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Σ-convergence revisited

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Abstract

Referring to the diachronic decrease of the overall dispersion of a regional dataset, σ-convergence is a dominant concept in the empirical regional convergence / divergence literature. The paper revisits the σ-convergence concept, expressing the, "classical", coefficient of variation (CV) and weighted coefficient of variation (wCV) formulas against the backdrop of the median. To this end, the paper specifies and proposes a pair of, "alternative", formulas for apprehending the σ-convergence concept. Such an endeavor stems from the, purely, statistical rationale that the mean is a central tendency measure highly sensitive to the eventual presence of outliers. The theory-driven propositions of the paper are supported from an illustrative empirical analysis of regional inequalities in France, at the NUTS III spatial level, for the period 2001-2013. The findings of the paper provide valuable insight to both theory and policy-making, indicating that different expressions of the σ-convergence concept may lead to different inferences with respect to regional inequalities.

Key words: *regional inequalities, σ-convergence, coefficient of variation, weighted coefficient of variation, mean, median*

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1. Introduction

Fueling the relative academic debate and providing insight to the evaluation of the relative policies, the evolution of regional inequalities is an issue of utmost importance (Islam 2003, Kostov and Le Gallo 2015, Artelaris and Petrakos 2016). Hence, the study of regional inequalities - in particular, the study of regional convergence[1] / divergence in terms of per capita Gross Domestic Product (GDP)[2] - is at the heart of regional science. From the policy viewpoint, the study of regional convergence / divergence may interpret as a sign with respect to the evaluation of the effectiveness and the efficiency of the implemented regional policy mix. Regional policy, aims, precisely, at reducing the level of regional inequalities in a growth-enhancing economic environment. From the theory viewpoint, the study of regional convergence / divergence may serve as an empirical exercise with respect to the affirmation of regional development theories. Questioning the position of the neoclassical theory that (regional) inequalities are bound to diminish with growth through the activation of market-emanating convergence mechanisms[3] in a policy-free environment, theories with sharply different policy implications, such as the endogenous (new) growth theory (Romer 1986, Lucas 1988, *inter alia*) and the new economic geography theory (Krugman 1991, Fujita 1993, *inter alia*), stress the argument[4] that growth is a spatially selective and cumulative process.

Referring to the diachronic decrease of the overall dispersion of a regional dataset, σ-convergence (Barro and Sala-i-Martin 1992) is a dominant concept in the empirical regional convergence / divergence literature.[5] Σ-convergence may, usually, apprehend through the coefficient of variation (CV) and the weighted coefficient of variation (wCV) formulas.[6] CV is a standardized (relative) measure of dispersion and may express as the ratio of the standard deviation of a regional dataset to the corresponding arithmetic mean (henceforth: mean), at a given date (Barro and Sala-i-Martin 1992). Including a

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[1] Intuitively, the term (regional) “convergence” suggests a process whereby poor(er) (regional) economies catch-up to rich(er) ones (Abreu et al. 2005).

[2] Customarily, this is the variable under consideration in the empirical regional convergence / divergence literature.

[3] Particularly, the neoclassical convergence mechanisms are the diminishing marginal productivity of capital (Solow 1956, Swan 1956, *inter alia*), the comparative advantage in interregional trade (Heckscher 1919/1991, Ohlin 1933/1966, *inter alia*) and the interregional production factors movement (Borjas 1979, Greenwood et al. 1991, *inter alia*).

[4] Bringing earlier theories regarding the operation of economic space (Perroux 1955, Myrdal 1957, Hirschmann 1958, *inter alia*) back to the forefront.

[5] Usually, σ-convergence is examined together with β-convergence. The concept of β-convergence refers to the relation between the levels of a regional dataset at a given date and the consequent corresponding growth rates for a given period, either in an unconditional (i.e. absolute) or in a conditional (i.e. *ceteris paribus*) fashion (Baumol 1986, Barro 1991, Barro and Sala-i-Martin 1992, Sala-i-Martin 1996). Β-convergence is a necessary (though not sufficient) condition for σ-convergence (Barro and Sala-i-Martin 1995).

[6] Σ-convergence may, also, apprehend through the mean logarithmic deviation (Dalgaard and Vastrup 2001). Gini coefficient (Gini 1912), Theil index (Theil 1967) and Atkinson index (Atkinson 1970) fall, also, within the σ-convergence rationale.

weighting factor in the CV formula (Petrakos and Artelaris 2009), so as to account for the corresponding relative regional size[7] in the treatment of the regional dataset, allows for the compilation of the wCV, the weighted CV counterpart.

The paper revisits the σ-convergence concept, expressing the, “classical”, CV and wCV formulas against the backdrop of the median (i.e. the central tendency measure that separates the higher half of the regional dataset from the corresponding lower one). To this end, the paper specifies and proposes a pair of, “alternative”, formulas for apprehending the σ-convergence concept. Particularly, next to the CV formula, the paper specifies and proposes the CV-median (CVmd) formula. CVmd is a standardized measure of dispersion that may express as the ratio of the standard deviation of a regional dataset to the corresponding median, at a given date. Correspondingly, next to the wCV formula the paper specifies and proposes the wCV-median (wCVmd) formula. Apparently, wCVmd is the weighed CVmd counterpart. Such an endeavor stems from the, purely, statistical rationale that the mean is a central tendency measure highly sensitive to the eventual presence of outliers. The theory-driven propositions of the paper are supported from an illustrative empirical analysis of regional inequalities in France, at the NUTS[8] III spatial level, for the period 2001-2013, on the basis of per capita GDP and (relative) population data obtained from EUROSTAT.

