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Change and Continuity in Quality of Government: Trends in subnational quality of government in EU member states

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Abstract:

Despite massive investments, studies suggest that anticorruption efforts often times fail and that countries and regions with historically deficient quality of government tend to be stuck in a vicious cycle of high levels of corruption and inadequate public service delivery. However, this study suggests that despite the stickiness of subnational quality of government, regional quality of government does shift over time. Using the 2021 European Quality of Government Index (EQI), and comparing the results to previous rounds of this survey, we show that there has indeed been noticeable shifts in the regional level of Quality of Government both within countries and across time. Overall, we find a slight increase in the perceived quality of government of European regions compared with 2017. However, some regions have evaded the positive trend, most notably in Poland and Hungary, whose response to the pandemic – probably not coincidentally – has involved important infringements of democratic rights and institutions. These changes in Quality of government call for a close mapping of the trends within countries and across regions and a focus on their determinants. To this end, the paper also serves as an introduction to the use of 2021 European Quality of Government (EQI) index, which is the most comprehensive survey to date to measure perceptions of subnational quality of government with a total of 129,000 respondents in 208 NUTS 1 and NUTS 2 regions and all EU 27-member state countries.

Keywords: Europe; regions; corruption; quality of government; time series; measurement; Covid-19.

JEL Classification: H70; H75; R11; R5; I3.

Cambio y Continuidad en la Calidad de Gobierno: Tendencias en la calidad de gobierno subnacional en los estados miembros de la UE

Resumen:

A pesar de masivas inversiones económicas, los estudios sugieren que los esfuerzos anticorrupción a menudo fracasan y que los países y regiones con una calidad de gobierno históricamente deficiente tienden a quedar atrapados en un círculo vicioso de altos niveles de corrupción y una prestación inadecuada de los servicios públicos. Sin embargo, este artículo sugiere que, a pesar de cierta continuidad en la calidad de gobierno a nivel subnacional, hay cambios sustanciales a lo largo del tiempo. Usando el Índice Europeo de Calidad de Gobierno (EQI) de 2021, y comparando los resultados con oleadas anteriores de esta encuesta, mostramos que, de hecho, ha habido modificaciones notables en el nivel regional de Calidad de Gobierno tanto dentro de los países como a través del tiempo. En general, encontramos un ligero aumento en la percepción ciudadana de la calidad de gobierno de las regiones europeas en comparación con 2017.

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No obstante, algunas regiones han evadido esta tendencia positiva, sobre todo en Polonia y Hungría, países cuya respuesta a la pandemia, probablemente no por casualidad, ha implicado importantes violaciones de los derechos ciudadanos y libertades democráticas. Estos cambios en la calidad de gobierno exigen un análisis más detallado de las tendencias dentro de cada país, así como de sus causas. Con este objetivo, este artículo también sirve como introducción al uso de la edición de 2021 del Índice Europeo de Calidad de Gobierno (EQI), que es la encuesta más completa hasta la fecha para medir las percepciones ciudadanas de la calidad de gobierno subnacional con un total de 129,000 encuestados en 208 regiones NUTS 1 y NUTS 2, y de los 27 estados miembros de la UE.

Palabras clave: Europa; regiones; corrupción; calidad de gobierno; series temporales; medición; Covid-19.

Clasificación JEL: H70; H75; R11; R5; I3.

1. Introduction

Despite massive investments, studies suggest that anticorruption efforts often times fail and that countries and regions with historically deficient quality of government tend to be stuck in a vicious cycle of high levels of corruption and inadequate public service delivery (Kaufmann et al 2011; Heywood and Rose 2014; Person et al 2013; Bauhr 2017). The continuity of corruption – or, its nemesis, quality of government – leads to perception of shifts being both rare and slow, and that the results of efforts to improve quality of government may take a generation or more to materialize.

In addition to the perception of stickiness, scholars also point out another constant in this literature: it mostly builds on country level data, which indeed runs the risk of masking potentially important and sometimes dramatic differences within countries and across regions (Barca, McCann and Rodríguez-Pose 2012; McDonnel and Metz 2000; Drápalová and Mascio 2020). Thus, while recent years have seen an increase in the research within social sciences focused on the sub-national level – regions - instead of countries (Rodríguez-Pose 2020), our opportunities to track changes over time in regional quality of government has been very limited, to date. This is concerning, not the least since the quality of government in a territory has been documented as a key factor for understanding its social, economic, political and cultural progress, and thereby human well-being broadly conceived (Bagenholm et al 2021; Holmberg, Rothstein and Nasiritousi 2009), and that regional differences in socio-economic development, are seen as one of the most important threats to the European Union's future prospects for social and economic cohesion (Iammarino et al 2019).[1]

In order to address both issues (Is quality of government sticky? And are there important subnational differences?), this study explores the results of the most comprehensive effort to date to map regional levels of quality of government in the European Union (EU) analyzing the opinion and direct experience of over 129,000 respondents in a total of 208 regions in all EU 27 member state countries and either the NUTS1 or NUTS2 level. Building on previous rounds of this survey (2010, 2013 and 2017), the data allows us to explore both variation across regions and within regions over time. Although our analysis concurs with the general consensus in the sense that some regions in Europe do indeed shift very little over time, we also document important regional level shifts in the geography of quality of government over time and within countries. As a first step to understand the sources of such shifts, this article maps these changes with the aim of also serving as a guide to the future use of the 2021 European Quality of Government index. In addition, we provide illustrative evidence of the connections between shifts in the index, and events and policy decisions taken by authorities in a region. In particular, we provide some narratives from Spain's Valencia, which experienced one of the highest increases from the 2017 round to the 2021 one. During these years, Valencia's regional government put in place numerous pro-quality of government policy initiatives, including the creation of an important anti-fraud agency, which, according to the experts, help

[1] Studies show for instance that corruption and quality of government is important for citizens willingness to support within EU redistribution and aid, and express a willingness to help other countries in times of crises (Bauhr and Charron 2018; Bauhr and Charron 2019)

to explain the overall improvement of the citizens' perception of quality of government in the region (Marco and Martínez 2022).

Conceptually, we follow the standard definition of quality of government in the literature, that of Rothstein and Teorell (2008) – i.e. Quality of Government (QoG) understood as impartiality in the exercise of public power. To measure it, we look at citizens' perceptions and experiences regarding three aspects: impartiality, i.e. that the government upholds an impartial treatment of all citizens irrespective of their personal characteristics or connections; corruption, i.e. that there is no abuse of public office for private gain), and quality, i.e. that the public services are perceived as high-quality. It builds on a previously published data from three previous rounds: 2010 (Charron, Lapuente and Rothstein 2013; Charron, Dijkstra and Lapuente 2014) 2013 (Charron, Dijkstra and Lapuente 2015) and 2017 (Charron, Lapuente and Annoni 2019)[2]. The EQI has had a significant impact on scientific research of territorial differences in several disciplines, becoming, "an instant hit since its release, with several researchers resorting to it as the main indicator of institutional quality across regions of Europe" (Rodriguez-Pose 2020: 374). The data has also been a key feature in the Economic, Social and Territorial Cohesion Reports[3], regularly published by the European Commission to monitor cohesion levels across the European regions.

Our mapping exercise allows us to contribute to the existing knowledge on regional variation in quality of government in several important ways. While the results of the 2021 EQI show that the level of quality of government remains stable over time in several regions, and thereby concurs with the findings of the 'stickiness' of QoG, we document surprisingly important changes along several dimensions: over time, between geographic parts of Europe and among regions within countries. We see that perceptions of the overall quality of government has improved in Europe since 2017, thereby lending support for the contention that quality of government may indeed be less sticky than previous research suggests. Furthermore, comparing different parts of Europe, we show that the geography of regional QoG is slowly shifting. While several Eastern European regions seem to be on a rise, several southern European regions see a marked decline. We also show that some countries seem to become more cohesive and converge over time (i.e. Portugal), while we see a remarkable divergence within others, such as Spain. Comparing the two highly economically developed Spanish regions the Basque Country and Catalonia, we find that the Basque country rates among the top 25% regions in Europe, while Catalonia, in contrast, rates just slightly above the 25% lowest performing regions. And these differences have been increasing over time since the first EQI round in 2010, generating a growing discussion among Spanish public administration scholars (Jiménez-Asensio 2021).

Further indications of the precariousness of quality of government are found in many Hungarian and Polish regions, where we find a noticeable decline in the EQI compared to the EU average in most regions. Thus, while the EQI in regions in i.e. Slovenia and Lithuania have increased, Polish and Hungarian regions seem to have largely evaded the general positive trend in quality of government. The response to the Covid 19 pandemic in Poland and Hungary involved– probably not coincidentally – important infringements of democratic rights and institutions (Hellmeier et al. 2021). While it is important to note that quality of government is a concept that should not be conflated with democracy, since democratic countries can also struggle with high levels of corruption and deficient public service delivery, studies suggest that in most international comparisons, liberal democracies fare the best in terms of containing corruption and improving the quality of government (Bauhr and Grimes 2021). Thus, infringement in democratic rights may have had implications for the perceptions of quality of government as well.

