)*
ITALY			25157.143(6175.334) 26800(18800,30200)	*25157.143(6175.334)* *26800(18800,30200)*
LATVIA	5980(729.383) 6000(5450,6525)	9100(1270.827) 8900(8125,10125)	13000(1098.484) 13000(12025,13975)	*9100(3059.915)* *8600(6400,12000)*
LITHUANIA	6416.667(854.205) 6600(5700,6900)	10080(1472.073) 10200(8875,11225)	14025(1271.154) 13950(12875,15250)	*9666.667(3352.753)* *9100(6900,12800)*
LUXEMBOURG	37950(5426.140) 35950(34100,42400)	51740(4324.697) 51300(48475,55325)	66200(3489.986) 66300(62875,69425)	*50080(12520.224)* *49200(37000,62500)*
MALTA	15300(1272.792) 15300(14400,16200)	16620(715.542) 16600(16275,17000)	18950(680.686) 19100(18250,19500)	*17227.273(1618.698)* *16800(16200,19000)*
NETHERLANDS	20363.889(3993.879) 19600(17450,22925)	26090(4511.593) 24700(22450,30025)	30668.75 (5678.446) 29250(26350,35025)	*25020.556(6258.025)* *24300(20525,28900)*
POLAND	7267.708(1661.926) 6900(6200,8000)	9556.25(2231.412) 9250(8000,10350)	12385.938(3023.919) 12050(10425,13325)	*9398.417(3062.026)* *8800(7200,10800)*
PORTUGAL	12926.19(3094.138) 12300(10600,14300)	17060(3626.634) 15500(14100,19900)	19939.286(4320.266) 18050(16100,24750)	*16174.286(4610.941)* *15500(12800,18500)*
ROMANIA	4947.917(1390.544) 4650(4125,5100)	6952.5(2905.255) 6150(5200,7375)	11081.25(5558.106) 9450(8175,11000)	*7251.667(4206.198)* *5850(4700,8500)*
SLOVAKIA	9791.667(4991.464) 7350(6650,13425)	14050(7878.986) 10100(9150,20300)	20200(11861.478) 14800(11900,30525)	*13986(9116.078)* *10400(7900,16400)*
SLOVENIA	13275(2820.421) 12950(10875,15675)	17950(3719.692) 17500(14400,20900)	21787.5(4460.761) 21700(17300,26200)	*17103.33(4947.621)* *16550(13300,20000)*
SPAIN	15402.632(3569.449) 14650(12800,17500)	20604.211(4142.255) 19800(17500,23900)	24792.105(4563.354) 23550(21475,28275)	*19640.351(5556.054)* *19300(15500,23350)*
SWEDEN	20125(3848.874) 18850(17750,20950)	24875(4375.266) 23450(22275,25175)	28521.875(5199.115) 26900(25625,28600)	*23947.5(5565.65)* *23400(19525,26300)*
UNITED KINGDOM	18117.453(6295.445) 16800(15100,19375)	23616.216(8441.085) 22200(19475,24800)	25695.946(10061.497) 23550(21125,26700)	*22042.018(8792.323)* *20600(17275,24125)*

In each cell, first line: mean (standard deviation); second line: median (Q1.Q3)

Source: Eurostat and own construction

Table 6.- Descriptive data for the variable: Gini Index (percentage)

Countries	1995-2000	2001-2005	2005-2009	*1995-2009*
AUSTRIA	25.333(1.116) 25.500(24.000,26.000)	25.850(1.237) 26.000(24.450,27.100)	25.850(0.383) 25.950(25.400,26.200)	*25.629(1.031)* *25.900(25.000,26.200)*
BELGIUM	28.333 (1.114) 28.500(27.000,29.000)	27.600(0.885) 28.000(26.575,28.225)	27.000(0.667) 26.950(26.325,27.725)	*27.743(1.090)* *27.900(27.000,28.300)*
BULGARIA	25.000(0.000) 25.000(25.000,25.000)	25.400(0.814) 26.000(25.000,26.000)	33.950(1.876) 34.350(31.750,35.750)	*28.780(4.453)* *26.000(25.000,33.400)*
CYPRUS	29.000(.) 29.000(29.000,29.000)	27.850(1.202) 27.850(27.000,28.700)	29.000(0.627) 28.950(28.425,29.625)	*28.671(0.867)* *28.800(28.300,29.100)*
CZECH REPUBLIC		25.500(0.516) 25.500(25.000,26.000)	25.100(0.249) 25.200(24.800,25.300)	*25.233(0.403)* *25.200(25.000,25.300)*
DENMARK	20.333(0.488) 20.000(20.000,21.000)	23.650(1.048) 23.900(22.475,24.575)	25.225(1.164) 25.150(24.050,26.475)	*23.318(2.188)* *23.900(21.000,25.100)*
ESTONIA	36.000(.) 36.000(36.000,36.000)	35.100(1.371) 35.000(34.075,35.600)	32.200(1.236) 32.250(31.025,33.325)	*34.030(1.975)* *34.050(33.100,35.000)*
FINLAND	22.800(1.000) 22.000(22.000,24.000)	26.100(0.500) 26.000(26.000,26.000)	26.075(0.183) 26.050(25.900,26.275)	*24.914(1.721)* *25.900(24.000,26.000)*
FRANCE	28.667(0.473) 29.000(28.000,29.000)	27.380(0.493) 27.000(27.000,27.700)	28.400(1.479) 28.550(26.775,29.875)	*28.167(1.035)* *28.000(27.000,29.000)*
GERMANY	26.000(1.531) 25.000(25.000,27.000)	25.550(0.554) 25.550(25.000,26.100)	29.125(1.435) 29.650(27.375,30.350)	*26.967(2.065)* *26.450(25.000,29.075)*
GREECE	34.333(0.750) 34.500(34.000,35.000)	33.475(0.719) 33.100(33.000,34.325)	33.775(0.541) 33.850(33.175,34.300)	*33.929(0.777)* *34.000(33.100,34.700)*
HUNGARY	26.000(.) 26.000(26.000,26.000)	25.900(1.486) 26.000(24.250,27.450)	27.200(3.601) 25.400(24.825,31.375)	*26.489(2.650)* *25.600(25.000,27.000)*
IRELAND	32.500(1.314) 33.000(32.000,33.000)	30.750(1.192) 31.050(29.400,31.800)	30.475(1.293) 30.600(29.075,31.375)	*31.421(1.556)* *31.700(30.000,33.000)*
ITALY	31.000(1.296) 31.000(30.000,32.000)	31.667(1.908) 32.800(29.000,33.200)	31.700(0.488) 31.800(31.125,32.175)	*31.369(1.339)* *31.500(31.000,32.200)*
LATVIA	34.000(.) 34.000(34.000,34.000)	36.100(.) 36.100(36.100,36.100)	37.425(1.563) 37.550(35.900,38.825)	*36.633(1.847)* *36.750(35.400,37.700)*
LITHUANIA	31.000(.) 31.000(31.000,31.000)	33.650(3.748) 33.650(31.000,36.300)	34.575(0.810) 34.500(33.850,35.375)	*33.800(2.094)* *34.000(31.000,35.500)*
LUXEMBOURG	26.833(1.472) 26.500(26.000,28.000)	26.900(0.523) 26.750(26.500,27.450)	28.025(0.802) 27.750(27.475,28.850)	*27.193(1.159)* *27.200(26.500,27.800)*
MALTA	30.000(.) 30.000(30.000,30.000)	26.900(.) 26.900(26.900,26.900)	27.100(0.658) 27.100(26.475,27.725)	*27.550(1.307)* *27.100(26.900,27.900)*
NETHERLANDS	27.333(1.712) 27.500(26.000,29.000)	26.975(0.044) 27.000(26.925,27.000)	27.200(0.495) 27.400(26.600,27.600)	*27.193(1.156)* *27.000(26.400,27.600)*
POLAND	30.000(.) 30.000(30.000,30.000)	32.800(2.845) 32.800(30.000,35.600)	32.225(0.692) 32.100(31.550,33.025)	*32.071(1.821)* *32.000(30.000,33.300)*
PORTUGAL	36.333(0.477) 36.000(36.000,37.000)	37.633(0.476) 37.800(37.000,38.100)	36.425(0.912) 36.300(35.500,37.475)	*36.662(0.832)* *36.800(36.000,37.000)*
ROMANIA	29.000(.) 29.000(29.000,29.000)	30.400(0.496) 30.000(30.000,31.000)	35.425(1.769) 35.450(33.475,37.350)	*32.270(2.870)* *31.000(30.000,34.900)*
SLOVAKIA		26.200(.) 26.200(26.200,26.200)	25.275(1.735) 24.650(23.900,27.275)	*25.460(1.588)* *24.800(24.500,26.200)*
SLOVENIA	22.000(.) 22.000(22.000,22.000)	22.450(0.833) 22.000(22.000,23.350)	23.250(0.389) 23.300(22.825,23.625)	*22.756(0.758)* *22.700(22.000,23.400)*
SPAIN	33.667(0.947) 34.000(33.000,34.000)	31.500(0.839) 31.000(31.000,31.800)	31.525(0.452) 31.300(31.225,32.050)	*32.373(1.328)* *32.000(31.200,34.000)*
SWEDEN	21.500(0.516) 21.500(21.000,22.000)	23.350(0.416) 23.200(23.000,23.850)	24.050(0.505) 24.000(23.550,24.600)	*23.260(1.050)* *23.400(23.000,24.000)*
UNITED KINGDOM	31.667(0.747) 32.000(32.000,32.000)	34.650(0.411) 34.800(34.150,35.000)	32.850(0.612) 32.550(32.425,33.575)	*32.857(1.386)* *32.450(32.000,34.000)*

In each cell, first line: mean (standard deviation); second line: median (Q1.Q3)

Source: Eurostat and own construction

Table 7.1.- Results of estimating the models. Fixed effects.

Dependent variables	**Life expectancy**	**Ischemic heart disease crude rate**	**Cancer standardized rate**	**Lung cancer crude rate**
B	-0.1307 (-0.160,-0.104)[1]	-0.2630(-0.4261,-0.0997)	-0.3366(-0.6129,-0.0576)	-0.1181(-0.2009,-0.03751)
Fixed effects:				
GDPPC	0.0031(-0.0014,0.0076)	-0.00151(-0.0366,0.0337)	-0.00454(-0.0332,0.0246)	0.00150(-0.0018,0.00477)
GDPPC_1	0.0001(-0.0002,0.0003)	-0.00141(-0.0054,0.0026)	0.00304(-0.0005,0.00656)	-0.00429(-0.0081,-0.00044)
GDPPC_2	-0.0002(-0.0005,0.00005)	0.00146(-0.00811,0.01104)	-0.0038(-0.0124,0.0047)	0.0007(-0.0047,0.0061)
GDPPC rate_1	-0.0068(-0.0143,0.0007)	0.1214(0.0214,0.2214)	0.09215(0.00291,0.1844)	0.0481(-0.0531,0.1494)
GDPPC rate_2	0.00055(-0.0084,0.0094)	0.1200(0.00919,0.2309)	0.02609(-0.07736,0.1344)	-0.0355(-0.1421,0.0711)
Sec	-0.000004(-0.0001,0.00009)	-0.00145(-0.00294,0.00005)	-0.00183(-0.0030,-0.00068)	-0.00269(-0.0042,-0.00122)
Univ	-0.00003(-0.00007,0.00002)	-0.00004(-0.0007,0.0006)	0.00075(0.00023,0.00128)	0.00142(0.00073,0.0021)
Pubexp	-0.00007(-0.0002,0.00004)	-0.0045(-0.00681,-0.0022)	0.00045(-0.0014,0.0023)	0.0014(-0.0005,0.0033)
Umy	-0.00002(-0.00006,0.00001)	0.00038(-0.0002,0.0009)	-0.00047(-0.0009,-0.00005)	0.000203(-0.00037,0.00077)
Ufy	0.000007(-0.00002,0.00004)	0.000001(-0.0004,0.0004)	-0.00026(-0.0006,0.00006)	-0.00051(-0.0010,-0.00004)
Bpg	0.00011(0.00003,0.00018)	-0.00043(-0.0020,0.00112)	0.00089(-0.00044,0.00222)	0.00205(0.00047,0.00362)
Gini	-0.01526(-0.0523,0.02232)	-0.2553(-0.8082,0.2989)	-0.0531(-0.69003,0.5718)	0.02948(-0.1849,0.2431)
Standard deviation of random effects:				
Heterogeneity	0.0461(0.0007)[2]	0.0504(0.0008)	0.0376(0.0008)	0.06362(0.0012)
α_j	0.7777(0.1201)	3.0965(0.4745)	2.6601(0.4717)	0.01068(0.0064)
β_j	0.0759(0.0121)	0.3217(0.0397)	0.4497(0.0679)	0.1800(0.0332)
β_t	0.0031(0.0006)	0.0726(0.0144)	0.2829(0.0537)	0.00625(0.00212)
$\gamma gdppc_j$	0.0110(0.0016)		0.0435(0.0117)	
$\gamma gdppc_t$	0.0028(0.0005)	0.0347(0.0090)	0.00729(0.0029)	
$\gamma gini_j$	0.0271(0.0062)	0.8757(0.1340)	0.8743(0.1449)	0.1942(0.03500)
$\gamma gini_t$	0.0040(0.0009)	0.1929(0.0503)	0.3672(0.0781)	0.0067(0.0023)
DIC	-28009.40	-6554.70	-7514.33	-5577.65
Effective number of parameters	2710.75	254.13	303.63	135.88
-log(mean(cpo))	-1.6383	-1.639	-1.6395	-1.6394

[1] mean (95% credible interval); [2] mean (standard deviation); the 95% credible interval did not contain the zero (statistically significant).