The paper proceeds as follows. The next section highlights the drawbacks of the “classical” CV and wCV formulas. The third section introduces the, “alternative”, CVmd and wCVmd formulas for the apprehension of σ-convergence. The fourth section provides the empirical assessment of the level and the evolution of regional inequalities in France, at the NUTS III spatial level, for the period 2001-2013, on the basis of both the “classical” and the “alternative” expressions of σ-convergence. The last section offers the conclusions and discusses the inferences with respect to regional inequalities.

2. The “classical” formulas of σ-convergence

CV and wCV are (ones among) the “classical” formulas for apprehending the σ-convergence concept (Barro and Sala-i-Martin 1992, Petrakos and Artelaris 2009).

CV (see equation 1.1) is a standardized (relative) measure of dispersion and may express as the ratio of the standard deviation of a regional dataset to the corresponding mean, at a given date. CV takes values within the interval [0, $\sqrt{n-1}$][9], from perfect

[7] Customarily, in terms of relative population i.e. the ratio of the regional to the corresponding country population.

[8] NUTS (Nomenclature des Unités Territoriales Statistiques; Nomenclature of Territorial Units for Statistics) is a EUROSTAT geocode standard for referencing the subdivisions of European Union (EU) countries for statistical purposes.

[9] In essence, given than the number of regions may reach infinity, the upper value of CV may reach infinity.

(regional) equality to perfect (regional) inequality.[10] Increasing (decreasing) values of the CV diachronically, evince an increase (a decrease) of (regional) inequality.

$$CV_{c,t} = \frac{\sqrt{\sum_{r=1}^{n}\left[\frac{(Y_{r,t} - \overline{Y_{r,t}})^2}{n}\right]}}{\overline{Y_{r,t}}}$$ *(equation 1.1)*,

where CV is the CV(-mean), Y is the variable under consideration, $\bar{Y}$ is the mean of the variable under consideration, Σ denotes sum, r stands for regions, n is the number of regions, t stands for time (date), c stands for country.

wCV (see equation 2.1) is a standardized (relative) measure of dispersion and may express as the ratio of the standard deviation of a regional dataset to the corresponding mean, at a given date, accounting for an included weighting factor in the treatment of the regional dataset. wCV takes values within the interval [0, n-1][11], from perfect (regional) equality to perfect (regional) inequality.[12] Increasing (decreasing) values of the wCV diachronically, evince an increase (a decrease) of (regional) inequality.

$$wCV_{c,t} = \frac{\sqrt{\sum_{r=1}^{n}[w_{r,t} \times (Y_{r,t} - \overline{Y_{r,t}})^2]}}{\overline{Y_{r,t}}}$$ *(equation 2.1)*,

where wCV is the weighted CV(-mean), Y is the variable under consideration, $\bar{Y}$ is the mean of the variable under consideration, Σ denotes sum, r stands for regions, n is the number of regions, t stands for time (date), c stands for country, w is the weighting factor.

Even though both CV and wCV comply with the vast majority of the axioms (properties) of inequality indicators[13] (Monfort 2008), they are subject to the criticism, stemming from a, purely, statistical rationale, that the mean is a central tendency measure highly sensitive to the eventual presence of outliers (i.e. regional dataset values extremely distant from the other corresponding values). This is so as the calculation of the mean is not based on any measure concerning position, and this is not without effect on standard deviation. Particularly, extremely high values connote fat- (i.e. with positive kurtosis) and right-tailed (i.e. with positive skewness) distributions[14], whereas extremely

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[10] When the mean is equal to 0, CV is not defined. In the case of using per capita GDP data, this means that CV is not defined in the theoretical case that each region under consideration has zeroed per capita GDP.

[11] In essence, given than the number of regions may reach infinity, the upper value of wCV may reach infinity.

[12] When the mean is equal to 0, wCV is not defined. In the case of using per capita GDP data, this means that wCV is not defined in the theoretical case that each region under consideration has zeroed per capita GDP.

[13] An inequality indicator should comply with the axioms (properties) of (Litchfield 1999, Monfort 2008, Cowell 2011, *inter alia*): a) the Pigou-Dalton transfer principle: the inequality indicator increases in response to a mean-preserving spread (Pigou 1912, Dalton 1920), b) the income scale independence: the inequality indicator is invariant to uniform proportional increases or decreases (Cowell 1999), c) the principle of population: the inequality indicator is invariant to replications of the population (Dalton 1920), d) anonymity (symmetry): the inequality indicator is dependent only on the variable in terms of which inequalities are measured (Amiel and Cowell 1994), and e) decomposability: the inequality indicator may be broken down into constituent parts (Bourguignon 1979).

[14] Such as the t-student, the Poisson and the Laplace distributions.

low values connote thin- (i.e. with negative kurtosis) and left-tailed (i.e. with negative skewness) distributions[15]. Thus, given the fact that such outliers represent actual, and not erroneous, regional values (that, usually, correspond to metropolitan and to outermost regions), turning to the use of the truncated mean (i.e. discarding the outliers and then taking the mean of the remaining regional dataset values) or, simply, assuming a normal distribution of the regional dataset values[16] are not risk-free, and beyond critique, methodological choices.