A unique feature in the 2021 EQI survey is also that it is the most comprehensive regional-level survey to date on citizens' perceptions of Covid 19. We included questions on citizens economic and health worries in relation to the pandemic as well as perceptions on how well the government handled the Covid 19 crises. Most of the public discussion during pandemic has focused on "which countries are doing better", but within country-differences have been sharper than cross-country ones (McCann et al 2021;

[2] Data was originally funded by the EU Commission (REGIO) and published in a report by Charron, Lapuente and Rothstein (2010).

[3] See for example, https://ec.europa.eu/regional_policy/en/information/cohesion-report/

Charron, Lapuente and Rodriguez-Pose 2022).[4] As the 2021 round took place during the Covid-19 pandemic, we provide indications of some key relationships with regional QoG and perceptions and experiences of citizens before and during the pandemic. We offer a parsimonious, baseline analysis that shows that previous levels of quality of government are strongly associated to perceptions of the COVID-19 pandemic in the region, and that citizens living in territories with higher levels of quality of government (both in previous rounds as in this 2021 one) exhibit lower levels of both health and economic worry compared with regions that have lower levels of quality of government. The quality of government thus could provide a sense of security and/or a reduction in vulnerability that signals resilience in challenging times. Likewise, the pandemic could also impact perceptions of the quality of government. Potentially, reductions in the interactions between citizens and public officials – due lo lockdowns, school closures and other restrictions – could reduce the opportunities for bribery. Much in line with this expectation we find a notable decreases in the self-reported experiences with petty corruption in regions across many EU Member States, including Italy, Czech Republic, Slovakia, Hungary and Bulgaria in the 2021 survey compared with previous waves. Potentially also as a result of increased exposure, visibility and perceived dependency of government institutions, we find that perceptions of QoG regarding health care services improved uniformly since the previous round.[5]

In the following, we present the 2021 round of data in brief, and highlight the key changes vis-à-vis previous rounds. Furthermore, we exploit the time series component of the data to highlight several interesting temporal trends in the data – namely the within-country, regional variation of QoG over time, and the within-region, over time relationship with the EQI on indicators of socio-economic development. Finally, as the 2021 round took place during the Covid-19 pandemic we indicate some key relationships between regional QoG and perceptions and experiences of citizens before and during the pandemic.

2. The European Quality of Government Index: Continuity and Changes in the 2021 Round

The data for the European Quality of Government Index 2021 relies on over 129,000 respondents in 208 NUTS 1 and NUTS 2 regions in all EU 27 member state countries[6]. Together with national estimates from the World Bank Governance Indicators (Kaufmann, Kraay and Mastruzzi 2011), we report the results for all EU 27 countries, and a total of 208 political units[7]. The core QoG survey questions (also called items) are based on the conceptual framework which understands the concept of QoG as a broad, latent multi-dimensional concept consisting of high **impartiality** and **quality** of public service delivery, along with low **corruption**. The concept also refers to how power is actually exercised, not necessarily the *de jure* formal rules but rather the *de facto* rules as perceived and experienced by the citizens. In other words, we can say that the EQI is describes the informal practices of formal institutions. To do this, it relies on European citizens' perceptions regarding these three concepts and also experiences with corruption, along with the extent to which they rate their public services as impartial and of good quality in the area in which they reside. A full list of the survey questions and how the index is constructed is found in several previous documents (see for example, Charron et al 2014; Charron, Lapuente and Bauhr 2021).

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[4] For instance, during the first wave of the pandemic – January to June 2020 - the largest cross-country gap within the EU was that between Spain, which experienced a 23,5% increase in excess mortality in comparison with the average mortality in the period 2015-2019, and Latvia, where excess mortality went down 8,8%[4]. That is, a remarkable divergence, but lower than the gap we see within some countries. For instance, in Italy, some regions experienced a decline in excess mortality, like Molise with -9%, while others saw outstanding augments, like Lombardy with almost a 55% rise in deaths with respect to the previous 5year average. Likewise, the Spanish Balearic Islands had a mortality decline of 1,4 %, whilst Madrid is the region with the largest increase in deaths in the EU during the first wave in comparison to the previous 5 years, nearly a 75%.

[5] Results of the Covid-19 analysis have nevertheless to be considered as preliminary, given that it only includes data of the first wave, and may be missing some important controlling indicators not available yet at the time of the analysis. We thus leave more systematic and rigorous analyses for future research.

[6] The 2021, 2017 and 2010 rounds of survey data and research were funded by the European Commission via public tenders while the 2013 round was funded through the ANTICORRP project https://anticorrp.eu/work_packages/wp5/

[7] The United Kingdom is not included in the 2021 sample as they are not part of the EU any longer.

The purpose of the EQI is to provide scholars and policy makers with a comparable metric of sub-national governance that can be used to compare QoG across European regions, such that regions in one country can be compared with regions in any other one. Now that the EQI had four rounds, the data can be used to track changes in regional QoG over time since 2010.

The 2021 EQI data largely builds on the work of previous rounds, although there are several differences.

One, for the first time the survey uses a hybrid survey administration approach. Whereas in previous rounds the EQI relied on computer assisted telephone interviews (CATI) via mobile and landline telephones, we now utilize online survey administration for 50% of the respondents. There are several reasons for this change. First, the online administration is of particular interest for a topic such as the EQI, where sensitive questions about perceptions and experiences with corruption, for example, could be affected by social desirability biases from interviewer-administered surveys, such as face-to-face or over a telephone. Studies show that respondents are more likely to answer truthfully about such sensitive topics when taking self-administered surveys, thus providing more accurate data (Kreuter, Presser, and Tourangeau, 2008; Heerwegh, 2009). Second, the costs and flexibility of online administration are superior to CATI: interviews are considerably cheaper and respondents can answer questions at their own pace without the time constraints of telephone interview[8]. Third, previous rounds of the CATI interviews showed that certain sub-groups of respondents, such as the youngest cohorts, were consistently under-sampled, due to lack of owning a landline and lower rates of response via mobile phones. The use of online administration has led to a greater proportion of the sample containing such groups[9]. With this shift to hybrid administration, the EQI data has increased the sample size considerably – from 78,000 in 2017 to 129,000 in 2021, an increase of more than 65% (see Charron, Lapuente and Bauhr 2021 for more details on the sample). In appendix 4, we assess the differences in perceptions and experiences of QoG across EU regions by survey administration. In sum, we find a high degree of correspondence in terms of the rank order in the EQI produced by both administration types, with just 9% of regions showing significant differences (see Figure A4).

The second major change with respect to previous EQI rounds is that the regional level is now the NUTS 2 in all the EU countries[10]. Compared with previous years, we now report NUTS 2 level data for Sweden, Greece and Slovenia from the NUTS 1 to NUTS 2 level, and Lithuania has added a second NUTS 2 region, thus we report multiple NUTS 2 regions for this member state as well for the first time. These changes allow for more flexibility and observations for research and greater opportunities to explore within-country regional variation.

Third, the EQI survey now samples all EU-27 member states[11]. Previous surveys included only those member states with at least 2 NUTS 2 regions. The 2021 survey has comparable survey data for previously omitted countries: Estonia, Slovenia, Cyprus, Luxembourg, Malta, Lithuania and Latvia, for which we relied on the World Bank Governance Indicators as proxies at the national level. For purposes of comparison over time, we have made retrospective changes to previous years that can be employed to analyze a common set of regions over time (see appendix section 3 for more details). In appendix section 4, we present a further validity check of the data via a comparison of the expert (WGI and ICRG) and citizen (EQI) assessments of QoG at the country level for all member states from the 2021 round, where we find a high degree of corresponds between the two sources.

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[8] The drawbacks of on-line survey administration are well-known (Pew Research 2018). Not everyone has easy access, or access at all, to the internet and the sample is no longer randomly selected as respondents choose to opt-in. In general, less educated, poorer or older respondents tend to have less internet access, thus online samples are usually skewed towards certain groups.

[9] Of course we acknowledge there is a trade-off in proportion size of the younger cohort that we gain via online via self-selected respondents versus randomly selected ones via CATI. Given the cost reduction in the online administration, we saw this as a helpful compliment to the declining CATI proportion of younger respondents even if they are self-selected.

[10] Even if data is collected at the NUTS2 level everywhere in the EU, the EQI scores are reported at the NUTS1 level for Belgium and Germany for political relevance and to allow consistent time comparisons.

[11] Previous waves included the UK, yet this was dropped in 2021 due to Brexit.