Source: own construction

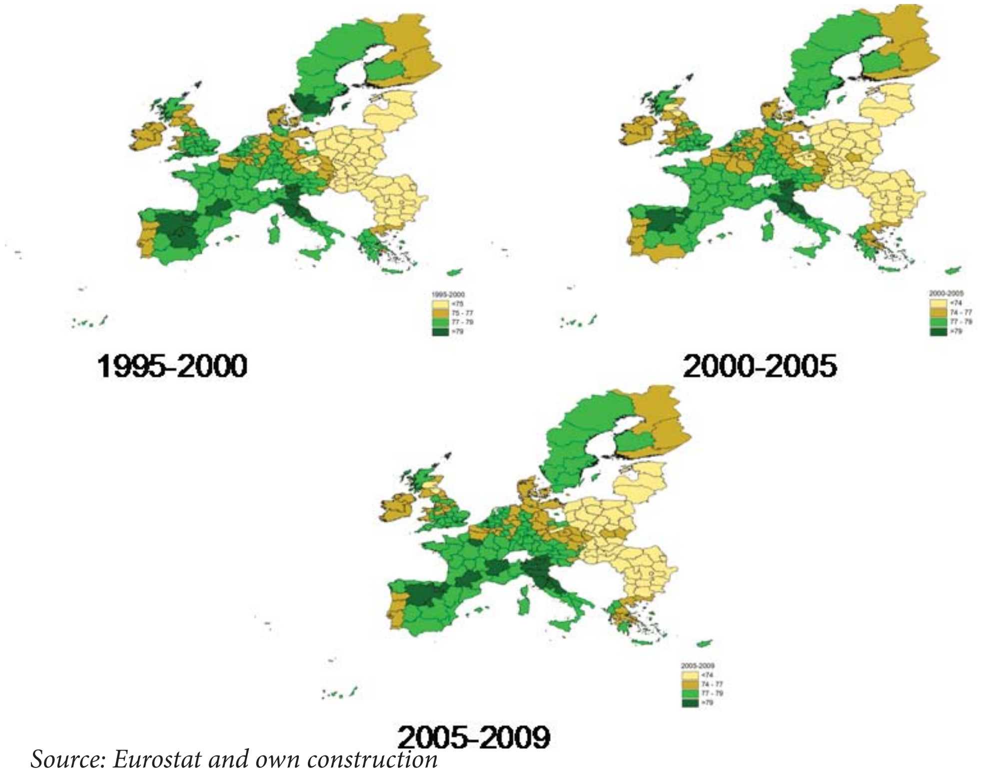
Table 7.2.- Results of estimating the models. Random effects[1].

Random effects	Life expectancy	Ischemic heart disease crude rate	Cancer standardized rate	Lung cancer crude rate
α_j		Bulgaria 7.9855(5.1901,10.7654) Czech Republic -5.9847(-8.7009,-3.2878) Finland 9.6170(7.0608,12.2052) Poland -5.0229(-7.9521,-2.1239)	Finland 6.8965(5.0247,8.8394) Greece -5.4328(-7.5479,-3.3867) Portugal 4.1434(1.4339,6.9639) UK -3.0494(-5.1355,-1.004)	
β_j	Malta -0.0436(-0.0917,-0.0018)[2] Portugal 0.0332(0.0036,0.0673) UK 0.0245(0.0014,0.0505)	Bulgaria -0.7441(-0.9651,-0.5268) Estonia 2.8070(0.0073,0.5554) Finland -0.5451(-0.7456,-0.3434) Greece -1.0776(-1.2600,-0.8970) Luxembourg 0.4856(0.1896,0.7844) Malta 0.3493(0.0371,0.6634) Netherlands 0.1761(0.0117,0.3418) Romania 0.3714(0.1641,0.5773)	Finland -0.7364(-0.9703,-0.5084) France 2.6596(0.0223,0.5080) Greece -1.4436(-1.6663,1.2277) Ireland 0.4454(0.0564,0.8425) Italy -0.5197(-0.7558,-0.2894) Portugal -0.5399(-0.7718,-0.3132) Romania 0.4549(0.1973,0.7146) Spain 0.3640(0.1138,0.6130) United Kingdom 0.3108(0.0806,0.5394)	Austria 0.12168(0.01487,0.2311) Finland -0.1267(-0.2535,-0.0029) France 0.0990(0.01198,0.1885) Greece -0.7050(-0.8531,-0.5667) Hungary 0.1225(0.01942,0.2282) Netherlands 0.0993(0.0016,0.1996) Poland 0.1283(0.0216,0.2380) UK 0.0971(0.0116,0.1845)
β_t	2003 -0.00316(-0.0061,-0.00035)	2009 0.2010(0.1462,0.2558)	2008 -0.2162(-0.4133,-0.0210) 2009 0.5854(0.3867,0.7883)	1999 -0.0131(-0.0294,-0.00163) 2008 0.01674(0.0025,0.0357) 2009 0.02255(0.0055,0.0453)
γ gdppc$_j$	Cyprus 0.0129(0.0011,0.02505) Malta 0.0474(0.0426,0.05229) Poland -0.00517(-0.0103,-0.0039)		Czech Republic -0.05786(-0.1078,-0.01177) Greece 0.1038(0.03895,0.1698)	
γ gdppc$_t$	1998 0.00050(0.00002,0.00098) 2003 0.00063(0.00017,0.0011) 2005 0.00067(0.0002,0.00113) 2008 -0.0022(-0.00363,-0.00081)	2009 0.0870(0.04341,0.1332)	2008 -0.1255(-0.0266,-0.00094) 2009 -0.0230(-0.0449,-0.0058)	
γ gini$_j$	Greece 0.0379(0.0099,0.0684) Malta -0.0820(-0.1348,-0.0243)	Austria 1.1912(0.01891,2.3772) Bulgaria -1.2913(-1.9677,-0.6193) Czech Republic 1.7244(0.9859,2.4646) Finland -2.1168(-2.7744,-1.4591) Greece 0.9246(0.26304,1.5873) Poland 1.2568(0.4778,2.0381)	Finland -1.0312(-1.6213,-0.4514) Greece 3.3630(2.7550,3.9952)	Austria -0.1473(-0.2682,-0.0297) France -0.1116(-0.2090,-0.0175) Greece 0.75553(0.60812,0.9143) Hungary -0.1449(-0.2674,-0.0254) Netherlands -0.11834(-0.2304,-0.0094) UK -0.1006(-0.1955,-0.0080)
γ gini$_t$	1996 -0.00477(-0.0096,-0.00005) 1998 -0.00429(-0.0085,-0.0003) 2009 0.0055(0.0008,0.01027)	2009 -0.4911(-0.6772,-0.3069)	2008 0.3663(0.08795,0.6478) 2009 -0.7714(-1.0626,-0.4864)	1999 0.0128(0.00035,0.03044) 2006 -0.0137(-0.03116,-0.00091) 2007 -0.0166(-0.0360,-0.00223)

[1] *mean (95% credible interval)*

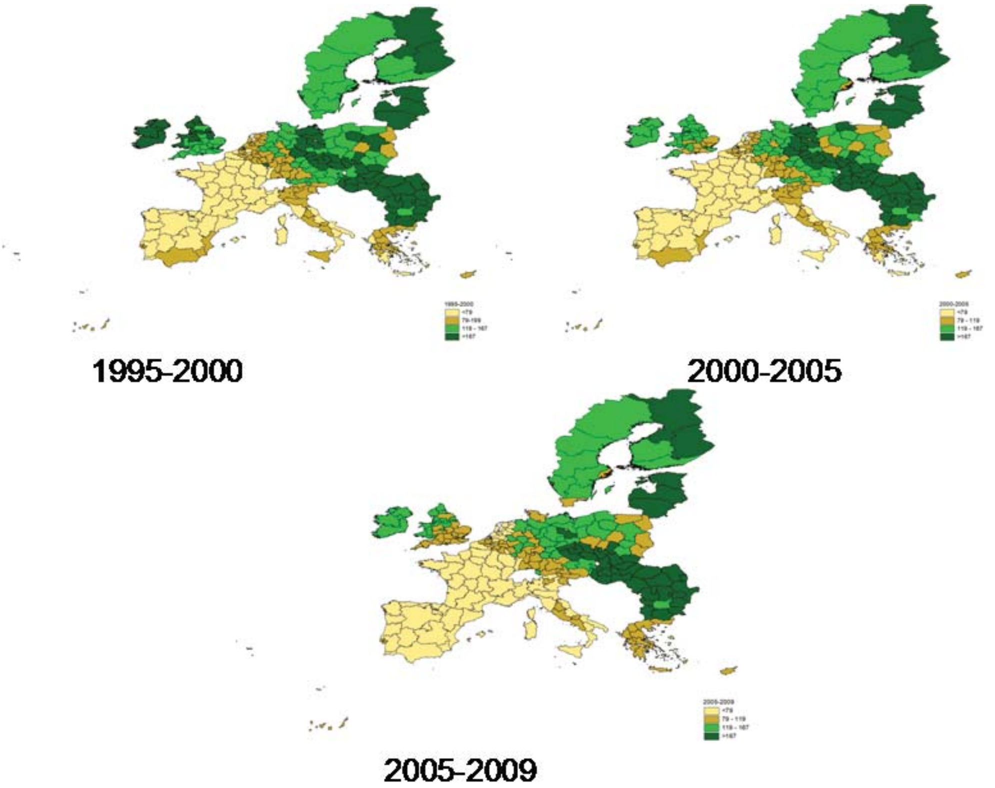
Source: own construction

Figure 1.- Life expectancy at birth (Index, 100 EU-27 average per period)



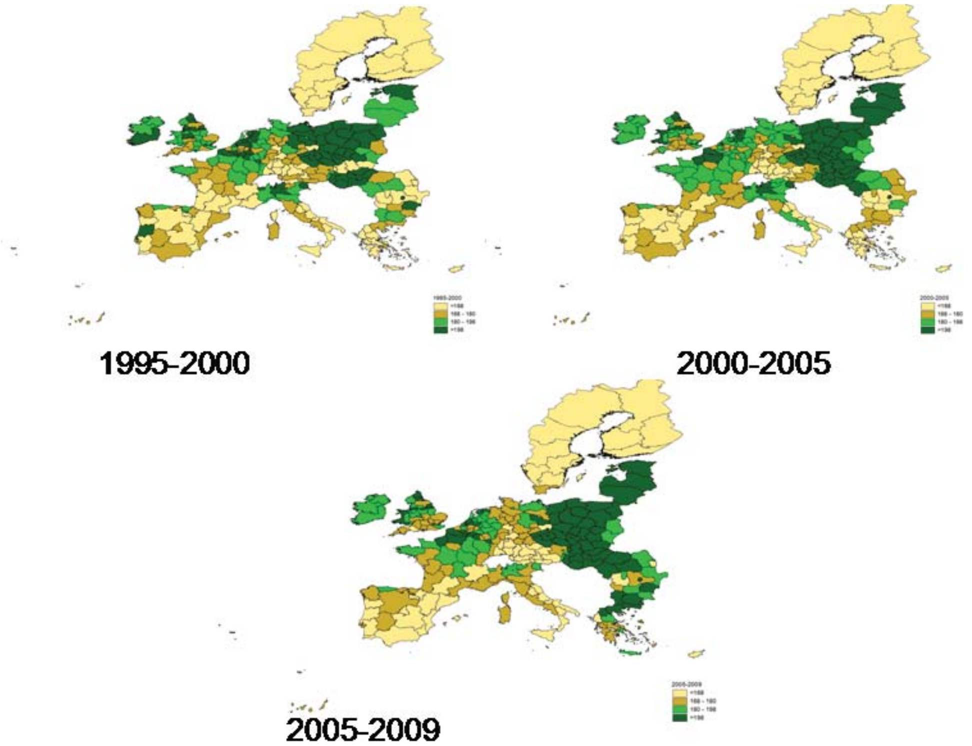
Source: Eurostat and own construction

Figure 2.- Ischemic heart mortality (Index, 100 EU-27 average per period)