3. Σ-convergence revisited: The "alternative" formulas for apprehending σ-convergence

The paper specifies and proposes a pair of "alternative" formulas for apprehending the σ-convergence concept, expressing the, "classical", coefficient of variation (CV) and weighted coefficient of variation (wCV) formulas against the backdrop of the median. Particularly, next to the CV formula, the paper specifies and proposes the CVmd formula, and, correspondingly, next to the wCV formula, the paper specifies and proposes the wCVmd formula.

CVmd (see equation 1.2) is a standardized measure of dispersion that may express as the ratio of the standard deviation of a regional dataset to the corresponding median, at a given date. CVmd takes values greater than (or equal to) 0, from perfect (regional) equality to perfect (regional) inequality.[17] Increasing (decreasing) values of the CVmd diachronically, evince an increase (a decrease) of (regional) inequality.

$$CVmd_{c,t} = \frac{\sqrt{\sum_{r=1}^{n}\left[\frac{\left(Y_{r,t} - \widetilde{Y_{r,t}}\right)^2}{n}\right]}}{\widetilde{Y_{r,t}}}$$ *(equation 1.2)*,

where CV_{md} is the CV-median, Y is the variable under consideration, $\tilde{Y}$ is the median of the variable under consideration, Σ denotes sum, r stands for regions, n is the number of regions, t stands for time (date), c stands for country.

[15] Such as the Bernoulli distribution.

[16] Given that the variable under consideration is a continuous one, the mean value of distributions with positive kurtosis and positive skewness is higher than the median value, whereas the mean value of distributions with negative kurtosis and negative skewness is lower than the median value. Normal distributions, in contrast, represent perfectly symmetrical distributions so as the mean value is equal to the median (and the mode) value (Gunver et al. 2017). Even though normal distributions rarely exist in nature (Pearson 1920) – this is so especially with economics and social data – it is the most frequently used distribution for explaining continuous variables.

[17] When the median is equal to 0, CVmd is not defined. In the case of using per capita GDP data, this means that CVmd is not defined in the theoretical case that the majority of regions under consideration has zeroed per capita GDP.

wCVmd (see equation 2.2) is a standardized measure of dispersion that may express as the ratio of the standard deviation of a regional dataset to the corresponding median, at a given date, accounting for an included weighting factor in the treatment of the regional dataset. wCVmd takes values greater than (or equal to) 0, from perfect (regional) equality to perfect (regional) inequality.[18] Increasing (decreasing) values of the wCVmd diachronically, evince an increase (a decrease) of (regional) inequality.

$$wCVmd_{c,t} = \frac{\sqrt{\sum_{r=1}^{n}[w_{r,t} \times (Y_{r,t} - \widetilde{Y_{r,t}})^2]}}{\widetilde{Y_{r,t}}}$$ *(equation 2.2)*,

where wCV_{md} is the weighted CV-median, Y is the variable under consideration, $\tilde{Y}$ is the median of the variable under consideration, Σ denotes sum, r stands for regions, n is the number of regions, t stands for time (date), c stands for country, w is the weighting factor.

Both CVmd and wCVmd overcome the drawback of the "classical" CV and wCV formulas. Being in line with the fact that international organizations (EUROSTAT 1999, OECD 2007, World Bank 2016, *inter alia*) perceive the median – and not the mean – as the central tendency measure for defining thresholds, such a methodological suggestion aims at offering an alternative perspective with respect to the empirical assessment of the level and the evolution of regional inequalities.

4. Regional inequalities in France: An illustrative empirical analysis

The theory-driven propositions of the paper are supported from an illustrative empirical analysis of regional inequalities in France, at the NUTS III spatial level, for the period 2001-2013, on the basis of per capita GDP[19] and population data obtained from EUROSTAT.

France, spanning 643,801 km^2, comprises of 101 NUTS III regions (see Appendix and Figure 1), with Mayotte, La Réunion, Guyane, Guadeloupe, and Martinique having the status of overseas regions[20].[21]

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[18] When the median is equal to 0, wCVmd is not defined. In the case of using per capita GDP data, this means that wCVmd is not defined in the theoretical case that the majority of regions under consideration has zeroed per capita GDP.

[19] Per capita GDP is expressed in Purchasing Power Parity per inhabitant (PPP/inh.).

[20] Overseas French regions are integral parts of France and have similar powers to the regions of metropolitan (i.e. European) France.

[21] Saint Pierre and Miquelon has the status of territorial collectivity.

Figure 1: The nomenclature of the NUTS III French regions

Sources: EUROSTAT / Authors' elaboration

During the period under consideration, France exhibits a per capita GDP level ranging from 23,500 PPP/inh. (year 2001) to 29,000 PPP/inh. (year 2013) (see Table 1). Systematically, Mayotte is the poorest French region, whereas Paris, the capital region of France, is the richest French region up to year 2007 and Hauts-de-Seine (i.e. the western inner suburbs of Paris) is the richest French region onwards. The mean value of per capita GDP ranges from 20,557 PPP/inh. (year 2001) to 24,544 PPP/inh. (year 2013), whereas the corresponding median value ranges systematically at lower level, from 19,800 (years 2001 and 2003) to 22,400 (year 2013). Vienne (years 2001 and 2002), Landes (years 2001 and 2006), Cher (year 2002), Jura (years 2002 and 2003), Maine-et-Loire (years 2002, 2004, 2007 and 2008), Corrèze (years 2003, 2009 and 2013), Vosges (year 2004), Oise (years 2005 and 2007), Somme (year 2005), Hautes-Pyrénées (year 2005), Moselle (year 2006), Loire (year 2006), Var (year 2006), Saône-et-Loire (years 2007, 2009 and 2013), Loir-et-Cher (years 2010 and 2012), Haute-Vienne (year 2010 and 2011), and Territoire de Belfort (year 2013) represent, occasionally, the median value.