Fourth, the number of languages offered during questions administration was extended in this round, with a focus on offering the survey in multiple languages in regions where there are sizable linguistic minority communities. In Spain, the EQI is now offered in Catalan and Basque in addition to Spanish; in Italy, respondents in the northern regions may answer in German, if at the border with Austria, or French, if at the border with France; Romanian respondents in the Nord Vest (RO11) and Centru (RO12) regions may now also answering in Hungarian, and respondents in Latvia and Estonia have the option of Russian in addition to their main respective languages. Belgians anywhere may answer in Dutch or French as in all the previous rounds.

3. The 2021 EQI[12]

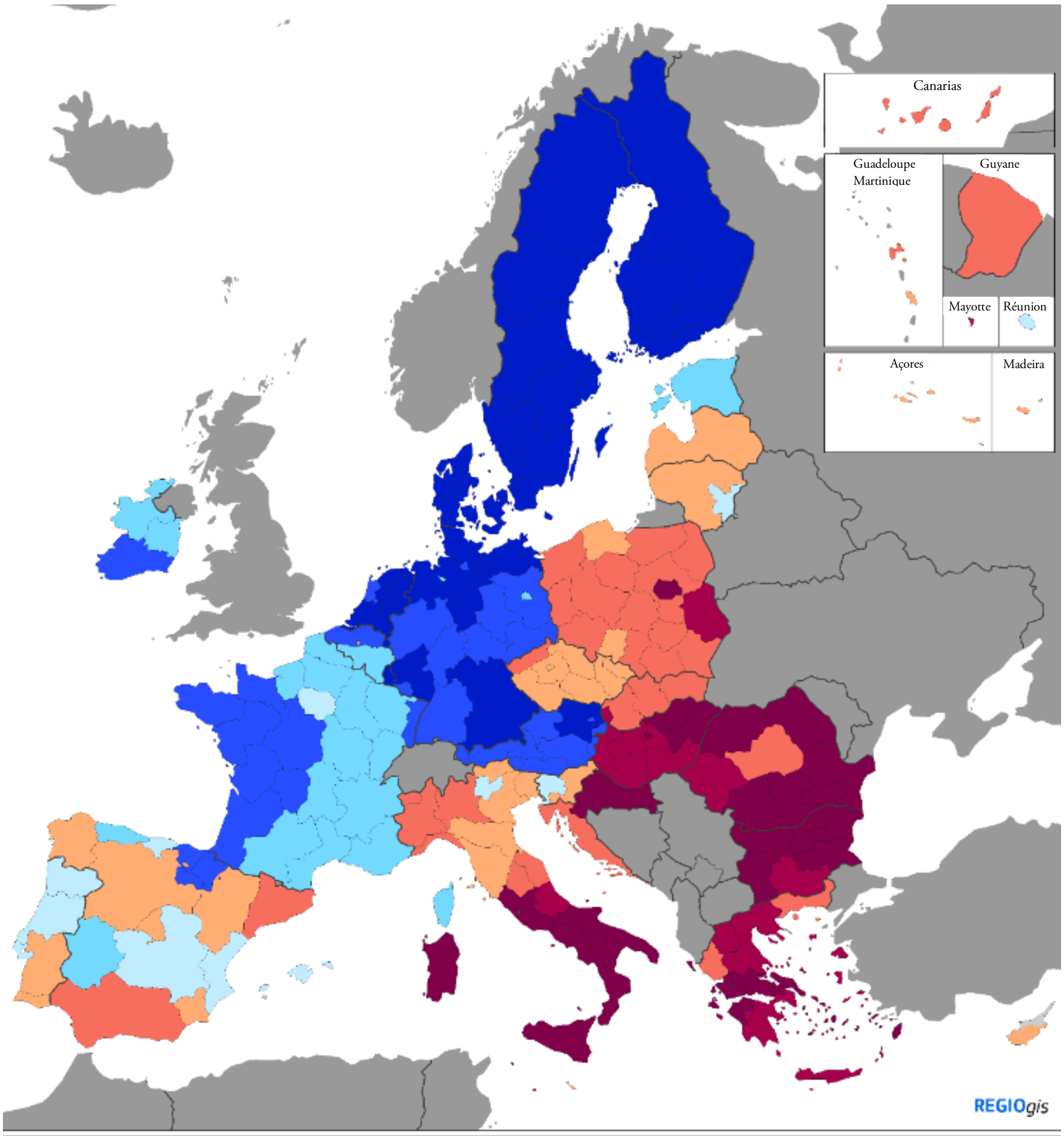
The 2021 picture is rather consistent with previous editions of the EQI (see Charron et al. 2014; 2015; 2019), with a north-western area performing better than the south-eastern part of the EU (Figure 1). There are also significant regional differences in some countries - Italy, Spain, Belgium, Ireland, Poland France, including its overseas regions, and Slovenia, in particular – but very little in others, the Nordic countries, especially, but also Austria and Slovakia (for full results, see appendix 5). Slovenia is also a noteworthy case, with the eastern, capital region (SI03) being roughly 0.6 standard deviations above the western region of SI04. Thanks to the new NUTS2 classification in Ireland, for the first time the capital region, Dublin (IE06) is assessed separately from the other two and scores significantly lower than the Southern region (IE05), taken into account the margins of error.

Figure 2 shows the distribution of regional scores by country (countries reordered according to their national value from the best performers, left-hand side, to the worst performer, right-hand side). Regions are displayed in three categories – from less developed to more developed passing through the transition category - according to their GDP per capita. These categories represent the region's eligibility criterion for EU cohesion policy funding, in particular for the European Regional Development Fund and the European Social Fund both highly relevant in the context of regional investment for jobs and growth. The lower the region's level of development, the higher the share of European investment funds the regions is eligible to receive. Overall, more developed regions are also those showing the highest levels of EQI, both within and within countries, as can be seen by the prevalence of green and yellow in the left-hand side of the figure.

One interesting observation is that the level of QoG in capital regions varies significantly within countries. We observe that Ljubljana, Lisbon, Vilnius and Prague are actually the best in the country, while many other cases capital regions scores in the middle. At the other end, we several cases where the capital is the poorest performer, which is observed at both ends of the QoG spectrum. From countries with higher levels of QoG, like the Netherlands and Germany where we see Amsterdam and Berlin regions the lowest within-country ranking, while in countries like Poland, Slovakia, Bulgaria and Romania, the capital regions of Warsaw, Bratislava, Sofia and Bucuresti-Ilfov show the lowest levels of QoG.

[12] For more details on the methodology of building the index see for example, Charron, Lapuente and Annoni (2019) Charron, Lapuente and Rothstein (2013).

FIGURE 1.
The European Quality of Government index (EQI), 2021



European Quality of Government index, 2021

Standard deviation, range from poor quality (negative) to high quality (positive)