Source: Eurostat and own construction

Figure 3.- Cancer mortality (Index, 100 EU-27 average per period)



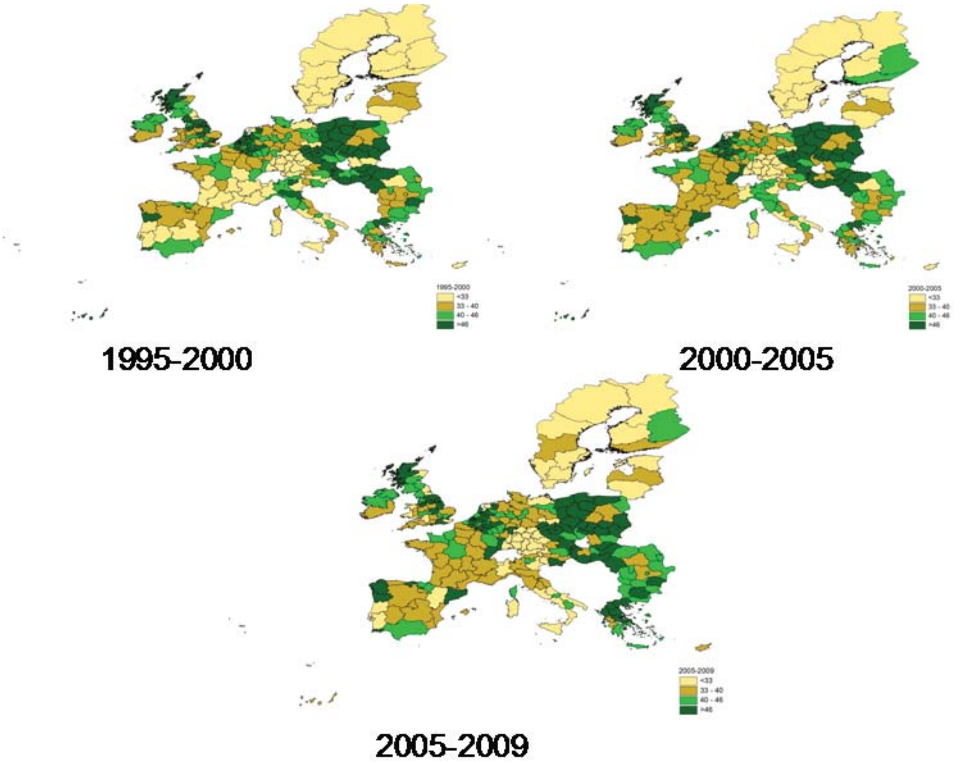
1995-2000

2000-2005

2005-2009

Source: *Eurostat and own construction*

Figure 4.- Lung cancer mortality (Index, 100 EU-27 average per period)



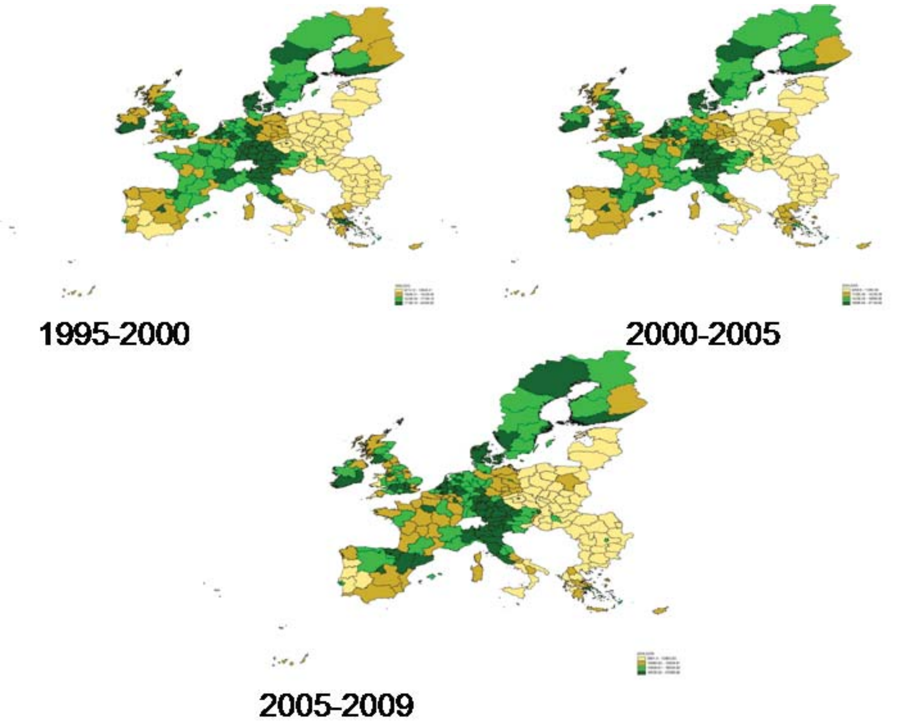
1995-2000

2000-2005

2005-2009

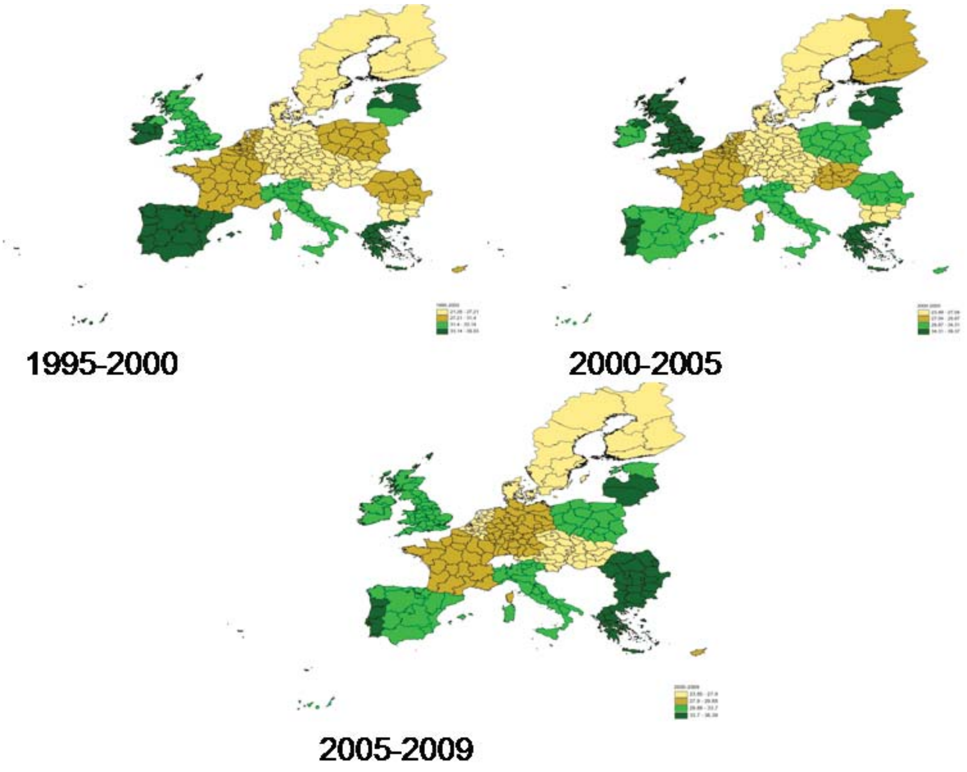
Source: Eurostat and own construction

Figure 5.- GDP per capita (quartiles)



Source: Eurostat and own construction

Figure 6.- Gini index (quartiles)

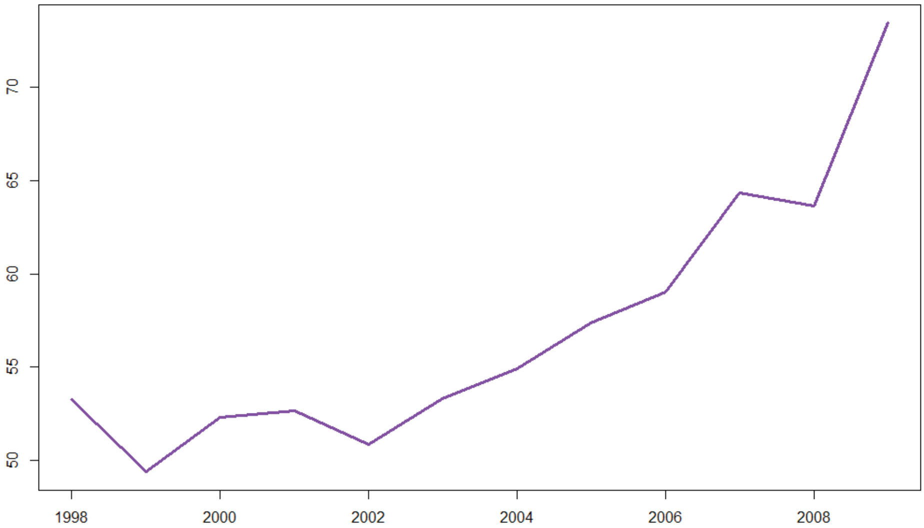


Source: Eurostat and own construction

Figure 7.- Sigma convergence (coefficient of variation)

σ-convergence (Life expectancy at birth/Lung cancer mortality)

σ-convergence (Ischemic heart disease/Cancer mortality)



Source: own construction

4.5. Bayesian estimation of small dynamic panel data

Paper 5. Maynou, L. and Saez, M. (2013) 'Bayesian estimation of small dynamic panel data' *Journal of Econometrics* (under revision)

"Take nothing on its looks; take everything on evidence. There's no better rule."

Charles Dickens, Great Expectations

Bayesian estimation of small dynamic panel data models

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Abstract

Our objective in this paper is to make several simulation studies to assess the performance of the estimators of the parameters of a dynamic panel data model computed from a (pure) Bayesian approach. We are particularly interested in the performance of these estimators on a very small panel and, specifically, when the standard assumptions of the dynamic panels are violated, in particular, the presence of cross-section and temporal dependence. Our approach has demonstrated its superiority to other consistent estimators in terms of both bias and efficiency. Furthermore, our approach allows us to easily make inferences on the unit-specific coefficients.

Key words: dynamic panel data models, consistent estimators, generalized methods of moments, Bayesian approach, INLA,

1.- Introduction

Dynamic panel model estimation has been widely discussed in the early literature, mainly because of an increase of interest in the long-run from both macroeconomists and microeconomists. While there are different approaches for dealing with these types of panel data, the one estimation which is widely used is the first-difference generalized methods of moments or the Arellano-Bond estimator (AB) (Arellano and Bond, 1991; based on the work of Holtz-Eakin *et al.*, 1988). This approach provides a consistent estimator and it is based on a two-step version, which is asymptotically efficient. Other important estimations used for dynamic panel data are the Within-groups estimator (WG), the Common Correlated Effects (CCE) approach by Pesaran (2006), and the Bayesian estimation by Hsiao *et al.* (1999). A newer estimation, and the one in which we are interested, is the Integrated Nested Laplace Approximation (INLA) approach (Rue *et al.*, 2009) based on a pure Bayesian approach.

The main objective of this paper is to assess the performance of the estimators of the parameters of a dynamic panel data model computed from a (pure) Bayesian approach through several simulations. We are particularly interested in the performance of these estimators on a very small panel and, specifically, when the standard assumptions of the dynamic panels are violated, in particular, the presence of spatial (i.e. cross-section) and temporal dependence. We complete our work with an application, based on the dynamic panel used by Maynou *et al.* (2013), where we evaluate the convergence dynamics of the core-periphery among the eurozone countries.

Our hypothesis is that the hierarchical strategy of the Bayesian approach (INLA), implying different prior and hyper-prior assignments, provides a greater flexibility to the estimation procedure. This leads to the control of the biases associated with dynamic panel data models i.e., individual effects bias, dynamic panel bias and state dependence. We believe that this control enables consistent estimations of the parameters to be obtained and is at least as efficient as the other estimators commonly used in dynamic panel data models (e.g., the AB estimator).