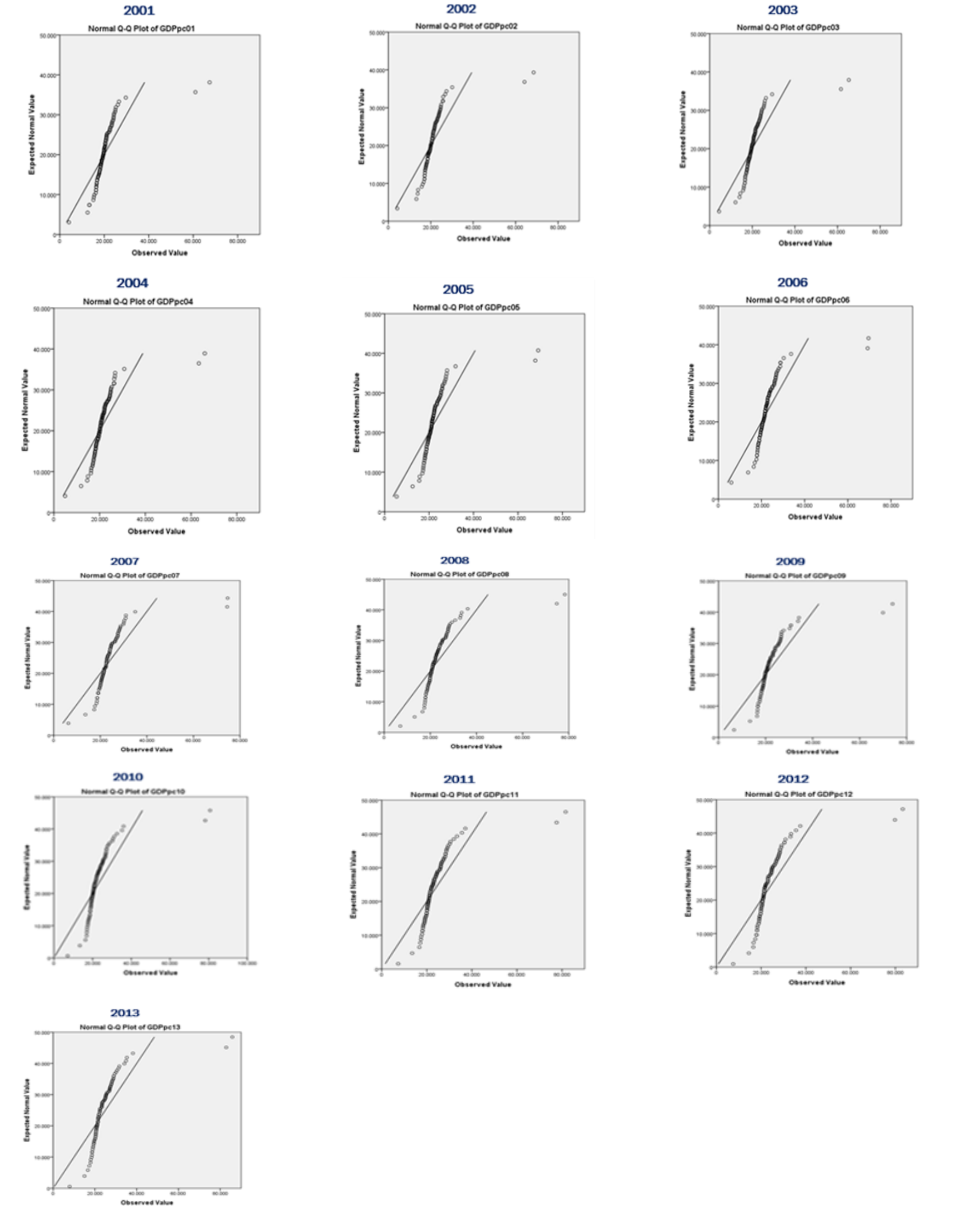
Table 1: The level and the evolution of per capita GDP (p.c. GDP) in France; analysis at the NUTS III spatial level, period 2001-2013