<-1.2
-1.2 - -0.9
-0.9 - -0.5
-0.5 -0
0 – 0.3
0.3 – 0.7
0.7 – 1.1
>1.1

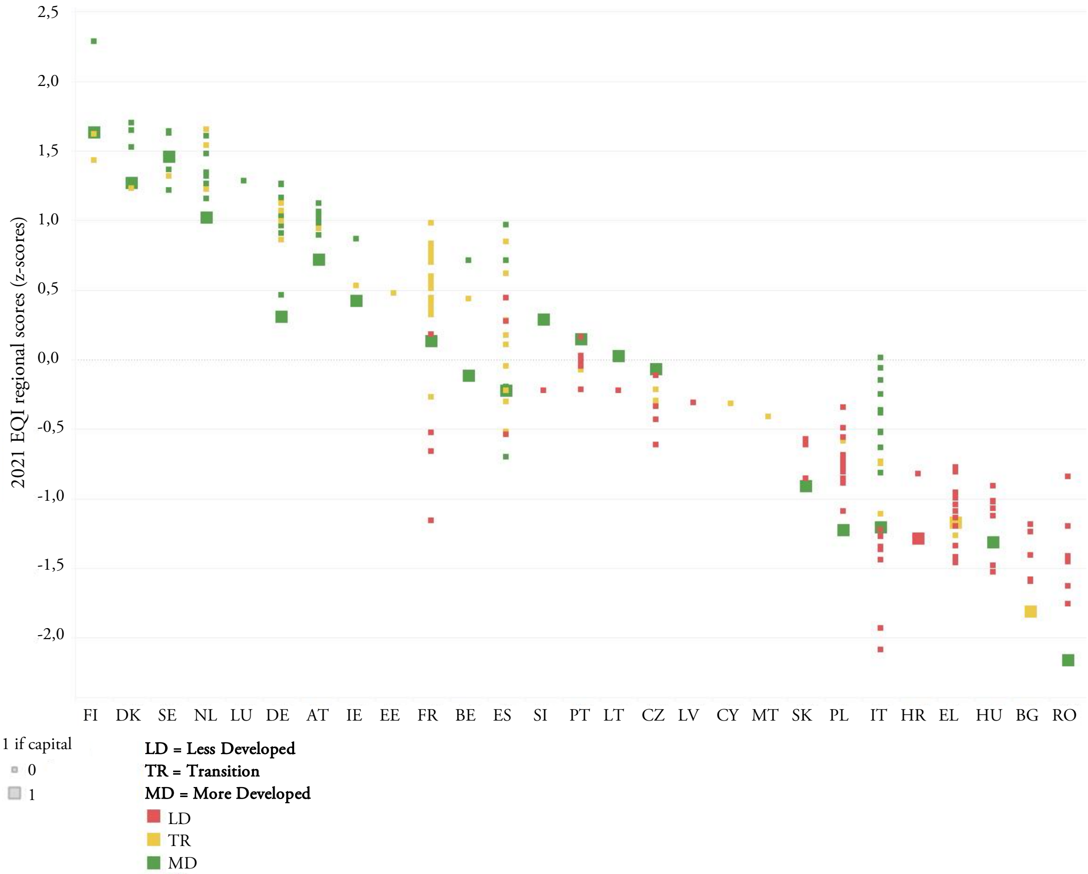
EU = 0

Source: The Quality of Government Institute, University of Gothenburg

0 500 Km

Note: Scores are expressed in z-scores, EU average is therefore equal to 0. Positive (negative) values reflect higher (lower) than the EU average quality of government. One unit of difference is equivalent to one standard deviation of difference.

Figure 2.
Distribution of 2021 EQI scores by region and country



Note: Capital regions are highlighted (larger symbol). Regions are classified according to their category for EU cohesion fund eligibility (see text for explanation). Countries reordered from best (left-hand side) to worst (right-hand side) according to their national average score.

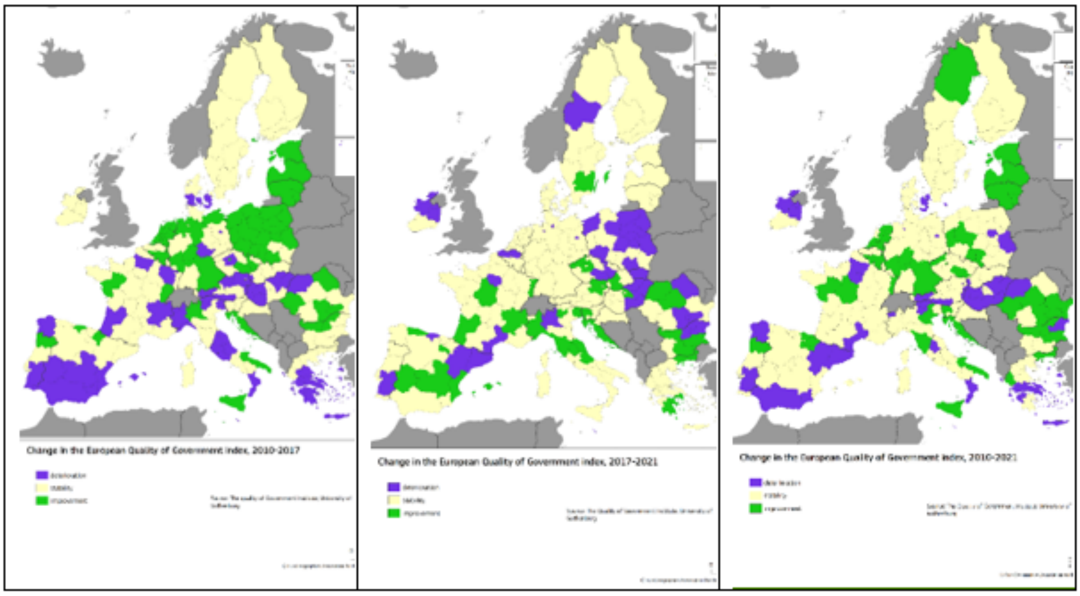
4. Notable regional trends over time in the EQI

Given the EQI now includes four rounds ranging 11 years in time, we can elucidate more valid temporal patterns in the data. Using the margin of error confidence intervals for the previous rounds 2010-2017 (Figure 3, left side), we can identify statistically significant improvements in the quality of government in the Baltic countries, most of Poland and Germany, the Netherlands, Croatia and some regions in Romania and Bulgaria. By contrast, there was a deterioration between 2010 and 2017 in Austria, Hungary, southern Greece, Cyprus, the southern part of Spain and some regions in Portugal and Italy. More recently, between 2017 and 2021 the index stabilised in the Baltic countries (Figure 3, center) [13] and worsened in most Polish regions, especially in the east of the country. The same is the case the eastern part of Romania, where the capital city region of Bucuresti-Ilfov, had the lowest score in the EU in 2021. On the other hand, there was some improvement in the index over this period in the south of Spain, southern Germany, southern Greece and the south and central parts of Italy. The change in the EQI is analysed separately for the period 2010-2017 and 2017-2021 to highlight recent pattern in quality of government perceptions that may have been caused by the exceptional circumstances due to the Covid-

[13] Because of changes in the NUTS2 classification in Ireland and Lithuania, regional values for these countries in 2021 are compared with national ones in previous editions.

19 pandemic. The overall trends since 2010 are shown by the right-hand side map of Figure 3 that, as expected, are more consistent with the 2010-2017 trends.

FIGURE 3.
Significant regional increases and decreases in the EQI over time



Note: Regions where scores increased (decreased) by more than 0.25 standard deviations in the period are shown on green (purple). Left side is 2010-2017, center is 2017-2021 and the right side is the total change, 2010-2021. Source: DG REGIO based on data by the Quality of Government Institute, University of Gothenburg.

Let us focus on one particularly remarkable improvement: Spain's Valencia, a region that has moved from below both the Spanish and European average in 2017 to clearly above both averages in 2021. Traditionally Valencia was a region covered with corruption scandals, including 17 cases against the conservative party, which had been in charge of some of the most important administrations -both the regional government and local administrations – from the 1990s (Gasparet 2018). The regional parliament has passed a large battery of measures to foster quality of government and fight corruption, chief among them the creation of the Agency of Prevention and Fight against Fraud and Corruption (AVA) in mid-2017, with has 40 employees and is headed by Joan Llinares, one of the most reputed anti-corruption civil servants in Spain (Bono 2021). Thanks to a regulation protecting whistleblowers that predated the EU legislation (European Union 2019), AVA has 25 protected whistleblowers (Bono 2017), and addressed hundreds of potential cases of corruption and mismanagement. Together with other measures, such as the creation of a Council of Transparency and an Office of Conflict of Interest, and the promulgation of a regional law for controlling lobbies and a regional enlargement of the national law of access to public information, Valencia is now widely seen by experts in public administration and other observers as an example in the improvement of quality of government (Marco and Martinez 2022), which we see is reflected in citizen perceptions.

Moving to the degree of regional divergence/convergence of QoG over time within member states, Table 1 provides two simple measures of within-country regional dispersion – the standard deviation of regional EQI scores, min-max range and the Gini index[14] for each of the four years to date, along with the within and between Member States and overall trends of the Gini index score. Italy remains the country with the greatest degree of within-regional variation in 2021 according to all three dispersion measures, although the variation is down from the high levels of 2013. Although 2021 reveals the fewest

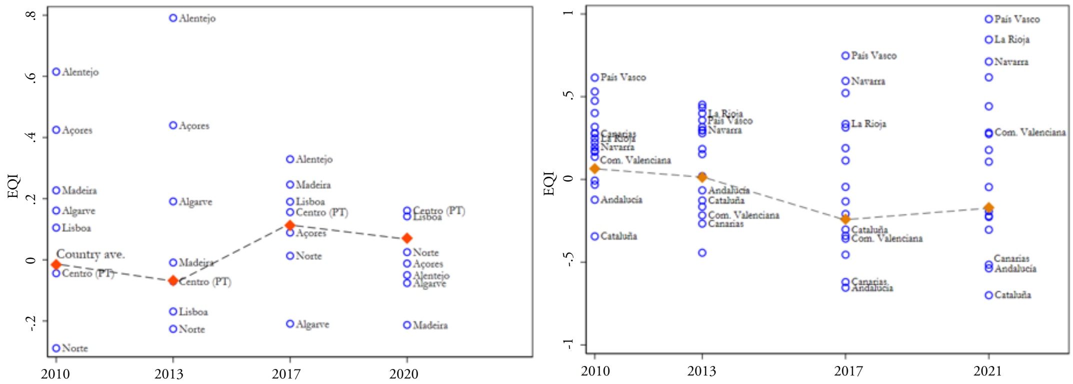
[14] The population (p) weighted (w) Gini coefficient ranges from '0' (perfect equality) to '1' (perfect inequality) is calculated as:

$$G_w = \left(\frac{1}{2EQI_a}\right)\sum_{i}^{n}\sum_{j}^{n}|EQI_i - EQI_j|\frac{P_iP_j}{P^2}$$

number of member states with a min-max range above one standard deviation in the data (4 countries – Italy, Spain, France and Romania), half of the countries that were included in 2017 increased on the standard deviation metric (11 of 22). Within-country convergence and divergence trends are working in different directions depending on the member states. On the one hand, while in some countries we observe the lowest levels of within-country QoG, such as Belgium, Bulgaria, Austria and Portugal on the other hand, we observe the highest levels of regional divergence to date in Poland, Germany, Netherlands, Denmark, Sweden, Slovakia and Croatia.