Following this introduction, in section two we describe the specification and the estimation of the model. We continue with a detailed explanation of the Bayesian approach (INLA) in section three, and in sections four and five we explain the simulations and the application, respectively. The results are shown in section six and we conclude in section seven.

2.- Specification and estimation of the model

Let us start by specifying the following dynamic panel data model,

$$y_{it} = x_{t}^{'}\beta_{l} + \rho_{l}\, y_{i,t-1} + u_{t} \qquad [1]$$

where y_{it} denotes the dependent variable of the individual i (i=1,…,N), at time t (t=1,…,T); x_{it} is a Kx1 vector of explanatory variables (it contains a one, i.e. the intercept); u_{it} is an error term; and β and ρ are unknown parameters. The subscript l can be i, t or both.

We assume that: i) the model is linear. In other words, the error term u is normally distributed. For simplicity, we assume that the error has zero mean and constant variance, σ_u^2; ii) the explanatory variables are exogenous (or weakly exogenous) and; iii) the parameters vary over individuals; l=i, and/or over time, l=t. In fact, we specify the model as a random coefficient model.

This is to say, $\theta = (\beta_l, \rho_l)'$ and $\theta_l = \theta + \alpha_l$, where α_l denotes an error term also.

Initially, we also assume that: the error term u is independently and identically over t (no serial autocorrelation) (assumption 1a) and; independently and identically over i (no cross-section dependence) (assumption 1b).

The simplest method for estimating model [1] is least squares, i.e. Pooled Least Squares (PLS). As is known, even though all assumptions were met, PLS estimates will be biased and inconsistent (Bond, 2002). The problem is that although $E(\alpha_l x_{it}')_l = 0$ was fulfilled, this would not be the case for the lagged dependent variable, i.e. $E(\alpha_l y_{i,t-1})_l \neq 0$. However, if $T \to \infty$ PLS estimates will be consistent (Pesaran and Smith, 1995). Nevertheless, when T is small, even with a large N estimates can be severely biased (Hsiao *et al.*, 1999).

Alternative estimation methods are well known. One such method is the Within-groups estimator (WG), which is also called the fixed-effects estimator. The individual effect is cancelled out by a demeaning process which subtracts the individual's mean value of the dependent, $y_{it} - \bar{y}_{i.}$, and each explanatory variable, , where and denotes the mean of yit and xit, over time. The WG estimation is then, the PLS estimation of the demeaned dynamic panel data model.

A technical problem with this estimator is that the parameters associated with time-fixed explanatory variables cannot be estimated. An even more crucial problem is the dynamic panel bias (Nickell, 1981). The demeaning process creates a correlation between the regressor and the error term. As a consequence, the estimate of ρ (the parameter associated with the lagged dependent variable) is biased and this bias is not mitigated by increasing N. In fact, the limit of $(\hat{\rho} - \rho)$ as $N \to \infty$ will be approximately $\frac{-(1+\rho)}{(T-1)}$. That is to say, even with reasonable T (i.e. 10 to 20, for instance) the bias will be of a sizeable value.

As a solution, the first difference generalized methods of moments or Arellano-Bond estimator (AB) (Arellano and Bond, 1991) has been widely used. The AB estimator first takes first differences to eliminate the individual effect, i.e. $y_{it} - y_{i.t-1}$ and $x_{it} - x_{i,t-1}$ and, in a second step using internal instruments, solves the dynamic panel bias by a generalized method of moments (GMM) estimator. That is to say, for t=3, $y_{i,1}$ will be a valid instrument (it is correlated with $y_{i,2} - y_{i,1}$ but not with $u_{i,3} - y_{i,2}$); for t=4, $y_{i,2} - y_{i,1}$ will be a valid instrument, and so on for all available T. In this paper we used the two-step GMM estimator, consistent in the same way as the one-step GMM, but asymptotically efficient (Arellano and Bond, 1991).

As the number of instruments is quartic in T, with small T we would not have had enough data to estimate such a matrix and, therefore, we would have had some problems with efficiency. Furthermore, Roodman (2009) points out that the high number of instruments can overfit endogenous variables.

When the coefficient associated with the lagged dependent variable tends to one, GMM estimators may have relevant small sample bias and may be inefficient (known as the weak instrument problems) (Blundell and Bond, 1998). Alternatively, Blundell and Bond (1998) propose a system GMM estimator, where a system of equations is estimated by adding equations in levels to first difference equations. However, Lucchetti *et al.* (2001) show that in empirical applications the AB estimates are more robust than the system GMM, especially with small sample size and when the two-step procedure is followed.

The Common Correlated Effects (CCE) approach by Pesaran (2006) is robust in different types of cross section dependence, possible unit roots and slope heterogeneity. The problem is that CCE was not proposed for dynamic panel data models. Very recently, Chudik and Pesaran (2013) have extended CCE to the case where the panel includes a lagged dependent variable and/or weakly exogenous explanatory variables. However, Chudik and Pesaran (2013) consider a panel with suitably large N and T. Although they propose jackknife and recursive de-meaning bias correction procedures to deal with small T bias of estimators, they point out that they can only mitigate such bias.

Consistent estimation of a dynamic panel data model was also addressed from a Bayesian perspective. Within the Bayesian approach it is easy to specify a hierarchical structure on the (observable) data and (unobservable) parameters; all of which are considered random quantities. A three-stage hierarchical strategy is followed where the dependent variable is distributed around a mean value that depends on regressors and some parameters, i.e. priors. In turn, these priors are distributed around a mean value that depends on (random) hyper-parameters (or hyper-priors).

The benchmark for the Bayesian estimation of dynamic panel data models is the estimator developed by Hsiao *et al.* (1999). This estimator has been derived under the assumption that the initial observation of the dependent variable, y_{i0}, is fixed constants, uncorrelated with unit-specific coefficients (i.e. α_1). The problem is that, with finite T, this assumption does not hold because of state dependence (Anderson and Hsiao, 1981, 1982). However, Hsiao *et al.* (1999) show that, even in this case, the use of a Bayesian approach performed fairly well in the estimation of the mean parameters (Hsiao and Pesaran, 2008).

Under the Bayesian perspective, Zhang and Small (2006), building on the Hsiao *et al.* (1999) estimator, allow the initial values to be correlated with the unit-specific coefficients and impose stationarity on the unit-specific AR(1) coefficients. Their approach provides good estimates even when T is small.

3.- The Integrated Nested Laplace Approximation (INLA) approach

Among the many alternatives in the (pure) Bayesian framework, we followed the Integrated Nested Laplace Approximation (INLA) approach (Rue *et al.*, 2009). In particular, our problem could be specified modelling the mean (of the dependent variable) for the it-th unit, $\mu_{it} = E(y_t)$, by means of an additive linear predictor, defined on the identity scale (Blangiardo *et al.*, 2013),

$$\mu_{it} = \sum \beta_m x_{m,t} + \sum f_l(z_{l,t})$$

where β denotes the parameters that do not vary between individuals or over time; and f a collection of functions defined in terms of a set of explanatory variables z. Varying the form of f, it is possible to accommodate both random effects and spatio-temporal adjustment (Rue *et al.*, 2009). The vector of parameters is represented by $\theta = \{\beta, f\}$. Note that all parameters are treated as random.

In keeping with Schrödle and Held (2011), in the INLA approach the models are built as Bayesian two-stage hierarchical models. The first stage is the observational model, $p(y|\theta)$, where y denotes the vector of observations of both the dependent and the explanatory variables, and θ are the unknown parameters. We assumed a Gaussian Markov random field (GMRF) prior on θ, $p(\theta|\psi)$, with mean 0 and a precision (inverse of the variance) matrix Q. The second stage is given by the 'hyperparameters' ψ and their respective prior distribution $p(\psi)$.

We are interested in the posterior marginals of the GMRF, i.e. $p(\theta_i|y)=\int_\psi p(\theta_i|\psi,y)p(\psi|y)d\psi$ that we approximate using the following finite sum

$$\tilde{p}(\theta_i|y)=\sum_k \tilde{p}(\theta_i|\psi_k,y)\tilde{p}(\psi_k|y)\Delta_k \qquad [2]$$

where $\tilde{p}(\theta_i|\psi_k,y)$ and $\tilde{p}(\psi_k|y)$ denote approximations of $p(\theta_i|\psi,y)$ and $p(\psi|y)$, respectively. The finite sum [2] is evaluated at support points ψ_k using appropriate weights Δ_k.

The posterior marginal $p(\psi|y)$ of the hyperparameters is approximated using a Laplace approximation (Tierney and Kadane, 1986).

$$p(\psi|y)=\frac{p(\theta,\psi|y)}{p(\theta|\psi,y)}\propto\frac{p(\psi)p(\theta|\psi)p(y|\theta)}{p(\theta|\psi,y)}\approx\left.\frac{p(\psi)p(\theta|\psi)p(y|\theta)}{\tilde{p}(\theta|\psi,y)}\right|_{\theta=\theta^*(\psi)}=\tilde{p}(\psi|y)$$

where the denominator $\tilde{p}(\theta|\psi,y)$ denotes the Gaussian approximation of $p(\theta|\psi,y)$ and $\theta^*(\psi)$ is the mode of the full conditional $p(\theta|\psi,y)$ (Rue and Held, 2005).

According to Rue *et al.* (2009), it is sufficient to "numerically explore" this approximate posterior density using suitable support points Δ_k in [4]. In this paper, these points are defined in the h-dimensional space, using the strategy known as 'central composite design'. Centre points are augmented with a group of star points which allow the curvature of $\tilde{p}(\psi|y)$ to be estimated (Rue *et al.*, 2009).

To approximate the first component of [2], we used here a 'simplified Laplace approximation'; less expensive from a computational point of view and with only a slight loss in accuracy (Schrödle and Held, 2011; Rue *et al.*, 2009; Martino and Rue, 2010). Finally, we specified minimally informative priors on the log of the precision of all hyperparameters, i.e. log Gamma (1,0.0005).

4.- Simulation studies

We simulated four dynamic panel data models with two scenarios each, balanced and unbalanced. For the balanced scenario, data consisted of 200 individuals (N=200). In total, NT=1000 observations. 5 observations were simulated for each individual (T=5). For the unbalanced scenario, data consisted of 200 individuals at time 1 (N_1=200), 192 individuals at time 2 (N_2=192), 171 individuals at time 3 (N_3=171), 146 individuals at time 4 (N_4=146) and 101 at time 5 (N_5=101). There were no entries of individuals in any of the five periods. In total, (N_1+ N_2+ N_3+ N_4+ N_5)T=NT=820 observations.

There were two explanatory variables. One of the variables, xi, was discrete, fixed in time, and was simulated as 200 draws of a Poisson distribution with mean 2 (range 0-6). The other, $x2_{it}$, was continuous, time-varying, and was simulated as 5 independent sets of N draws of Gaussian distribution with mean 5 and standard deviation equal to 1. In the unbalanced scenario we only considered data for the individuals present in the simulations.

In all simulations we allowed for the initial observation of the dependent variable to be correlated with unit-specific coefficients.

Simulation 1. Non spatial or temporal dependence. Fulfilment of assumptions 1a and 1b

$$y_{it} = \beta_{0i} + \beta_1 x1_i^{'} + \beta_2 x2_t + \rho y_{i,t-1} + u_t \qquad [3a]$$

$$\beta_0 = 5 + \eta_i \qquad \beta_1 = 0.5 \qquad \beta_2 = 0.9 \qquad \rho = 0.3$$

In this simulation we allowed that the intercept to vary over individuals but was fixed on time (known as ‘random effects’ model). The error term of the random intercept, η, was simulated as 200 draws of Gaussian distribution with mean zero and standard deviation equal to 1. The error term, u_{it}, was simulated as N*T draws of a standard Gaussian distribution.

Simulation 2. Spatial dependence. Violation of assumption 1b.

$$y_{it} = \beta_{0i} + \beta_1 x1_i^{'} + \beta_2 x2_t + \rho y_{i,t-1} + S_i + u_t \qquad [3b]$$

$$\beta_0 = 5 + \eta_i \qquad \beta_1 = 0.5 \qquad \beta_2 = 0.9 \qquad \rho = 0.3$$

S_i were random effects capturing the spatial (i.e. cross-section) dependence. In fact, we simulated that individuals were located in a Gaussian Field. First, we considered that individuals were located on a square within area one, and with the density in bottom left corner being higher than that of the top right corner (Figure 1a). Second, using the NxN matrix of distances between the points, we computed a Matérn covariance matrix (Figure 1b) and, third, we simulated one realization of a multivariate standard Gaussian distribution.