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
p.c. GDP *(PPP / inh.)*	23.500	24.400	23.700	24.500	25.400	26.300	27.600	27.500	26.200	27.400	28.200	28.400	29.000
minimum	*4.100*	*4.200*	*4.400*	*4.900*	*5.400*	*6.000*	*6.300*	*7.000*	*6.600*	*7.100*	*7.300*	*7.500*	*7.900*
	FRA50	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*
maximum	*67.400*	*68.500*	*65.300*	*66.000*	*69.100*	*69.600*	*74.700*	*78.300*	*74.000*	*80.700*	*81.600*	*83.300*	*85.800*
	FR101	*FR101*	*FR101*	*FR101*	*FR101*	*FR101*	*FR101*	*FR105*	*FR105*	*FR105*	*FR105*	*FR105*	*FR105*
mean	*20.577*	*21.338*	*20.782*	*21.483*	*22.280*	*22.999*	*24.097*	*23.547*	*22.509*	*23.233*	*24.043*	*24.072*	*24.544*
median	*19.800*	*20.500*	*19.800*	*20.500*	*21.200*	*21.700*	*22.700*	*22.100*	*20.800*	*21.200*	*22.000*	*21.900*	*22.400*
	FR534 FR613	*FR241 FR432 FR512 FR534*	*FR432 FR631*	*FR414 FR512*	*FR222 FR223 FR626*	*FR413 FR613 FR715 FR825*	*FR222 FR263 FR512*	*FR512*	*FR263 FR631*	*FR245 FR633*	*FR633*	*FR245*	*FR263 FR434 FR631*
outliers (high)	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*6*	*4*	*4*	*4*	*4*	*3*
	FR101 FR105 FR716	*FR101 FR105 FR716*	*FR101 FR105 FR716*	*FR101 FR105 FR716*	*FR101 FR105 FR716*	*FR101 FR105 FR716*	*FR101 FR105 FR716*	*FR101 FR103 FR104 FR105 FR107 FR716*	*FR101 FR105 FR107 FR716*	*FR101 FR105 FR107 FR716*	*FR101 FR105 FR107 FR716*	*FR101 FR105 FR107 FR716*	*FR101 FR105 FR716*
outliers (low)	*1*	*1*	*1*	*2*	*1*	*1*	*2*	*1*	*1*	*1*	*1*	*1*	*1*
	FRA50	*FRA50*	*FRA50*	*FRA30 FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*	*FRA50*

Sources: EUROSTAT / Authors' elaboration

Three high-level outliers are observed during the entire period under consideration: Paris, Hauts-de-Seine and Rhône. Some other regions around Paris join, sporadically, the group of high-level outliers, that is: Val-de-Marne (period 2008-2012), Yvelines (2008), and Essonne (2008). In contrast, Mayotte is a low-level outlier during the entire period under consideration. Guyane is a low-level outlier once (year 2003).

Figure 2: The annual Q-Q plots of the per capita GDP level of the NUTS III French regions, years 2001-2013



Sources: EUROSTAT / Authors' elaboration

The annual Q-Q plots[22] of the per capita GDP level of the NUTS III French regions (see Figure 2) demonstrate that data do not follow the normal distribution. Instead, the annual distributions of the data show positive kurtosis and positive skewness, indicating that the majority of regions considered exhibit per capita GDP level lower than the mean value. Such an observation is considered to be perfectly awaited taking into consideration that systematically, during the entire period under consideration the mean values are higher than the corresponding median values. Moreover, the relative gap between the mean and the median values is, continuously, increasing, from less than 4% (year 2001) to 9% (years 2012 and 2013). This is so as the number of high-level outliers is systematically higher than the corresponding number of low-level outliers.

Table 2: Linear correlation between the per capita GDP (p.c. GDP) level and the (relative) population ((r.)pop.) of the NUTS III French regions, years 2001-2013

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Pearson correlation coefficient (p.c. GDP and (r.)pop.)	0.545	0.544	0.552	0.552	0.555	0.566	0.568	0.597	0.598	0.601	0.601	0.605	0.601

Sources: EUROSTAT / Authors' elaboration

Diachronically, the linear correlation between the per capita GDP level and the (relative) population level of the NUTS III French regions appears to be positive. Particularly, Pearson correlation coefficient[23] (see Table 2) ranges from 0.544 (year 2002) to 0.605 (year 2012). Yet, it is still quite far from being characterized as perfectly positive. Such an observation indicates that the inclusion of the relative population as weighting variable in the assessment of the level and the evolution of regional inequalities may impact on the results.

Towards performing the empirical analysis, the paper estimates both the "classical" (i.e. CV, wCV) and the "alternative" (i.e. CVmd, wCVmd) expressions of σ-convergence (see Table 3 and Figure 3). CV ranges from 0.327 (year 2004) to 0.393 (year 2013) and wCV ranges from 0.514 (years 2004 and 2006) to 0.620 (year 2013). Both CV and wCV record ups (periods 2004-2005, 2006-2008, 2009-2010, and 2011-2013) and downs (periods 2001-2004, 2005-2006, 2008-2009, and 2010-2011), experiencing changes ranging from -1.6 and -3.2 percentage points, respectively (period 2001-2004) to 3.9 and 6.2 percentage points (period 2006-2008), respectively. CVmd ranges from 0.346 (year 2004) to 0.441 (year 2013) and wCVmd ranges from 0.553 (year 2004) to 0.713

[22] Q-Q plot provides a graphical way to determine the level of normality (Wilk and Gnanadesikan 1968).

[23] Pearson correlation coefficient is a measure of the linear correlation of two variables (Pearson 1895). It takes values in the interval [-1, 1], where -1 indicates perfectly negative linear correlation, 0 indicates no linear correlation, and 1 indicates perfectly positive linear correlation.