The above country by country analysis enabled us to find interesting cases of convergence, in the case of Portugal, and divergence, in the case of Spain, of regional QoG levels. The performance of Portuguese regions featured a rather high variability both in 2010 and 2013, with a range above one standard deviation, to a rather limited one in 2017 and especially in 2021, with a range that is less than halved (Figure 4). This converging pattern is largely a result of the higher ranking regions declining and converging to the national average, in particular Alentejo[15]. In Spain conversely, we observe the strongest trends of regional divergence of all EU member states during the time period. The right side of Figure 4 demonstrates the variation of regions with respect to QoG range has roughly doubled since 2013 as strong performers - Pais Vasco, La Rioja, Navarra - have steadily improved, while regions such as Catalonia, Canarias and Andalucía have declined over time.

FIGURE 4.
Examples of Regional Convergence and Divergence – Portugal and Spain



Note: blues circles show regional EQI estimates in Portugal (left) and Spain (right), and red diamond is the population weighted country average of the regional EQI by year. Select regions are noted in Spain.

Finally, we test the dynamic relationship with the EQI and several relevant indicators via cross-sectional, time series panel data analyses. In this case we are not making causal claims, but providing initial descriptive statistical associations over time to stimulate future research. To motivate relevant covariates, we selected key indicators from the EU Cohesion Policy – unemployment rates, GDP per capita (PPP, logged), percentage at risk of poverty, and percentage in material deprivation (from Eurostat, see appendix for more details). We estimate the effects 1) via partial-pooled, random intercept models, which capture the combined spatial and temporal effects of the EQI on our selected outcomes, and 2) via fixed effects models, which capture the average within-regional effects over the 11 year period. In both cases, we include year fixed effects to account for the over trends in key variables and include only a parsimonious set of controls - population density and capital region (for random intercept models).

[15] The EQI score of the region of Alentejo (PT18) has dropped from 0.79 in 2013 to 0.33 in 2017 to -0.05 in 2021 – one of the largest declines among all regions during this period. Looking more closely at the three QoG pillars, the data show that while the 'quality' pillar has remained mostly the same, and the 'impartiality' has dropped modestly (from 0.38 in 2013 to 0.06 in 2021). Yet the decline is most strongly driven by the 'corruption' pillar, which was 1.13 in 2013 and dropped to -0.25 in 2021; nearly 1.4 standard deviations. More in depth investigation is needed to better understand the underlying causes of this decline, such as the occurrence of high profile political corruption scandals in this area during the period for example.

TABLE 1.
Measures of Within-country regional dispersion of the EQI over time

	2010			2013			2017			2021		
MS	**st. dev.**	**range**	**Gini**	**st. dev.**	**range**	**Gini**	**st. dev.**	**range**	**Gini**	**st. dev.**	**range**	**Gini**
AT	0.14	0.46	0.015	***0.260***	0.816	0.028	0.148	0.432	0.017	0.118	0.407	0.013
BE	0.57	1.10	0.063	***0.589***	1.039	0.056	0.557	1.085	0.058	0.423	0.831	0.046
BG	0.55	1.41	0.150	***0.776***	2.238	***0.190***	0.494	1.279	0.121	0.238	0.626	0.055
CZ	0.29	0.78	0.047	0.214	0.678	0.032	***0.344***	1.015	***0.049***	0.173	0.540	0.026
DE	0.15	0.58	0.017	0.207	0.644	0.025	0.231	0.751	0.026	***0.257***	0.958	***0.027***
DK	0.13	0.32	0.011	0.115	0.280	0.010	0.156	0.420	0.013	***0.215***	0.471	***0.020***
EL	***0.26***	0.95	***0.046***	0.128	0.375	0.024	0.161	0.498	0.031	0.214	0.691	0.045
ES	0.24	0.96	0.033	0.279	0.895	0.040	0.426	1.402	0.064	***0.503***	1.669	***0.073***
FI			0.000	***0.612***	1.412	***0.046***	0.410	0.992	0.031	0.351	0.851	0.028
FR	0.37	1.41	0.048	0.373	1.507	0.049	***0.553***	2.331	***0.067***	0.498	2.140	0.059
HR	0.10	0.14	0.015	0.093	0.132	0.014	0.059	0.084	0.008	***0.332***	0.470	***0.044***
HU	***0.26***	0.60	0.040	0.146	0.349	0.025	0.251	0.707	***0.049***	0.230	0.620	0.047
IE			0.000			0.000			0.000	***0.234***	0.450	***0.023***
IT	0.74	2.50	0.141	***0.831***	2.948	***0.160***	0.574	1.836	0.120	0.592	2.097	0.115
LT			0.000			0.000			0.000	***0.173***	0.245	***0.017***
NL	0.11	0.32	0.012	0.112	0.396	0.012	0.114	0.253	0.012	***0.189***	0.632	***0.020***
PL	0.11	0.43	0.021	0.206	0.653	0.036	0.136	0.535	0.022	***0.215***	0.889	***0.039***
PT	0.29	0.9	0.040	***0.368***	1.017	***0.048***	0.176	0.538	0.023	0.129	0.374	0.018
RO	***0.48***	1.58	***0.128***	0.301	1.044	0.079	0.277	0.871	0.064	0.390	1.321	0.090
SE	0.08	0.17	0.008	0.066	0.140	0.006	0.078	0.160	0.007	***0.146***	0.423	***0.015***
SI			0.000			0.000			0.000	***0.356***	0.504	***0.034***
SK	0.11	0.25	0.016	0.126	0.247	0.020	***0.193***	0.386	***0.030***	0.169	0.338	0.026
W/in MS			0.004			***0.005***			0.004			0.004
between MS			0.032			***0.033***			0.032			0.032
Total			0.154			0.154			0.154			***0.155***

Note: 'st. dev.' is the unweighted standard deviation of regional EQI scores within the noted country for the given year. 'Range' is the absolute difference in max-min regional score within a country. 'Gini' is the Gini coefficient of the re-scored EQI index via 'ineqdec0' (Jenkins 2008), whereby we add the absolute value of the most negative observation to avoid negative integers dropping '0' values. Finland, Croatia and Ireland not included in 2010. Ireland's previous NUTS level regional dispersion from the 2013 and 2017 years discontinued due to NUTS 2 reform between 2017 and 2021. Cyprus, Estonia, Latvia, Luxembourg and Malta not included, due to no years with multiple NIUTS 2 regions. Each country's highest year of dispersion rate according to st. dev. is highlighted in red.

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Table 2 reveals the results. We observe first that in all cases, the EQI is in the direction expected with the outcome variable in question. Second, we see that in the random effects models, the EQI significantly explains variation in all four outcomes. A one standard deviation increase of QoG is associated with a lower unemployment rate by 1.27%, lower at risk for poverty by 3.4%, lower material deprivation by 5% and higher GDP per capita (logged) by 12%. We also observe that when the estimates isolate the average within-unit effects over time (models 5-8), that the effects are on average smaller, yet significant at the 95% level of confidence or higher (save model 5). Overall, although we do not draw directional, causal inferences from these observational results, we do interpret these findings as evidence that the EQI and several salient indicators of socio-economic development are strongly correlated over time.