The Matérn correlation function was specified as (R INLA, 2013):

$$Corr(d) = \frac{1}{2^{\nu-1}\Gamma(\nu)}(\kappa d)^{\nu} \mathrm{K}_{\nu}(\kappa d)$$

where d denoted the distance between two points; K_{ν} was the modified Bessel function; and $\Gamma(.)$ the Gamma function. For the simulation we set $\kappa = 7; \nu = 1$; the marginal variance of the field, $\sigma_s^2 = 5$; and the nugget parameter $\sigma_\varepsilon^2 = 0.3$.

Simulation 3. Serial autocorrelation and spatial dependence Violation of assumptions 1a and 1b.

$$y_{it} = \beta_{0i} + \beta_1 x1_i^{'} + \beta_2 x2_t + \rho y_{i,t-1} + S_i + \phi u_{t-1} + \varepsilon_t \qquad [3c]$$

$$\beta_0 = 5 + \eta_i \qquad \beta_1 = 0.5 \qquad \beta_2 = 0.9 \qquad \rho = 0.3 \quad \phi = 0.5$$

We simulated an autoregressive of order one, AR(1), for the error term ($\phi = 0.5$). In this case ε it was a white-noise error term.

Simulation 4. Random coefficients model, serial autocorrelation and spatial dependence (violation of the assumptions 1a and 1b)

$$y_{it} = \beta_{0i} + \beta_1 x1'_i + \beta_2 x2_{it} + \rho_t y_{i,t-1} + S_i + \phi u_{t-1} + \varepsilon_{it} \qquad [3d]$$

$$\beta_0 = 5 + \eta_i \qquad \beta_1 = 0.5 \qquad \beta_2 = 0.9 \qquad \rho_t = 0.3 + \upsilon_t \qquad \phi = 0.5$$

The parameter associated with the lagged dependent variable varied over time (known as 'random coefficient' model). η was simulated as T draws of Gaussian distribution with mean zero and standard deviation equal to 0.1.

All models were estimated by PLS, WG, AB (two-step GMM) and the INLA approach. In the estimations by PLS, WG and AB, we adjusted for the temporal dependence present in models [3c] and [3d], including time dummies. In the estimation of all models by AB we chose the option of the robust inference of the covariance matrix, i.e. the heteroskedasticity-consistent covariance matrix (White, 1980 and 1984). In the context of panel data, this option is also consistent versus serial autocorrelation (Croissant and Millo, 2008).

For the adjustment of spatial dependency in the INLA approach, we followed the recent work of Lindgren *et al.* (2011), and specified a Matérn structure (Stein, 1999). In short, we used a representation of the Gaussian Markov Random Field (GMRF) explicitly constructed through stochastic partial differential equations (SPDE) and which has as a solution a Gaussian Field (GF) with a Matérn covariance function (Lindgren *et al.*, 2011). To sum up, instead of using the Matérn in a regular lattice, which is the usual practice and would imply an estimation with a high computational cost as well as one that would be weak in terms of efficiency (Lindgren *et al.*, 2011), we specified the structure of the spatial Matérn covariance in a triangulation (Delaunay triangulation – Hjelle and Daehlen, 2006) of the studied area (Figure 1c) which means a low computational cost and, more importantly in our context, much greater efficiency. Temporal dependency was approximated through an autoregressive of order 1, linked to the random effect associated with a linear trend.

All analyses were made with the free software R (version 3.0.1) (R Development Core Team, 2013), through the plm Package (WG and AB) (Croissant and Millo, 2008) and the INLA library (The R-INLA project, 2013; Rue *et al.*, 2009).

5.- Application

As an application, we consider the dynamic panel used by Maynou *et al.* (2013). Our main objective there was to evaluate the convergence dynamics of the core-periphery among the eurozone countries. Our hypothesis was that, as a result of the policies implemented to establish the European Monetary Union, the eurozone countries began a process towards convergence and, as a consequence, the distance between core-periphery countries has been reduced during the past decade. However, we supposed that this convergence was not the same for all countries or throughout the whole period analyzed.

In Maynou *et al.* (2013), we only considered regions in the seventeen European Union countries that represent the eurozone. In particular, we used the 174 regions (NUTS 2 level) of these 17 EU countries; from 1990 to 2009 (additional details can be found in Maynou *et al.*, 2013).

Models were specified based on the well-known beta-convergence hypothesis (Baumol, 1986; Barro and Sala-i-Martin 1991, 1992; Sala-i-Martin 1996), originally specified as a cross-section model:

$$g_T = \alpha + \beta y_0 + u \qquad\qquad u \sim N\left(0, \sigma_u^2 I\right) \qquad\qquad [4]$$

where g_T denoted the vector of (dependent variable) average growth rate in the period *(0,T)*; y_0 was the vector of (dependent variable) initial levels; u was a zero-mean and homoskedastic (σ_u^2 was the constant variance) normally distributed disturbance term; and α and β denoted (unknown) parameters.

The absolute β-convergence hypothesis (equation [4]) rests on the assumption that there is a negative correlation between the initial level (of the dependent variable) and the growth rate (of such variable). Therefore, β–convergence exists if the estimated value for β, the coefficient of interest, is (statistically significant) negative. If this is true, poorer economies (periphery) grow faster than richer ones (core) and will catch them up in the long run.

However, it is more reasonable to assume that a negative correlation exists between growth rate and, rather than level, the distance the level of the dependent variable is from its steady state equilibrium. Therefore, poorer regions do not necessarily grow faster than richer regions, because the latter may be even further from their steady state equilibria (Baumont *et al* 2002). So, in this paper we use the conditional specification of the β-convergence hypothesis:

$$g_T = \alpha + \beta y_0 + X\gamma + u \qquad\qquad u \sim N\left(0, \sigma_u^2 I\right) \qquad\qquad [5]$$

where X is a matrix of explanatory variables (of convergence); and γ the associated (unknown) parameters.

Here, we considered one of the dependent variables used by Maynou *et al.* (2013), Gross Domestic Product per inhabitant in PPS (GDPPC) (data from 1995 to 2009).

As explanatory variables we considered only real and not nominal variables. Once the country met the criteria of nominal convergence and adopted the Euro, changes in price levels would be (theoretically) temporary and would be controlled by the European Central Bank. Changes in price levels would only distort the analysis. Owing to the difficulty in obtaining some variables at a regional level, we also considered a few variables at the country level. We primarily use economic variables, but we also use variables representing the level of education. In this way we try to distinguish the most specific characteristics of the country or region.

Regional level

Gc: Gross fixed capital formation	This consisted of resident producers' acquisitions, fewer disposals of fixed assets during a given period plus certain additions to the value of non-produced assets realized by the productive activity of producer or institutional units (European System of Accounts). It was measured in millions of euro.

Unempl: Unemployment rate	Ratio of unemployed (both sexes) over active population.
Youngunempl: Young unemployment rate	Ratio of youth (15-24 years old) unemployed (both sexes) over youth active population.
Empf: Female employment rate	Ratio of female employed over active population.
Empht: High-tech employment	Employment in technology and knowledge-intensive sectors (thousands of employees).
Sec: Percentage of secondary students	Ratio of the sum of level 2 students (lower secondary or second stage of basic education), level 3 students (upper secondary education) and level 4 students (post-secondary non-tertiary education) over total population.
Univ: Percentage of university students	Ratio of the sum of level 5 and 6 students (tertiary education) over total population.

Country level

Exports: Export rate	Ratio of the value of exported goods and services over the country's GDP.
Imports: Import rate	Ratio of the value of imported goods and services over the country's GDP.
Bpg: External balance	The ratio of exported goods minus imported goods over the country's GDP.
Pubexp: Public expenditure rate	Ratio of goods and services bought by the State over the country's GDP.

In contrast to more standard studies, we did not specify cross-section but rather spatio-temporal models, i.e., dynamic panel data. In fact, we would like to explicitly consider the time dimension in our data. As we argued, our hypothesis states that, as a result of the policies implemented to establish the European Monetary Union (from 1999 onwards) the eurozone countries began a process towards convergence. In addition, the convergence rate may have been different for each country and/or have varied during the period under analysis.

In particular, we specified the following dynamic panel data model:

$$\frac{GDPPC_{ijt} - GDPPC_{ijt-1}}{GDPPC_{ijt-1}} = \alpha_j + \beta_t \log(GDPPC_{ijt-1}) + \gamma_1 \log(empht_{ijt}) + \gamma_2 \log(\sec_{ijt}) + \gamma_3 \log(univ_{ijt}) + \gamma_4 \log(unempl_{ijt}) +$$
$$\gamma_5 \log(g_{ijt}) + \gamma_6 \log(youngunempl_{ijt}) + \gamma_7 \log(empf_{ijt}) + \gamma_8 \log(\text{exports}_{jt}) + \gamma_9 \log(\text{imports}_{jt}) +$$
$$\gamma_{10} \log(pub\exp_{jt}) + \gamma_1\, bpg_{jt} + u_{ijt}$$

[6]

where *i* denoted region *(i=1,…,174)*; *j* country *(j=1,…,17)*; *t* year *(t=1995 1996,…, 2009)*; *α*, *β* and γ denoted unknown parameters; and u, the normally distributed disturbance term.

Some of the coefficients, and in particular the coefficient of interest, *β*, had subscripts. In fact, we specified (dynamic) random coefficient panel data models (Hsiao and Pesaran, 2008) or, in mixed models terminology, we allowed (some of the) coefficients to be random effects (Pinheiro and Bates, 2000). In other words, we allowed them to be different for the various levels we considered. Thus, for example, the coefficient of interest, *β*, varied per year, $\beta_t = \beta + \nu_t$.

Models were estimated by PLS, WG, AB (two-step GMM) and INLA. As above, for AB we chose the option of the robust inference of the covariance matrix. In estimating with AB, we considered all available and admitted lagged GDP PPS per capita, from lag 2 onwards. Previously, we tested the consistency (i.e. the exogeneity) of these instruments by means of the Sargan test (Sargan, 1958; Bowsher, 2002; Arellano, 2003).

In the case of INLA, we specified random effects in both the intercept and in the conditional convergence rate. When the random effects varied by country (the intercept) we assumed they were identical and independent Gaussian random variables with constant variance, i.e. $\upsilon_j \sim N\left(0,\sigma_\upsilon^2\right)$. When the random effects varied by year, we assumed a random walk of order 1 (i.e. independent increments) for the Gaussian random effects vector (although we also assume a constant variance) (R INLA, 2013). For PLS, WG and AB, we allow the interaction between time and the coefficient of the lagged GDP PPS per capita.

For the adjustment of the spatio-temporal dependence in PLS, WG and AB, we introduced time and also country dummies. In the case of INLA we proceeded as explained above.

6.- Results

Results of the simulation

The results of the estimation are shown in Tables 1 and 2 and Figures 2 to 5. With the estimate of the parameter of interest, which is associated with the lagged dependent variable, we set it equal to 0.3 and lower bias was obtained with INLA estimation, in both balanced and unbalanced scenarios (Figures 2a, 3a, 4a and 5a). Note that, perhaps with the exception of simulation 3, i.e. random intercept and serial autocorrelation and spatial dependence (Figure 4a), the INLA estimation is also the most efficient, because it is the one that provides a lower (95%) credibility/confidence interval. However, note that in simulation 3, the INLA estimation is at least as efficient as that of AB.

PLS, WG and AB estimators behave as theoretically expected and, as we explained above, with only the exception of AB (and PLS) in simulation 2. When all the assumptions are fulfilled, i.e. there is neither temporal nor spatial dependence and only the intercept is allowed to vary over individuals in the dynamic panel data model, the AB estimate of the parameter of interest is very biased. Note that in this case, the PLS estimate is unbiased and only slightly less efficient than the INLA estimate.

As regards to the parameter associated with the continuous time-varying variable, in all cases the (95%) confidence/credibility intervals contain the true value of the parameter (that we set equal to 0.9). In this case, although the bias, measured as the difference from the true value of the parameter, is similar in the INLA and the AB estimates, greater efficiency is obtained with the INLA estimation.

In all cases, there seems to be no difference between the balanced and unbalanced scenarios, at least as regards the bias (again, measured as the difference from the true value of the parameter). However, note that in the unbalanced scenario in all cases the estimation is less efficient.

Finally, with respect to the residual standard error, $\hat{\sigma}_u$, note that the lowest estimated is obtained with WG, in both scenarios, followed by INLA in the balanced scenario and AB in the unbalanced scenario.