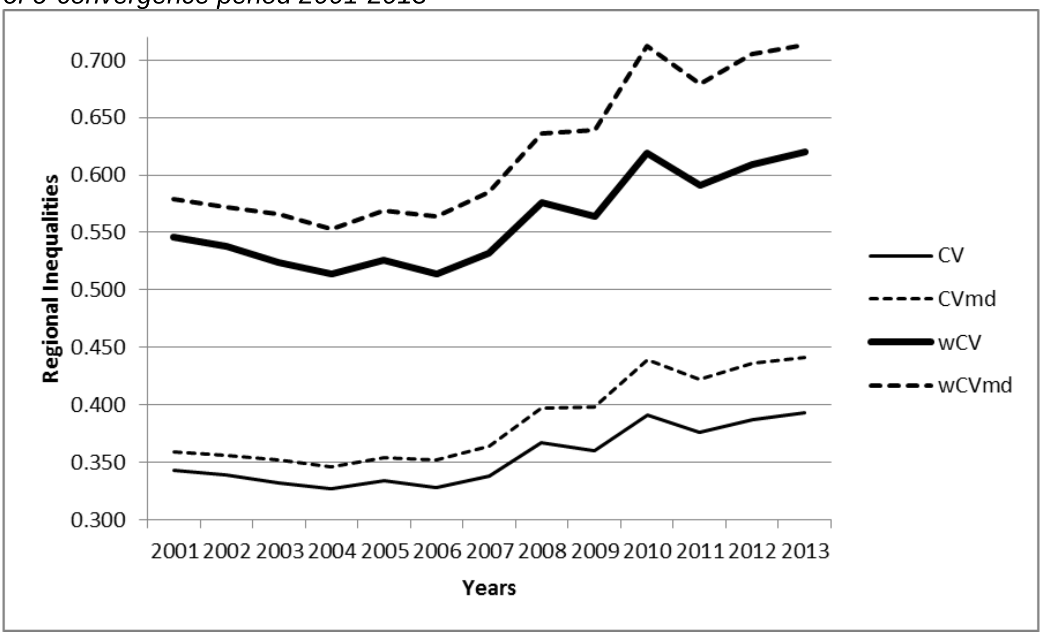
(year 2013). Both CVmd and wCVmd record ups (periods 2004-2005, 2006-2010, and 2011-2013) and downs (2001-2004, 2005-2006, and 2010-2011) as well, experiencing changes ranging from -1.7 and -3.3 percentage points, respectively (period 2010-2011) to 8.7 and 14.8 percentage points (period 2006-2010), respectively.

Table 3: Regional inequalities among the NUTS III regions of France, estimation on the basis of both the "classical" (CV, wCV) and the "alternative" (CVmd, wCVmd) measures of σ-convergence period 2001-2013

		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
non-weighted	CV	0.343	0.339	0.332	0.327	0.334	0.328	0.338	0.367	0.360	0.391	0.376	0.387	0.393
	CVmd	0.359	0.356	0.352	0.346	0.354	0.352	0.364	0.397	0.398	0.439	0.422	0.436	0.441
weighted	wCV	0.546	0.538	0.524	0.514	0.526	0.514	0.532	0.576	0.564	0.619	0.591	0.609	0.620
	wCVmd	0.579	0.572	0.566	0.553	0.569	0.564	0.585	0.636	0.639	0.712	0.679	0.705	0.713

Sources: EUROSTAT / Authors' elaboration

Figure 3: Regional inequalities among the NUTS III regions of France, estimation on the basis of both the "classical" (CV, wCV) and the "alternative" (CVmd, wCVmd) measures of σ-convergence period 2001-2013



Sources: EUROSTAT / Authors' elaboration

The results of the empirical analysis evince that the level of regional inequalities in France appears to be higher in terms of the "alternative", formulas of the σ-convergence concept, comparing to the corresponding "classical" ones.[24] Particularly, the level of regional inequalities is, systematically, higher in terms of CVmd, comparing to the corresponding level in terms of CV, and in terms of wCVmd, comparing to the corresponding level in terms of wCV. Concerning the evolution of regional inequalities, it comes that the pattern is quite similar irrespective of the formula considered. Yet, a closer look indicates that the results are more sensitive, in given per capita GDP and (relative) population changes, against the backdrop of the median. Particularly, even though the median is a central tendency measure not sensitive to outliers, CVmd and wCVmd exhibit higher variability than CV and wCV, respectively. In a nutshell, the illustrative empirical analysis of regional inequalities in France indicates that the estimation of the level and the evolution of regional inequalities with the use of the "classical" formulas of σ-convergence may mask the actual regional problem. This is so as regional inequalities appear to be lower and less sensitive against the backdrop of the mean. Even though sometimes it might be useful to policy-makers, such a discrepancy with the "alternative" formulas of σ-convergence may, in each case, lead to conclusions scientifically misleading.

5. Conclusions and inferences

The paper revisits the σ-convergence concept and specifies the "alternative" CVmd and wCVmd formulas, expressing the "classical" CV and wCV formulas against the backdrop of the median. Such an endeavor stems from the, purely, statistical rationale that the mean is a central tendency measure highly sensitive to the eventual presence of outliers, and is in line with the fact that international organizations perceive the median as the central tendency measure for defining thresholds. The illustrative empirical analysis that supports the theory-driven propositions of the paper, indicates that regional inequalities in France appear to be lower and less susceptible against the backdrop of the mean. Even though, sometimes, such results might be useful to policy-makers, the discrepancy between the "classical" and the "alternative" formulas of σ-convergence may mask the actual regional problem.

[24] The results of the empirical analysis, also, evince that, whilst the corresponding evolution seems to follow a similar pattern, the level of regional inequalities is higher in terms of wCV and wCVmd, comparing to the corresponding CV and CVmd formulas, respectively. In line with the considerations and the arguments of the corresponding literature (Firebaugh 2003, Sala-i-Martin 2003, Tortosa-Ausina et al. 2005, Petrakos and Artelaris 2009), it comes that the inclusion of a weighting factor (the variable of relative population, in particular) in the assessment of the level and the evolution of regional inequalities, indeed, impacts on the results.