TABLE 2.
Testing the effects of the EQI on socio-economic development

	Random intercept models				Fixed effects models			
	1	2	3	4	5	6	7	8
Dep. Var.	Unemploy-ment	% poverty	% Material deprivation	GDP p.c.(log)	Unemploy-ment	% poverty	% Material deprivation	GDP p.c.(log)
EQI	-1.27***	-3.35***	-5.01***	0.12***	-0.42	-1.85**	-3.02***	0.05***
	(0.257)	(0.539)	(0.409)	(0.012)	(0.395)	(0.906)	(0.991)	(0.015)
Constant.	8.514***	26.885***	10.550***	9.92***	8.083***	21.376***	4.222	10.019***
	(0.38)	(0.83)	(0.66)	(0.02)	(0.86)	(3.51)	(3.84)	(0.04)
σ (region)	1.51***	2.18***	1.70***	-1.23***				
	(0.05)	(0.05)	(0.06)	(0.05)				
σ (cons-tant)	0.85***	1.35***	1.42***	-2.46***				
	(0.02)	(0.04)	(0.04)	(0.03)				
Year FE's	✓	✓	✓	✓	✓	✓	✓	✓
Regional FE's					✓	✓	✓	✓
Obs.	809	466	466	698	809	466	466	698
R-squared					0.354	0.275	0.322	0.999

Note: marginal effects indicate the change in the dependent variable as a function of a 1 standard deviation increase of the EQI. Robust standard errors, clustered by region in parentheses. Models 1-4 a hierarchical models with random regional intercepts, while models 5-8 are estimated via regional, fixed effects models. Control variables are population density (models 1-8) and capital region (models 1-4). Models include data from 2010, 2013, 2017 and 2021, with 2010 as the reference year.
*** p<0.01, ** p<0.05, * p<0.1

5. TRENDS IN EXPERIENCE AND PERCEPTIONS OF REGIONAL QOG PRE/POST COVID-19 ONSET

Although much research has looked at the relationship between generalized and political trust as causes and consequences of various aspects of the Covid-19 virus (see for example Bol et al 2021; Charron et al 2022; Newton 2020; Oksanen et al 2020) much less has been studied on the relationship between citizen perceptions and experiences with corruption. While this section does not claim to perform exhaustive analysis of the effect of the pandemic on QoG (or QoG on the handling of the pandemic), we present some big picture, 'birds eye' differences between previous (pre-Covid) and the 2021 EQI waves. In 2021, Europeans have seen their national, regional and local governments in action in the fight to contain the virus. They have also been highly restricted in their ability to socialize, work and utilize public services. We would thus expect that the experiences and perceptions would be affected the pandemic in some significant ways. Although we leave a more systematic analysis for future research, we explore several simple correlations to establish whether there are any noticeable patterns, highlighting those we find most relevant.

First, we would expect that given the lock-downs, school closures, and restricted access to non-essential services in many areas in the EU, that rates of experiences with petty corruption would go down. Figure 5 shows the relationship between regional rates of petty corruption experiences (proportion 'yes') in 2017 and 2021[16]. The figure demonstrates that in most cases (70% of the regions) the rates of personal experience with petty corruption in any of our inquired services was lower in 2021 than in 2017. The overall average dropped from 9.3% in 2017 to 6.1% in 2021[17]. In particular, remarkable decreases are observed in Italian regions, as well as in Czech Republic, Slovakia, Hungary and Bulgaria. However, in some cases, such as in several Romanian regions among others, we find that petty corruption has in fact increased. The most notable case in this instance is the Canary Islands (ES70) in Spain, which increased from 3.5% to 13.6% ($p<0.001$)[18]. The island region was hit especially hard economically by strict tourism restrictions[19], which likely created significant pressure on the health care system and shortages of goods and services, increasing incentives for informal exchanges (Rose 2015). While this simple analysis does not allow to assess any causal effect per se, the pattern observed suggests that during the pandemic there was a sizeable decline of experiences with petty corruption, as we would anticipate in a pandemic as such.

Second, in Table 3 we also check if the perceptions in quality, corruption and impartiality components have changed since 2017 by sector – education, health care and law enforcement. In this case, rather than the standardized score, we look at the raw regional averages by EQI pillar, as each survey uses the exact same question formulation and question measurement scale. The table reveals several interesting patterns in the data. First, there is positive and significant change from 2017 in terms of perceptions of all service quality – in particular in the health care sector, followed by education. This could be of course because these two sectors in particular were most affected by the pandemic and that people saw their local health care and education institutions in action and quickly responding to the concerns of the virus. Second, these quality perceptions are also accompanied by improved perceptions of (control of) corruption, which certain seems reasonable considering the clear drop in corruption experiences shown in Figure 5. Again, it is the health care sector that benefits most from the positive changes, with the mean regional increase of 0.342 since 2017. Third, we see however that the positive quality and corruption scores are not accompanied by perceptions of impartiality, which dropped from 2017 to 2021, most pronounced by law enforcement, which dropped by -0.212. That people perceive somewhat higher levels of favouritism in law enforcement could reflect a perception that law enforcement permitted some people to evade some of the lockdown measures.

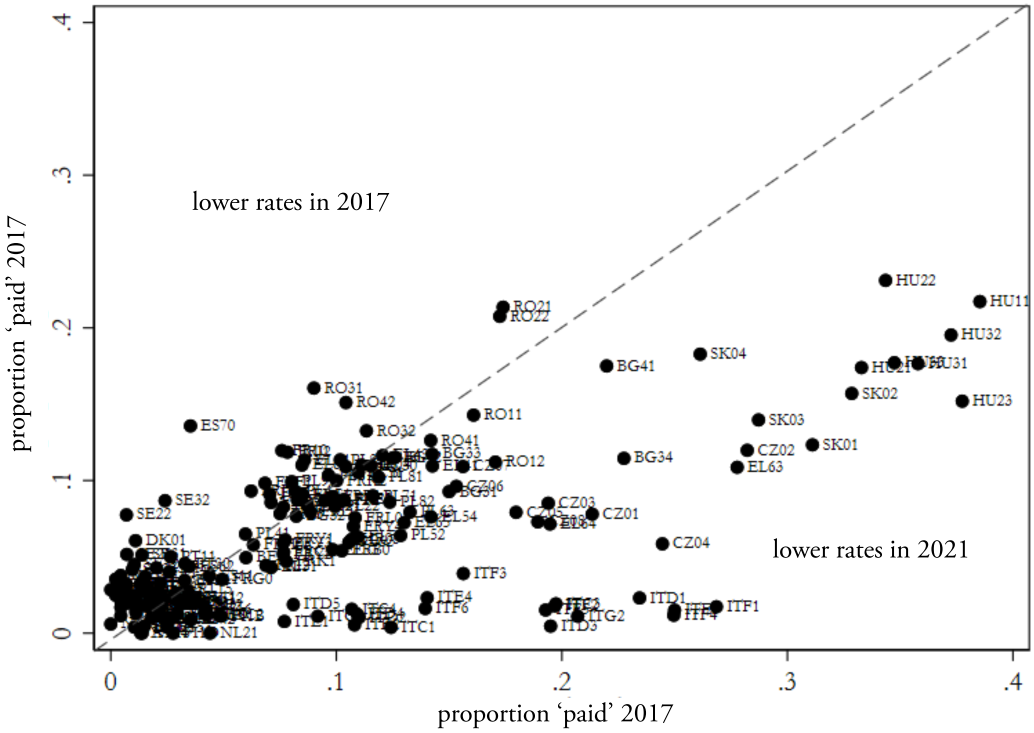
[16] For the sake of valid comparison, we compare only CATI interviews.

[17] Among comparable regions, the regional overall mean was 8.1% in 2013.

[18] The increase from 2017 to 2021 was driven by education (0.05 to 6.5%, $p<0.001$) and health care (1.4% to 7%, $p<0.001$). Bribes to law officials and 'other services' went up slightly but not significantly. Moreover, there was no increase in citizens being approached by public officials to pay, indicating that citizens were initiators.

[19] National statistics show that by December 2020, GDP fell by 24% and 11% of business in the region went bankrupt in Canarias, while GDP fell by 9% among and just 2% of firms went bankrupt in mainland Spanish regions. Moreover, the unemployment rate rose roughly 4-fold from 8.7% at the start of the pandemic (march 2020) to 32% in January 2021 when the EQI survey was fielded, compared with a change of 13.7% to 16.3% on average among mainland regions (Brinklow et al 2021).

FIGURE 5.
Regional Rates of Experiences with Petty Corruption: 2017 vs 2021



Note: regional estimates aggregated from microdata using post-stratification weights.

TABLE 3.
Averages of 3 EQI Pillars by Service (Raw Scores)

Variable	2017	2021	Difference	p-value
QUALITY				
Education	6.426	6.692	.265	0.000
Health Care	6.211	6.553	.342	0.000
Law enforcement	6.557	6.666	.109	0.000
IMPARTIALITY				
Education	5.993	6.109	.035	0.001
Health Care	5.477	5.581	-.103	0.008
Law enforcement	6.313	6.101	-.212	0.000
CONTROL OF CORRUPTION				
Education	7.317	7.108	.208	0.000
Health Care	6.487	6.824	.336	0.000
Law enforcement	6.742	6.859	.116	0.004

Note: averages are across regions for all common EQI regions in both 2017 and 2021 (n=195). Higher scores equate to higher QoG on all indicators, scored 1-10. Significance tests are simple differences of means.