Results of the application

The dynamic panel data model of the application is, in fact, very similar to simulation 4. That is to say, we have a random coefficient model where the intercept varies over countries and the coefficient of interest varies over time, with serial autocorrelation and spatial dependence. Unlike the simulation, however, the area under study is much more irregular (compare Figure 6 with Figure 1c). Considering that the number of regions differs greatly between eurozone countries (Figure 6b), we actually faced a very unbalanced panel.

The results of the estimation are shown in Table 3. With the exception of PLS, we estimate that in the period considered there was (conditional) convergence, as the estimator of β is negative and statistically significant. Leaving aside PLS, the (95%) confidence/credibility intervals overlap (Table 3a). As in the simulation, the INLA estimator has been the most efficient. Note that in this case, however, the AB estimator is in fact much more inefficient than INLA. As we find in the simulation, the residual standard error was lower in WG, followed, in this case, by INLA.

In Table 3b, we show the deviations from the estimate of β, fixed effects in the case of PLS, WG and AB, and random effects in the case of INLA. For INLA we find years that the (conditional) convergence rate was lower than average (1997-1998 and 2000) and others in which this rate was higher (2003, 2008-2009).

7.- Concluding remarks

The results of the simulations seem to confirm our hypothesis. That is to say, the greater flexibility of the INLA estimation, a consequence of its hierarchical strategy, and as it is a Bayesian approach, this leads to better control of the biases associated with dynamic panel data models.

This control has allowed us to obtain estimates of the parameter of interest (i.e. that associated with the lagged dependent variable) with less bias and greater efficiency than the other estimators considered (PLS and WG and, more importantly, in the most commonly used estimator in dynamic panel data models (i.e. the AB estimator). In particular, at least with respect to the parameter of interest, INLA estimation proved to be superior to not only dynamic models commonly used in panel date, but also to AB.

For other parameters, although we have not found whether the INLA estimate is clearly superior to the AB in terms of bias, we have found that INLA has provided more efficient estimations.

Application results corroborate the findings of the simulations, in particular simulation 4, i.e., the random coefficient model with serial autocorrelation and spatial dependence. In this case, the INLA estimation is much more efficient than any other estimates, including AB. This finding may be a consequence of having a very unbalanced panel in the application, which would, as we have found in the simulations, increase relative inefficiency. The inefficiency of the other estimates, AB in particular, may be also a consequence of the area under study being very irregular. This irregularity leads, on one hand, to a serial autocorrelation that could not be captured by means of standard linear models (AR or MA) and, on the other hand, to spatial dependence and, above all, spatial heterogeneity. In fact, it is known that AB (and the system GMM) is designed for situations with autocorrelation and heteroskedasticity within individuals units' errors, but not across them (Baum, 2006).

Furthermore, the INLA approach (in fact, all the estimators under the Bayesian approach) allows us to easily make inferences on the unit-specific coefficients, for instance, variation in time and/or between individuals of the conditional convergence rate; an aspect that frequentist alternatives are unable to perform.

In any case, we believe that the INLA approach has shown its superiority, at least for efficiency, with respect to other consistent estimates of the parameters of (small) dynamic panel data models.

Conflicts of Interest

There are no conflicts of interest for any of the authors. All authors disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organisations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

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Table 1. Results of the simulation. Balanced scenarios.

	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\rho}$	$\hat{\sigma}_u$	$\hat{\sigma}_{\beta 0}$	$\hat{\sigma}_S$	$\hat{\sigma}_{Trend}$	$\hat{\sigma}_\rho$	$\hat{\phi}$
Model 3a.- Non spatial nor temporal dependence										
PLS	4.7855 (4.0562, 5.5147)	0.5238 (0.4484,4.8608)	0.9416 (0.8395,1.0438)	0.3136 (0.2752,0.3519)	1.4773					
WG			0.8194 (0.7341,0.9047)	0.0531 (0.0207,0.0855)	0.8973					
AB			0.9126 (0.7626,1.0626)	0.5765 (0.4963,0.6566)	1.5314					
INLA	5.0129 (4.5313,5.4944)	0.5351 (0.4350,0.6312)	0.9314 (0.8521,1.0106)	0.2950 (0.2826,0.3074)	1.1690	0.8763				
Model 3b. Spatial dependence										
PLS	6.2667 (5.0947,7.4386)	0.6040 (0.4748,6.3959)	0.9375 (0.7582,1.1168)	0.1955 (0.1423,0.2488)	2.5924					
WG			0.7716 (0.5823,0.9610)	-0.0657 (-0.1220,-0.0094)	1.9995					
AB			0.9327 (0.6432,1.2222)	0.2616 (0.1594,0.3638)	2.9108					
INLA	5.0129 (4.5313,5.4944)	0.5331 (0.4350,0.6312)	0.9314 (0.8521,1.0106)	0.2950 (0.2826,0.3074)	2.5657	1.1277	4.2685			
Model 3c. Serial autocorrelation and spatial dependence										
PLS	6.7732 (5.5741,7.9723)	0.5875 (0.4566,6.9042)	0.9305 (0.7507,1.1103)	0.5301 (0.3177,0.7425)	2.5980					
WG			0.7472 (0.5608,0.9335)	-0.1930 (-0.2677,-0.1183)	1.9593					
AB			0.9235 (0.6342,1.2128)	0.2565 (0.1546,0.3584)	2.9125					
INLA	7.5917 (4.9978,10.1959)	0.5594 (0.4342,0.6872)	0.9226 (0.7623,1.0828)	0.2446 (0.1576,0.3239)	2.5498	1.2408	3.7570	1.7013		0.4776 (0.2989,0.9397)
Model 3d. Random coefficients model, serial autocorrelation and spatial dependence										
PLS	5.6283 (4.4244,6.8322)	0.5966 (0.4653,5.7596)	0.9347 (0.7546,1.1148)	0.2169 (0.1558,0.2780)	2.6022					
WG			0.8183 (0.6110,1.0256)	0.1101 (0.0539,0.1664)	2.1906					
AB			0.9265 (0.6376,1.2155)	0.2590 (0.1555,0.3625)	2.9203					
INLA	5.5036 (4.3028,6.6843)	0.5185 (0.4039,0.6332)	0.9313 (0.7704,1.0921)	0.3322 (0.2884,0.3756)	2.5773	1.0627	3.8769	2.1066	0.1054	0.4891 (0.2981,0.9868)

Within brakets 95% confidence interval (credibility interval for INLA)

Source: own construction

Table 2. Results of the simulation. Unbalanced scenarios.

	$\hat{\beta}_0$	$\hat{\beta}_1$	$\hat{\beta}_2$	$\hat{\rho}$	$\hat{\sigma}_u$	$\hat{\sigma}_{\beta 0}$	$\hat{\sigma}_S$	$\hat{\sigma}_{Trend}$	$\hat{\sigma}_\rho$	$\hat{\phi}$
Model 3a.- Non spatial nor temporal dependence										
PLS	5.1969 (4.3695,6.0243)	0.5624 (0.4767,5.2826)	0.9161 (0.8005,1.0317)	0.2873 (0.2435,0.3310)	1.4836					
WG			0.8163 (0.7176,0.9149)	0.0457 (0.0078,0.0835)	0.8571					
AB			0.9145 (0.7242,1.1048)	0.5803 (0.4710,0.6896)	1.1804					
INLA	5.4508 (4.8495,6.0517)	0.5704 (0.4508,0.6899)	0.9086 (0.8072,1.0100)	0.2740 (0.2486,0.3194)	1.3799	1.0339				
Model 3b. Spatial dependence										
PLS	6.2719 (5.0293,7.5144)	0.6199 (0.4811,6.4107)	0.9346 (0.7445,1.1246)	0.1932 (0.1367,0.2497)	2.5995					
WG			0.7725 (0.5712,0.9739)	-0.0702 (-0.1307,-0.0097)	1.9784					
AB			0.9379 (0.6166,1.2593)	0.2616 (0.1447,0.3785)	2.5860					
INLA	5.0815 (4.0880,6.0673)	0.5492 (0.4240,0.6743)	0.9454 (0.7748,1.1158)	0.2800 (0.2534,0.3068)	2.5940	1.3753	5.2546			
Model 3c. Serial autocorrelation and spatial dependence										
PLS	7.1024 (5.7527,8.4521)	0.6130 (0.4643,7.2511)	0.8945 (0.6928,1.0961)	0.5021 (0.2488,0.7554)	2.5863					
WG			0.7249 (0.5100,0.9397)	-0.2257 (-0.3145,-0.1369)	1.8564					
AB			0.8976 (0.5271,1.2681)	0.2536 (0.1158,0.3913)	2.2360					
INLA	9.6446 (4.3208,13.7512)	0.6854 (0.4886,0.8819)	0.8830 (0.7112,1.0546)	0.2314 (0.1353,0.3773)	2.5086	1.3413	4.5619	3.1797		0.6439 (0.1090,0.9549)
Model 3d. Random coefficients model, serial autocorrelation and spatial dependence										
PLS	5.9986 (4.6396,7.3575)	0.6077 (0.4587,6.1476)	0.8995 (0.6973,1.1018)	0.2085 (0.1383,0.2787)	2.5938					
WG			0.8007 (0.5623,1.0391)	0.0795 (0.0130,0.1459)	2.0786					
AB			0.9065 (0.5339,1.2790)	0.2501 (0.1135,0.3867)	2.2416					
INLA	5.7202 (4.0495,7.1732)	0.6696 (0.5279,0.8193)	0.8884 (0.7150,1.0615)	0.3500 (0.2847,0.3977)	2.5622	1.1868	5.4505	4.8685	0.1464	0.5220 (0.1608,0.9330)

Within brakets 95% confidence interval (credibility interval for INLA)

Source: own construction

Table 3a.- Application. Estimation of the coefficient of interest β.

	$\hat{\beta}$	**95% Confidence Interval**	**Residual standard error**
PLS	1.8523	(-0.0084, 3.7130)	2.2036
Within	-5.2389	(-9.4558, -1.0222)	1.9943
AB	-2.4720	(-4.9336, -0.0097)	2.9791
INLA	-1.3154	(-1.8649, -0.7638)[1]	2.6409

[1] 95% Credibility interval

Source: own construction

Table 3b.- Application. Deviations from the estimate of the parameter of interest β.

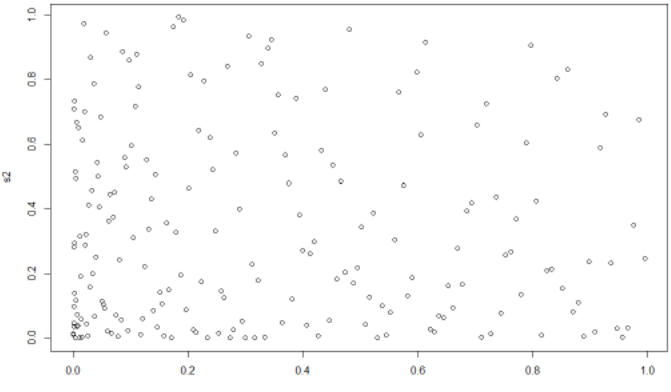
	$\hat{\beta}$ **(95% Confidence interval)**			
	PLS	**WG**	**AB**	**INLA**[1, 2]
1997	NS	NS	NS	0.2837 (0.1036, 0.4708)[1]
1998	NS	NS	NS	0.2290 (0.0497, 0.4150)[1]
1999	NS	NS	NS	NS
2000	2.6048 (0.3648, 4.8447)	3.7732 (1.4992, 6.0472)	NS	0.2975 (0.1340, 0.4600)[1]
2001	NS	NS	NS	NS
2002	NS	NS	NS	NS
2003	NS	NS	NS	-0.2964 (-0.4613, -0.1340)[1]
2004	2.8885 (0.6487, 5.1284)	NS	NS	NS
2005	NS	NS	NS	NS
2006	NS	NS	NS	NS
2007	NS	NS	NS	NS
2008	-3.6667 (-6.9038, -0.4296)	NS	NS	-0.2177 (-0.3841, -0.0543)[1]
2009	NS	NS	NS	-0.8901 (-1.0685, -0.7184)[1]

[1] Random effects estimated with the INLA approach, [2] 95% Credibility interval