Indicating that different expressions of the σ-convergence concept may, in fact, lead to different inferences with respect to regional inequalities, the findings of the paper provide valuable insight to both theory and policy-making. Revisiting the σ-convergence concept, the paper casts strong doubts on the ability of the "classical" formulas to offer results not leading to conclusions scientifically misleading. Even though further empirical research is needed before the marginalization of the "classical" formulas of σ-convergence, the paper sets the ground for provoking the relative debate.

Bibliography

ABREU M., DE GROOT H. L. F. and FLORAX R. J. G. M. (2005), A meta-analysis of b-convergence: The legendary 2, *Journal of Economic Surveys*, 19(3): 389-420.

AMIEL Y. and COWELL F. A. (1994), Income inequality and social welfare, in CREEDY J. (ed.), *Taxation, poverty and income distribution*, Cheltenham: Edward Elgar, 193-219.

ARTELARIS P. and PETRAKOS G. (2016), Intraregional spatial inequalities and regional income level in the European Union: Beyond the inverted-U hypothesis, *International Regional Science Review*, 39(3): 291-317.

ATKINSON A. B. (1970), On the measurement of inequality, *Journal of Economic Theory*, 2: 244-263.

BARRO R. J. (1991), Economic growth in a cross-section of countries, *Quarterly Journal of Economics*, 106: 407-443.

BARRO R. J. and SALA-I-MARTIN X. X. (1992), Convergence, *Journal of Political Economy*, 100(2): 223-251.

BARRO R. J. and SALA-I-MARTIN X. X. (eds.) (1995), *Economic growth*, Boston: McGraw-Hill.

BAUMOL W. (1986), Productivity growth, convergence and welfare: What the long-run data show? *American Economic Review*, 76(5): 1072-1085.

BORJAS G. (1989), Economic theory and international migration, *International Migration Review*, 23(3): 457-485.

BOURGUIGNON F. (1979): Decomposable income inequality measures, *Econometrica*, 47(4): 901-920.

COWELL F. A. (ed.) (2011), *Measuring inequality* (*3rd edition*), New York: Oxford University Press.

COWELL F. A. (1999), Measurement of inequality, in ATKINSON A. B. and BOURGUIGNON F. (eds.), *Handbook of income distribution*, Amsterdam: North Holland, 87-166.

DALGAARD C.-J. and VASTRUP J. (2001), On the measurement of σ-convergence, *Economics Letters*, 70: 283-287.

DALTON H. (1920), The measurement of inequality of incomes, *Economic Journal*, 30: 348-361.

EUROSTAT, *http://ec.europa.eu/eurostat/web/regions/overview* (*last access: May 2017*).

EUROSTAT (ed.) (1999), *European Community Household Panel survey: Selected indicators from the 1995 wave*, Luxembourg: Office for Official Publications of the EC, www.uni-mannheim.de/edz/pdf/eurostat/99/CA-22-99-765-EN-N-EN.pdf (*last access: May 2017*).

FIREBAUGH G. (ed.) (2003), *The new geography of global income inequality*, Cambridge MA: Harvard University Press.

FUJITA M. (1993), Monopolistic competition and urban systems, *European Economic Review*, 37: 308-315.

GINI C. (ed.) (1912), *Variability and mutability*, C. Cuppini: Bologna (*in Italian*).

GREENWOOD M. J., HUNT G. L., RICKMAN D. S. and TREYZ G. I., (1991), Migration, regional equilibrium and the estimation of compensating differentials, *American Economic Review*, 81: 1382-1390.

GUNVER M.G., SENOCAK M. S. and VEHID S. (2017), To determine skewness, mean and deviation with a new approach on continuous data, *PONTE International Journal of Sciences and Research*, 73(2): 30-44.

HECKSCHER E. (1991) [1919], The effect of foreign trade on the distribution of income, in FLAM H. and FLANDERS M. (eds.), *Heckscher - Ohlin trade theory*, Cambridge MA: MIT Press, 43-69.

HIRSCHMANN A. (ed.) (1958), *The strategy of economic development*, New Haven: Yale University Press.

ISLAM N. (2003), What have we learned from the convergence debate? *Journal of Economic Surv*eys, 17: 309-362.

KOSTOV P. and LE GALLO J. (2015), Convergence: A story of quantiles and spillovers, *Kyklos*, 68(4): 552-576.

KRUGMAN P. R. (1991), Increasing returns and economic geography, *Journal of Political Economy*, 99: 183-199.

LITCHFIELD J. A. (1999), Inequality: Methods and tools, *http://siteresources.worldbank.org/INTPGI/Resources/Inequality/litchfie.pdf* (*last access: May 2017*).

LUCAS R. (1988), On the mechanics of economic development, *Journal of Monetary Economics*, 22(1): 3-42.

MONFORT P. (2008), Convergence of EU regions: Measures and evolution, *EU DG for Regional Policy Working Papers*, 1.

MYRDAL G. (ed.) (1957), *Economic theory and underdeveloped regions*, London: Hutchinson.