6. Conclusion and Discussion

Does the quality of government change over time? This study analyses the results of the most comprehensive survey to date to measure the perceptions of quality of government, the EQI 2021, and compared the results to previous rounds of this survey. The 2021 survey collects the opinions of over 129,000 respondents in a total of 208 NUTS 1 and NUTS 2 regions in all EU 27 member state countries. Since this survey builds on previous rounds of the survey (2010, 2013 and 2017) it also allows for systematic analysis of shifts over time and how both changes and inertia can be explained, as well as an analysis on a range of potential determinants, also including variables related to the recent Covid-19 pandemic. This allows for several new insights into the quality of public services in three of the public service sectors; health care, education and law enforcement

In this paper, we highlight some of the main results of the EQI 2021 survey and changes in the data vis-à-vis previous rounds, and suggest venues for future research for studies using this data. Despite widespread concerns over the 'stickiness' of corruption levels (see i.e Heywwod and Rose 2014; Person et al 2013; Bauhr 2017; Charron 2021), the results show that regional level quality of government does indeed change over time, both across regions in Europe and between regions within the same country. In all, citizens' perceptions of the QoG as well as their experiences with public services has shown some clear improvements between the 2017 and 2021 round of the survey. Citizens rate the quality of public service delivery higher and report lower level of bribing and other forms of corruption. We also find that the geography of regional QoG is slowly shifting. While several Eastern European regions seem to be on a rise, several southern European regions see a marked decline. Interestingly we see a remarkable convergence between regions in some countries, while we see a divergence within others, indicating that the relative ranking among regions within countries are far from stable. However, despite the potential optimism suggested by the overall trend in this survey compared to previous rounds, it is also important to note the decline in the EQI in most regions in Poland and Hungary relative to the EU average. Infringements on media rights and the independence of the judiciary system may explain this drop, much in line with evidence on such infringements being detrimental to containing corruption in democracies (Bauhr and Grimes 2021).

This survey also provides an opportunity to analyze perceptions of the Covid 19 pandemic, since it is, to the best of our knowledge, the survey with the greatest regional coverage of citizens perceptions of the Covid 19 pandemic to date. It thereby allows for a systematic analysis of regional levels of quality of government and Covid 19 outcomes, such as excess mortality due to Covid-19, which studies show vary considerably within European countries (Rodríguez-Pose and Burlina 2021). Our analysis indicates that citizens in regions with higher quality of government are less worried about the economic and health consequences of the pandemic, and are more likely to perceive that their authorities have handled the crises well. In particular, past levels of corruption perceptions are strongly related to economic worries due to Covid -19. The Covid 19 pandemic also seems to be related to perceptions of improved health care in Europe, as the salience and performance of domestic institutions could have increased (Hetherigton and Husser, 2012; Hetherington and Rudolph 2008). This could also potentially be explained by a "rally around the flag" effect (Mueller 1970; Bol et al. 2020), i.e. that citizens express a form of empathy towards their leaders in a time when they perceive themselves to be vulnerable and dependent upon leadership and public service delivery. At the same time, the documented decreases in bribery levels experienced in several public service sectors may partly be explained by more limited interactions with public service providers due to lockdowns and restrictions. Further investigations, such as future rounds of this survey, may answer the big underlying question: will these positive trends will last over time?

The important link between corruption levels and the extent to which citizens worry about the economic consequences of the pandemic provides evidence that the slow shift in the geography of QoG may also lead to a slow shift in the geography of citizens concerns about their future. It is therefore of imperative importance to continue to explore the causes and sometimes dire consequences of low quality of government. What explains the rise in quality of government in many eastern European regions? Why are many southern European regions lagging behind, some of them so highly socioeconomically developed as Catalonia? Why are some countries diverging (such as Spain) while others are converging? How and why do some regions succeed in maintaining relatively good quality of government in countries that are affected by democratic backsliding?

By providing this freely available indicator, we hope to encourage other scholars of economic geography, political science and Europeanists, *inter alia*, to explore these and other salient questions. This should include an in-depth analysis on how and why regions evade the stickiness of quality of government, and, in particular, when and how such shifts can lead to positive improvements in citizens-state interactions and the provision of public services, since, as our analysis indicates, the importance of geography does not imply determinism. Future research should also explore other interesting patterns that seem to emerge from this data, such as the stark and noticeable variation in the scores of EUs capital regions, with some capital regions being way below their country mean (i.e. Romania, Poland, Hungary, Bulgaria, and Slovakia), while others are significantly higher (i.e. Czech Republic, Lithuania and Slovenia). Many puzzles thus come our from this data which both confirm and challenge conventional views on why some governments can, or cannot, improve.

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On-line supplementary material

Appendix

Articles

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Actions fostering the adoption of Industry 4.0 technologies in manufacturing companies in European regions

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Abstract:

Industry 4.0, a concept comprising a range of promising innovations enabled by the recent advancements in digital technologies, has become a priority of industrial policy in many European countries and regions. In this paper, we present actions undertaken by regional organisations (including the so-called Digital Innovation Hubs), fostering the adoption of Industry 4.0 technologies in manufacturing companies. Using examples from Germany, Italy and Poland, we show actions that enable the creation of general conditions for such implementations and help companies develop an individual strategy for adopting Industry 4.0 innovations.

Keywords: Industry 4.0; support; actions; regions; Digital Innovation Hubs.

JEL classification: L6; O31; O33; O38.

Acciones de fomento de la adopción de tecnologías Industria 4.0 en empresas manufactureras de regiones europeas

Resumen:

La Industria 4.0, un concepto que comprende una serie de prometedoras innovaciones posibilitadas por los recientes avances en las tecnologías digitales, se ha convertido en una prioridad de la política industrial de muchos países y regiones europeos. En este documento presentamos las acciones emprendidas por organizaciones regionales (incluidos los denominados Centros de Innovación Digital) para fomentar la adopción de las tecnologías de la Industria 4.0 en las empresas manufactureras. Utilizando ejemplos de Alemania, Italia y Polonia, mostramos acciones que permiten crear condiciones generales para tales implementaciones a nivel regional, pero también ayudan a las empresas individuales a crear una estrategia individual para la adopción de las innovaciones de la Industria 4.0.

Palabras clave: Industria 4.0; soporte; acciones; regiones; Digital Innovation Hubs.

Clasificación JEL: L6; O31; O33; O38.

1. Introduction

Industry 4.0 (I4.0), a concept comprising a range of innovations enabled by the recent advancements in digital technologies, is believed to create a range of opportunities for the manufacturing sector all over the World (Schwab 2016; Hervas-Oliver, Di Maria, Bettiol 2021a). With many possible positive outcomes

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outcomes for the structure of firms, regional economic development or job markets, in recent years, scholars and scholars and policymakers started debating the necessary actions to be undertaken at various administrative levels to foster the implementation of I4.0 technologies (De Propris, Bailey 2020a).

Given the recent introduction of these technologies, it is still little known what elements at various territorial levels can represent better conditions for their implementation in manufacturing firms. Not surprisingly, the early adopters of I4.0 innovations differ between countries and regions and sectors and firms depending on their size (Capello, Lenzi 2021; OECD 2021). In the European Union alone, it is estimated that 58% of large enterprises are highly digitised, but only 20% of Small and Medium Enterprises (SMEs); 56% of computing companies and just 8% of metal product companies (EC 2021a). Therefore, policy instruments and special funding schemes at the supranational, country and regional levels have been introduced (CoR 2021) to reduce disparities in digitalisation and help SMEs, in particular, to discover and invest in I4.0 solutions that best fit their needs. Some of the most important, Europe-wide initiatives implemented were the Digital Innovation Hubs (DIH) – units offering consultancy and support in making I4.0 investment decisions and contributing to the digital transformation of regional economies (Rissola, Sörvik 2018; Hervas-Oliver et al. 2021b). Although having similar goals, regional organisations operate in different socio-economic conditions, and as a consequence – must face different challenges.

Therefore, the paper's aims are 1) to analyse framework conditions for the implementation of Industry 4.0 in the manufacturing sector in the diverse European regions and 2) to investigate actions undertaken by regional organisations and Digital Innovation Hubs to foster the adoption of Industry 4.0 technologies in manufacturing companies – to overcome their implementation barriers.

For the analysis, we selected three areas for case studies: Baden-Württemberg (south-western Germany, hereafter in this paper "G"), Veneto and Friuli Venezia Giulia (North-Eastern Italy, "I"), and Wielkopolska (western Poland, "P"). Selected regions are characterised by strong manufacturing sectors in terms of gross value added and their share in overall regional employment (both exceeding average values for the European Union), but at the same time differences in the GDP and innovativeness level (which may lead to different actions undertaken to facilitate I4.0 implementation and varying prospects for this type of technology). To address the research aims, we analysed available statistics and composite indicators and conducted in-depth individual interviews with representatives of regional organisations and Digital Innovation Hubs.