Source: own construction

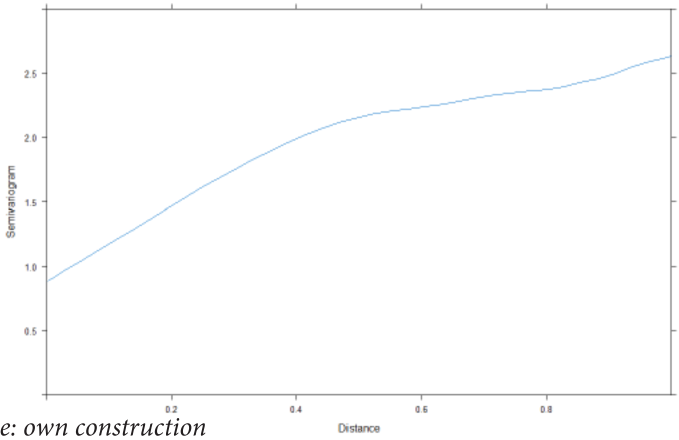
Figure 1.- Simulated Gaussian Field

Figure 1a.- Location of the individuals on space



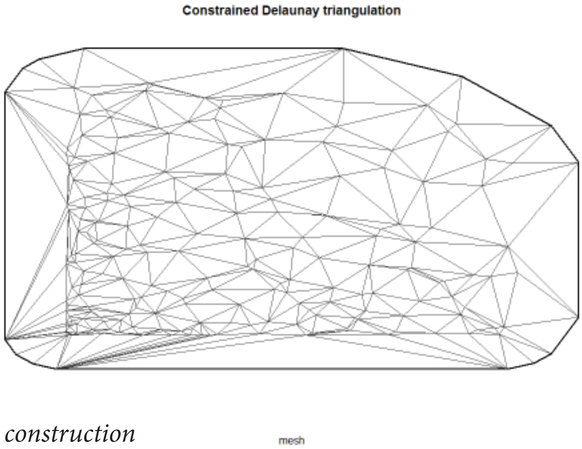
Source: own construction

Figure 1b.- Semivariogram. Matérn covariance matrix



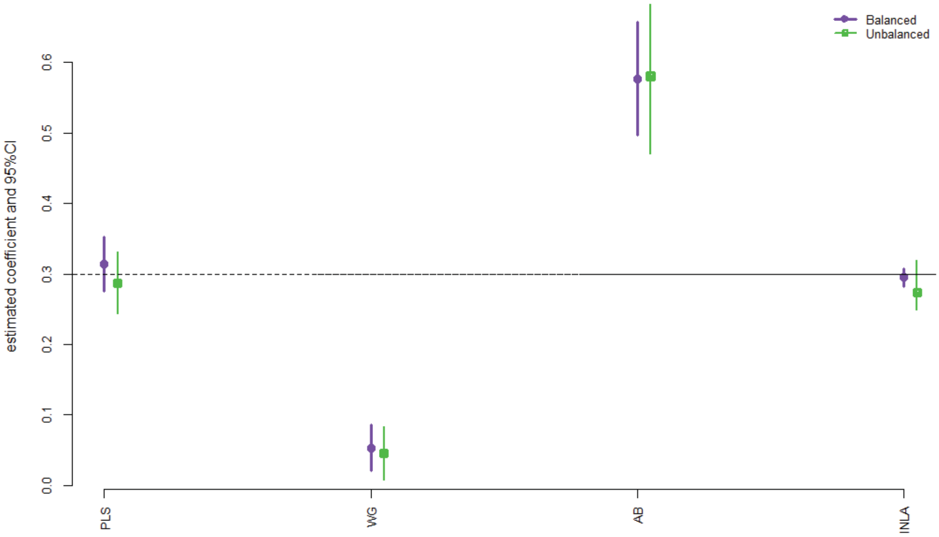
Source: own construction

Figure 1c.- Mesh



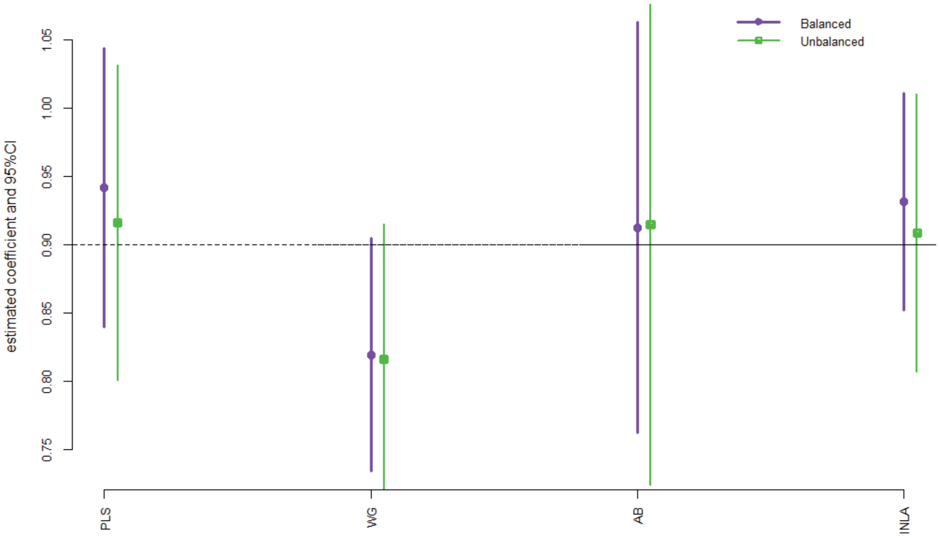
Source: own construction

Figure 2a.- Parameter estimate associated with the lagged dependent variable. Dynamic panel data model. Random intercept. Non spatial or temporal dependence



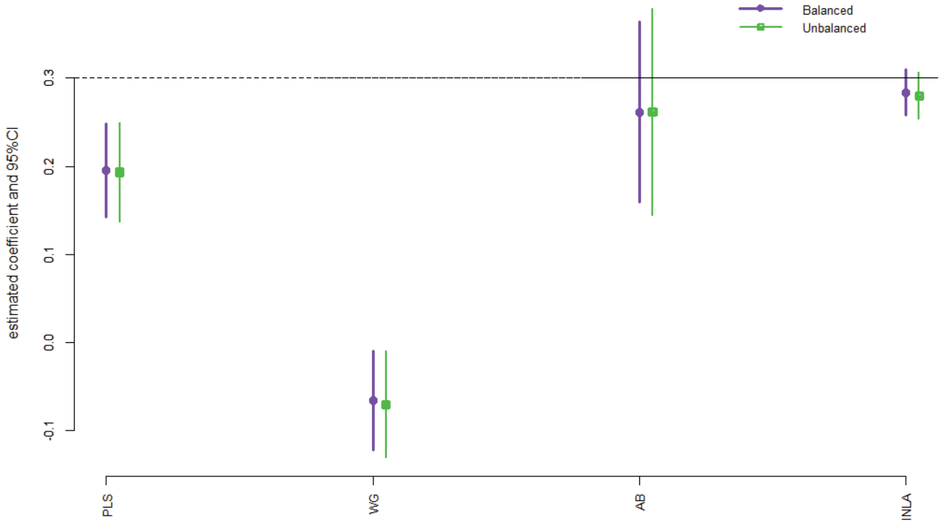
Source: own construction

Figure 2b.- Parameter estimate associated with the continuous time-varying variable. Dynamic panel data model. Random intercept. Non spatial or temporal dependence



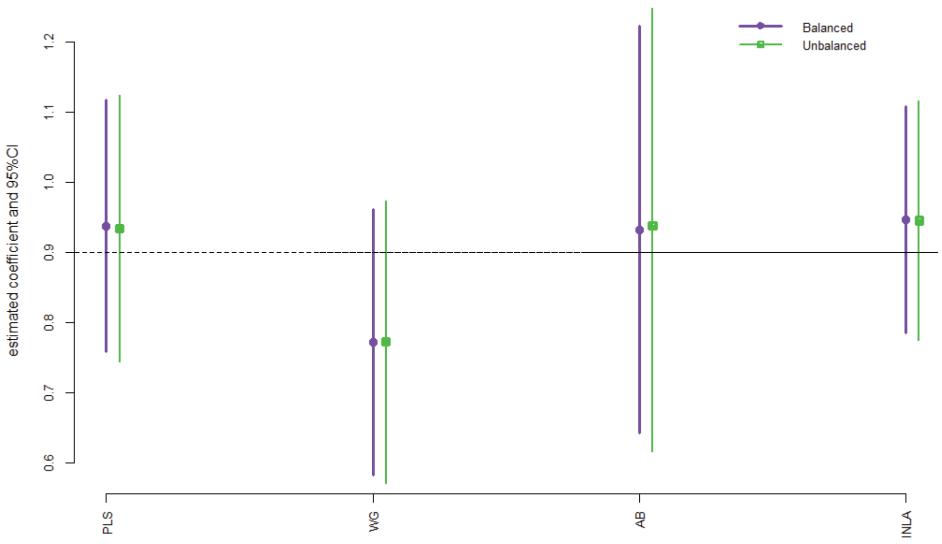
Source: own construction

Figure 3a.- Parameter estimate associated with the lagged dependent variable. Dynamic panel data model. Random intercept. Spatial dependence



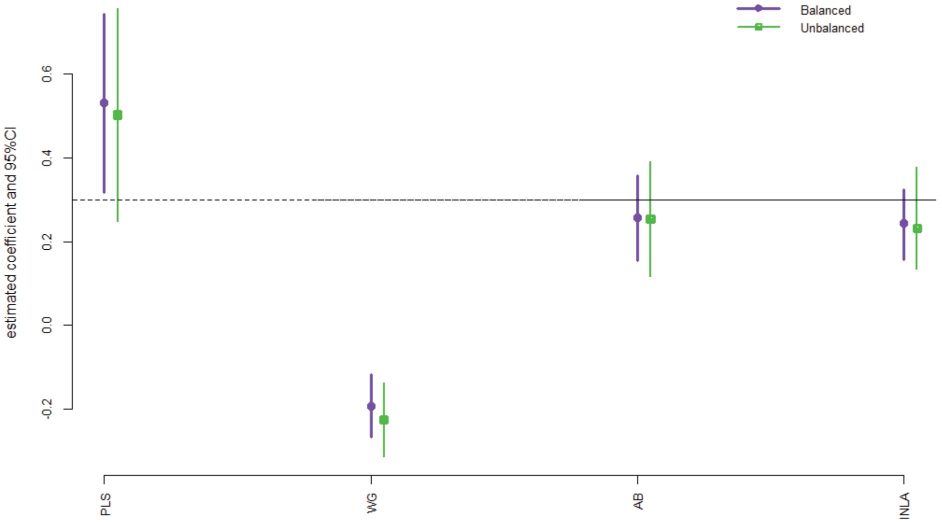
Source: own construction

Figure 3b.- Parameter estimate associated with the continuous time-varying variable. Dynamic panel data model. Random intercept. Spatial dependence



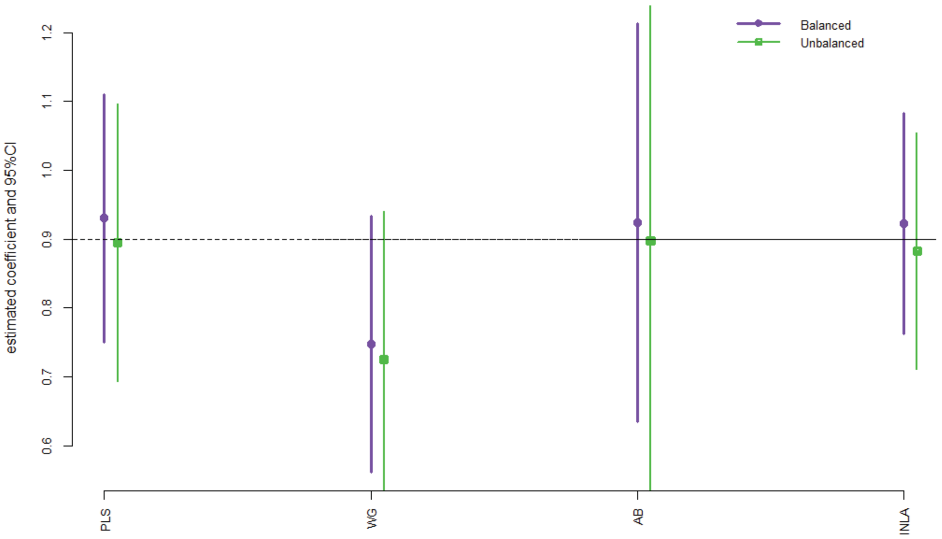
Source: own construction

Figure 4a.- Parameter estimate associated with the lagged dependent variable. Dynamic panel data model. Random intercept. Spatial dependence and serial autocorrelation