OECD (ed.) (2007), *Society at a glance 2006: OEDC Social indicators*, Paris: OECD Publishing, http://www.oecd-ilibrary.org/social-issues-migration-health/society-at-a-glance-2006_soc_glance-2006-en (*last access: May 2017*).

OHLIN B. (ed.) (1966) [1933], *Interregional and international trade*, Cambridge MA: Harvard University Press.

PEARSON K. (1895), Notes on regression and inheritance in the case of two parents, *Proceedings of the Royal Society of London*, 58: 240-242.

PEARSON K. (1920), The fundamental problem of practical statistics, *Biometrika*, 13(1): 1-16.

PERROUX F. (1955), Note on the notion of growth poles, *Economic Appliquee*, 1(2): 307-320 (*in French*).

PETRAKOS G. and ARTELARIS P. (2009), European regional convergence revisited: A Weighted Least Squares approach, *Growth and Change*, 40(2): 314-331.

PIGOU A. F. (ed.) (1912), *Wealth and welfare*, London: Macmillan.

ROMER P. M. (1986), Increasing returns and long-run, *Journal of Political Economy*, 94(5): 1002-1037.

SALA-I-MARTIN X. X. (1996), The classical approach to convergence analysis, *Economic Journal*, 106: 1019-1036.

SALA-I-MARTIN X. X. (2003), Keynote speech: Convergence and divergence- theoretical underpinnings, in TUMPEL-GUGERELL G. and MOOSLECHNER P. (eds.), *Economic convergence and divergence in Europe: Growth and regional development in an enlarged European Union*, Cheltenham: Edward Elgar, 117-127.

SOLOW R. (1956), A contribution to the theory of economic growth, *Quarterly Journal of Economics*, 70: 65-94.

SWAN T. (1956), Economic growth and capital accumulation, *Economic Record*, 32: 334-361.

THEIL H. (ed.) (1967), *Economics and information theory*, Amsterdam: North Holland.

TORTOSA-AUSINA E., PÉREZ F., MAS M. and GOERLICH F. (2005), Growth and convergence: Profiles in the Spanish Provinces (1965–1997), *Journal of Regional Science*, 45: 147-182.

WILK M. B. and GNANADESIKAN R. (1968), Probability plotting methods for the analysis for the analysis of data, *Biometrika*, 55(1): 1-17.

WORLD BANK (ed.) (2016), *Poverty and shared prosperity 2016: Taking on inequality*, Washington: International Bank for Reconstruction and Development and World Bank, http://www.worldbank.org/en/publication/poverty-and-shared-prosperity (*last access: May 2017*).

Appendix

Nomenclature of the NUTS III French regions.

France consists of 101 NUTS III regions:

FR101	Paris	FR413	Moselle	FR631	Corrèze
FR102	Seine-et-Marne	FR414	Vosges	FR632	Creuse
FR103	Yvelines	FR421	Bas-Rhin	FR633	Haute-Vienne
FR104	Essonne	FR422	Haut-Rhin	FR711	Ain
FR105	Hauts-de-Seine	FR431	Doubs	FR712	Ardèche
FR106	Seine-Saint-Denis	FR432	Jura	FR713	Drôme
FR107	Val-de-Marne	FR433	Haute-Saône	FR714	Isère
FR108	Val-d'Oise	FR434	Territoire de Belfort	FR715	Loire
FR211	Ardennes	FR511	Loire-Atlantique	FR716	Rhône
FR212	Aube	FR512	Maine-et-Loire	FR717	Savoie
FR213	Marne	FR513	Mayenne	FR718	Haute-Savoie
FR214	Haute-Marne	FR514	Sarthe	FR721	Allier
FR221	Aisne	FR515	Vendée	FR722	Cantal
FR222	Oise	FR521	Côtes-d'Armor	FR723	Haute-Loire
FR223	Somme	FR522	Finistère	FR724	Puy-de-Dôme
FR231	Eure	FR523	Ille-et-Vilaine	FR811	Aude
FR232	Seine-Maritime	FR524	Morbihan	FR812	Gard
FR241	Cher	FR531	Charente	FR813	Hérault
FR242	Eure-et-Loir	FR532	Charente-Maritime	FR814	Lozère
FR243	Indre	FR533	Deux-Sèvres	FR815	Pyrénées-Orientales
FR244	Indre-et-Loire	FR534	Vienne	FR821	Alpes-de-Haute-Provence
FR245	Loir-et-Cher	FR611	Dordogne	FR822	Hautes-Alpes
FR246	Loiret	FR612	Gironde	FR823	Alpes-Maritimes
FR251	Calvados	FR613	Landes	FR824	Bouches-du-Rhône
FR252	Manche	FR614	Lot-et-Garonne	FR825	Var
FR253	Orne	FR615	Pyrénées-Atlantiques	FR826	Vaucluse
FR261	Côte-d'Or	FR621	Ariège	FR831	Corse-du-Sud
FR262	Nièvre	FR622	Aveyron	FR832	Haute-Corse
FR263	Saône-et-Loire	FR623	Haute-Garonne	FRA10	Guadeloupe
FR264	Yonne	FR624	Gers	FRA20	Martinique
FR301	Nord	FR625	Lot	FRA30	Guyane
FR302	Pas-de-Calais	FR626	Hautes-Pyrénées	FRA40	La Réunion
FR411	Meurthe-et-Moselle	FR627	Tarn	FRA50	Mayotte
FR412	Meuse	FR628	Tarn-et-Garonne		

Source: EUROSTAT