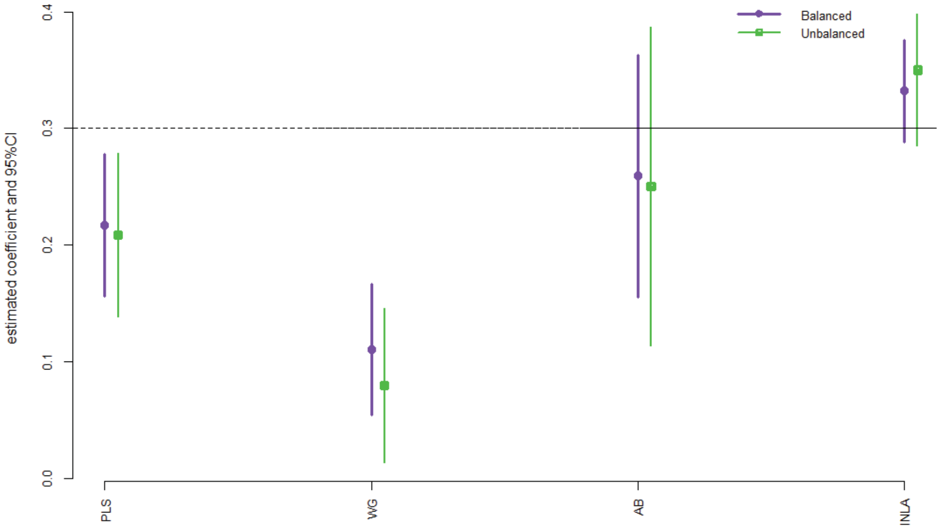
Source: own construction

Figure 4b.- Parameter estimate associated with the continuous time-varying variable. Dynamic panel data model. Random intercept. Spatial dependence and serial autocorrelation



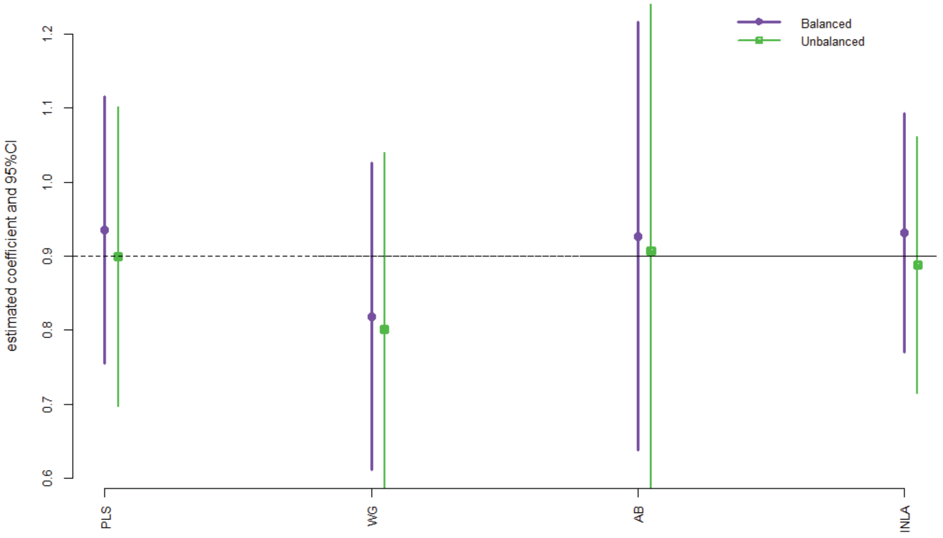
Source: own construction

Figure 5a.- Parameter estimate associated with the lagged dependent variable. Dynamic panel data model. Random intercept and random parameter associated with lagged dependent variable. Spatial dependence and serial autocorrelation



Source: own construction

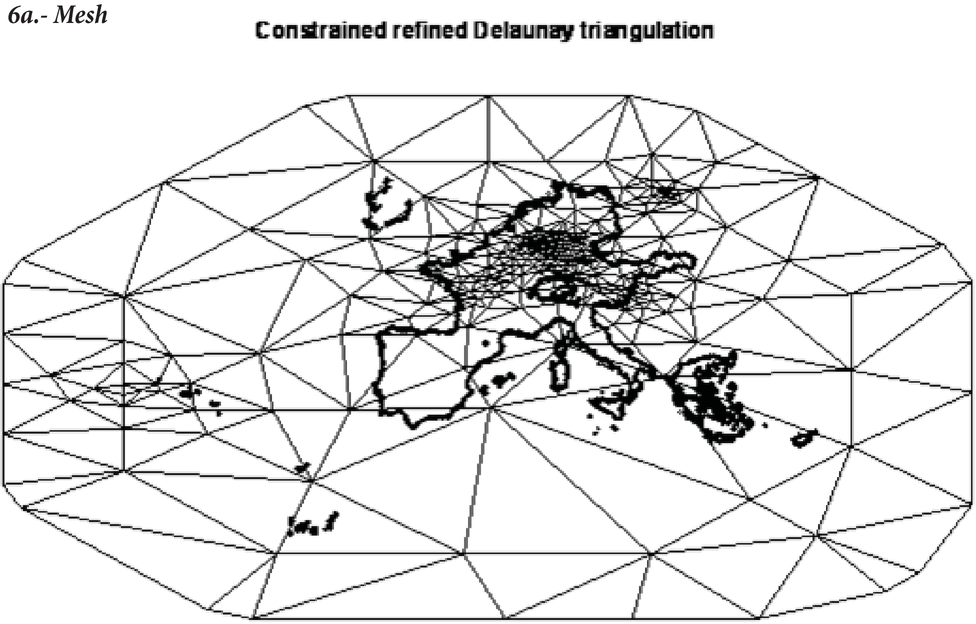
Figure 5b.- Parameter estimate associated with the continuous time-varying variable. Dynamic panel data model. Random intercept and random parameter associated with lagged dependent variable. Spatial dependence and serial autocorrelation



Source: own construction

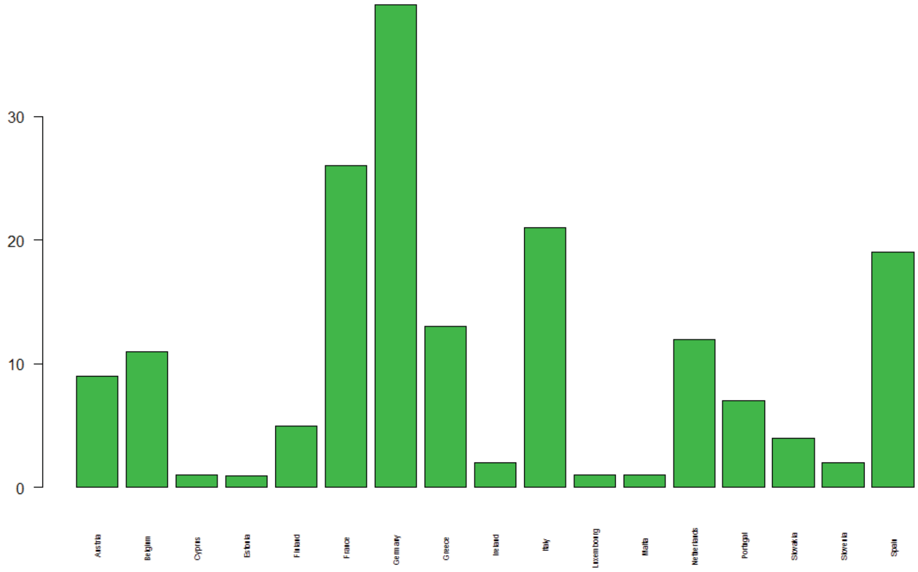
Figure 6.- Mesh and number of regions by country of the eurozone

6a.- Mesh



Source: own construction

6b.- Number of regions



Source: own construction

Conclusions

Specific objective 1.- Our results show significant convergence in terms of GDP per capita across the eurozone countries, whereas, they show significant divergence in terms of productivity. We corroborate our hypothesis, as the patterns of convergence are not significant on a regional level, but they are on a country level. This can be explained by the policy implementation on a national level, instead of a regional one.

Specific objective 2.- The Structural and Cohesion funds have positively contributed to the GDP per capita growth of the regions or countries which have received them. These funds have favoured the less developed areas of the eurozone by increasing their GDP per capita and facilitating their path towards convergence. However, public and private debt has increased in the past twenty years; which can be explained by way of the principles of partnership and additionality.

Specific objective 3.- The results show that the distance between core-periphery has been reduced in recent years (mainly from 2004 onwards), as the core diverged while the periphery converged. It seems, therefore, that our hypothesis holds i.e., eurozone membership spurred on the growth of the periphery countries, leading to convergence. However, the core countries growth slowed which, in turn, prompted a divergence from the rest of the eurozone countries. This unexpected finding could be due to the market reforms that the core countries needed to adopt in 2003. We also computed the sigma-convergence for the core and periphery. In economic terms large disparities still exist within areas.

Specific objective 4.- In an effort to look beyond income we focus on health and find that there has been a catching-up process among the EU regions. Surprisingly, however, we find no reduction, on average, in dispersion levels. So, we can state that we find beta-convergence, but we do not find sigma-convergence. This is in line with the fact that we find significant differences in terms of time and regions. So, disparities in health among regions within the EU still exist.

Specific objective 5.- We demonstrate, through several simulations, that the Integrated Nested Laplace Approximation (INLA) approach, used to estimate the dynamic panel models designed in our papers, is superior, in terms of bias and efficiency, to other consistent estimation methods for dynamic panel data model.

By summing up the specific objectives, we can reach a conclusion for our general objective. The main impetus for this thesis was to evaluate the reduction of economic and social disparities in the European Union from 1990-2010. Through different dynamic panel models, we have shown that in simple economics terms there has been a catching-up process within the eurozone and that the distance between the core-periphery has been reduced. However, in terms of disparities, significant economic differences across the eurozone regions still exist. In an attempt to go beyond economic terms, we showed that the EU countries also catch-up in terms of health, while in terms of sigma-convergence there are still significant inconsistencies among the EU regions. Consequently, if the reduction of dispersion is the ultimate measure of convergence, as various authors have agreed (e.g. Quah, 1993), then our overall study shows a lack of convergence across EU regions in terms of economics and health.

This thesis can be concluded by saying that, even if the policies implemented to reduce the disparities among the regions and countries forming the Union have managed a caching-up process between the regions, they have not been far-reaching enough to reduce the existing inequalities. Consequently, the foremost priority of the Union, social and economic cohesion, has not yet been achieved. An effort must be made at all levels, from the top (EU) to the bottom (regions), to reduce the large inequalities that still exist in the Union today. It is not an easy goal but it is a worthwhile one and it would be highly constructive if each and every one of the EU countries came together, acknowledged the importance of working together and started a process of moving together, not only in economic terms, but also, and sometimes more importantly, in social terms.

Notwithstanding the important findings in this thesis, we did have to confront some limitations during our analysis. The main restriction can be attributed to the lack of data. As were unable to find all the regional level data from 1990 to 2010, we were somewhat restrained when choosing the appropriate data for each of our econometric model. Besides, even if we proved that the approach used to estimate the dynamic panel models was superior (in bias and efficiency) to other consistent estimation methods, there are still some restraints. One condition is the fulfilment of the hypothesis of weak exogeneity that completely affects the consistency of the estimates. To meet this requirement, the error terms should be identically and independently distributed once the spatio-temporal adjustment has been made. Another stipulation, mainly related to Bayesian methods, is the choice of the prior. As explained in the methods sections of the papers, in the specification of the priors, we have followed the default options of the INLA approach with some modifications. In our work, we specified minimally informative priors). Although we show that results were in fact robust to the choice of them, other models or, more likely, the modelling of non-continuous dependent variables could imply the use of other priors.

This thesis is merely the starting point for further fundamental research into an extensive analysis of European policy evaluation. The foremost conclusions of this work are that EU policies have not helped to reduce the inequalities among the EU regions. Thus, it would be worthwhile to proceed even further to see just what can be done to change the effect of these policies. I would like to extend my research by using these results to design and explain how such analysis could be used as a tool for policy evaluation. More ambitiously, I would like to use the results of such investigation to design future policies that aim to reduce inequalities at EU and regional levels. While this may not be an easy goal to reach, we can endeavour to outline and define alternative regional policies which will improve the current situation, for example, policies that shape education or plans that improve the labour market by making it more flexible and accessible. It is time to re-evaluate our approach because present-day policies have yet to reduce the inequalities that still exist among regions nowadays.

Και Πες μου αυτό, πρέπει να είναι απολύτως ασφαλή,

αυτό το site που έχω φτάσει, είναι πραγματικά Ιθάκη;

“And tell me this: I must be absolutely sure. This place
I’ve reached, is it truly Ithaca?”. *Homer, The Odyssey*

“And tell me this: I must be absolutely sure.
This place I’ve reached, is it truly Ithaca?”.

Homer, The Odyssey