The paper's novelty lies in the comparative investigation of regional approaches toward I4.0. As an international study, it is based on the original data obtained in regions located in three countries during the first author's research visits and written by an international team of researchers. After the introduction, we explain the idea of I4.0, ways of measuring regional preparedness for implementation of I4.0 technologies in manufacturing and what role DIHs can play in this process. It is followed by an empirical part consisting of the chapter devoted to analysing conditions for I4.0 development and two sections on the actions undertaken to implement the I4.0 solutions (in regions in general and by outstanding DIHs). In the end, we present conclusions and limitations, indicating possible further research.

2. Industry 4.0 as a policy priority

Industry 4.0 describes the process of increasing digitalisation and automation of manufacturing along the value chain (Lasi et al. 2014; Capello, Lenzi 2021). Its characteristic features include integrating various information and communication, network technologies in the production process, and utilising digital innovations and the Internet functionality in all elements of the business models, allowing higher involvement of suppliers, customers, and business partners (Liao et al. 2017). A systematic literature review by Culot et al. (2020) showed that the understanding of I4.0 in science and business contains a range of physical-digital interface product and process technologies (based on hardware applications) and also network and data-processing technologies (software applications).

Due to its high potential, I4.0 and, more broadly, digitalisation has recently become essential priorities of innovation policy in Europe. First impulses came from the national governments (starting from the German strategy Industrie 4.0 – Kagermann et al. 2013) and various actions at the European

Union level, aiming at stimulating, accelerating and monitoring Industry 4.0 (Dosso 2020). Also, in the next ten years, digitalisation and I4.0 will remain one of the most significant policy priorities at the European Union level. Under "the Digital Decade" framework, supporting initiatives will focus on digital infrastructures, skills and digitalisation of public services and businesses (DIGITAL 2021; EC 2021a).

While European and national strategic policies clearly indicate that the I4.0 is a primary issue, the regions seem the most appropriate territorial level to undertake actions fostering the implementation of I4.0 technologies. At the regional level, it is possible to discover or shape a regional innovation system and indicate organisations that can be made responsible for specific actions (Asheim, Coenen 2005), including those creating conditions for implementing innovations. The regions succeeded in devising governance structures to foster learning in the knowledge-based economy, utilising four mechanisms based on physical and cognitive proximity among actors: knowledge spill-overs, spin-offs, intra-regional labour mobility and networks (Cooke et al. 1997). At the regional level, it is possible to program and conduct innovation policy adjusted to the local conditions, needs and institutional infrastructure (Tödtling, Trippl 2005).

First studies on the regional dimension of I4.0 show that it creates a development potential for all types of regions (even given differences in defining the I4.0 scope – De Propris, Bailey 2020b; Abonyi et al. 2020; Capello, Lenzi 2021). On the one hand, the production of I4.0 technologies counted by patents and the largest share of their first applications in Europe has concentrated, so far, in the most innovative and economically strong regions (Castelo-Branco et al. 2019; Balland, Boschma 2021). Moreover, I4.0 technologies, allowing automation of processes and higher production efficiency, could encourage firms from high-income and innovative countries to re-shore activities that were previously offshored (Cosimato, Vona 2021). Lagging regions may perceive this as a threat considering their often-weak innovation systems. However, on the other hand, I4.0 creates encouraging perspectives to maintain or raise competitiveness through fast technological upgrading (Szalavetz 2019). The specificity of many I4.0 innovations, especially software-related ones, lies in the possibly rapid implementation, which may be treated as a chance for firms in less-developed regions to raise production efficiency, increase production and sales – also in the international markets (Barzotto et al. 2019; Capello, Lenzi 2021).

3. Capturing territorial preparedness

Although Industry 4.0 is a promising concept for all territories, countries and regions may have different conditions for implementing I4.0 innovations in companies. In the international and interregional comparisons, one of the valuable tools to assess such characteristics is the European Innovation Scoreboard and its regional counterpart – Regional Innovation Scoreboard. It is one of the well-known measures to investigate innovation drivers and performance in territorial innovation systems (Zabala-Iturriagagoitia et al. 2007). The measurement framework includes 32 (or 27 at the regional level) indicators divided into four groups: 1. Framework conditions (human resources, attractive research systems, innovation-friendly environment), 2. Investment (finance and support, firm investments, use of information technologies), 3. Innovation activities (innovators among SMEs, linkages, intellectual assets), and 4. Impacts (employment sales, sales impact and environmental sustainability) (EC 2021b; Regional Innovation Scoreboard 2021).

Two other indicators explicitly used to analyse territorial differences in digitalisation – as a precondition or manifestation of implementation of I4.0 technologies in manufacturing – are: the DESI Index (at the national level) and the Digital Preparedness in Regions – the DPR (at the regional level).

The Digital Economy and Society Index (DESI) is a composite index developed by the European Commission to monitor the digital performance of European countries. The DESI overall index is calculated as the weighted average of the five main dimensions: 1. Connectivity (25%), 2. Human Capital (25%), 3. Use of the Internet (15%), 4. Integration of Digital Technology (20%) and 5. Digital Public Services (15%). Dimension no. 4 concerns manufacturing firms and is calculated as the weighted average of the two sub-dimensions: business digitisation, 60% and e-commerce, 40% (EC 2021c).

Comparing current digitalisation at the regional level has not been easy due to the lack of data (so far, the DESI index has no equivalent at the regional level, CoR 2021). Firm-specific data on obtaining and using particular digital technologies in regions are usually collected through surveys, albeit only by a few regions (for example, the Digital Maturity Survey for Wales 2020 by Henderson et al. 2020). However, in 2021, a framework commissioned by the European Committee of the Regions was created to measure and compare the digital preparedness of regions (DPR)[1]. DPR measures conditions necessary for the regional digitalisation – shows factors that are drivers for I4.0 investments. Currently available indicators for all EU regions that can be used for measuring DPR by component groups include[2]: a) human capital (employment in information and communication and people who graduated and are employed in science and technology), b) business environment (presence of Digital Innovation Hubs, number of ICT companies, number of unicorns), c) public and private investment (money spent in purchasing digital goods and services through public procurement, intramural R&D expenditure by source of funds), d) digital infrastructure (fast broadband coverage and broadband access) and e) digital economy and services (GVA at basic prices in the ICT sector)[3] (CoR 2021).

Apart from the regional conditions that may foster or impede the implementation of I4.0 technologies in companies, the process also has certain common barriers at the firm level. Among the most important, both in developed and developing economies, are lack of a digital strategy alongside resource scarcity (Raj et al. 2020). Cugno et al. (2021) indicate four groups of barriers hampering the introduction of I4.0 technologies: knowledge (insufficient know-how within companies, few skills, little information on public facilities to support investments in I4.0), financing (insufficient financial resources within the firm, scarcity of external financing), culture (inadequate information on the potential offered by I4.0 technologies, the perception that investment in I4.0 is not required, organisational resistance) and system (legal uncertainties, insufficient economic infrastructure). Therefore, special actions undertaken by regional organisations are needed to create conditions for implementing Industry 4.0 technologies and help companies in this process.

4. Digital Innovation Hubs as a tool to disseminate Industry 4.0 technologies in European regions

One of the most important Europe-wide initiatives facilitating the popularisation of Industry 4.0 is Digital Innovation Hubs (DIHs). They were first introduced in 2016 as one of the priority policy initiatives of the EU Strategy Digitising European Industry. The program aimed at broad digitalisation of European regions in the public and private sector (Kalpaka et al. 2020). DIHs are organisational structures providing firms with one-stop-shops services needed to introduce digital innovations. Their key tasks include individual consultancy on the digitisation of business model elements (including the so-called digital assessment and advice on the investment strategy); organisation of webinars, training, workshops, innovation camps, hackathons and other events where the potential of digital technologies is explained (creating awareness about I4.0 and shaping skills needed for the digital transition at the company level); as well as provision of specialised infrastructure, for example for "testing before investments" (Miörner et al. 2019a). Digital Innovation Hubs are a specific type of Knowledge-Intensive Business Service (KIBS, Opazo-Basáez et al. 2020), supporting firms to innovate in terms of I4.0 technologies or digitalisation. Still, the broader effects on regional digitalisation and economic development are also important aspects of their activity.

The idea behind introducing DIHs as a policy instrument consisted in providing broad support for the availability of digitalisation in the European regions, with locations close to potential recipients, especially small and medium enterprises (Rissola, Sörvik 2018). The framework for designating DIHs has been formulated in a general way by the European Commission to enable its creation under various regional conditions. An analysis of DIHs in Europe showed a considerable variation between them,

[1] It was built based on the DESI Index, as well as two additional indicators: The Local and Regional Digital Indicator LORDI, constructed by ESPON (at the time of the research under consultations), as well as the Cisco's digital readiness framework.

[2] Many indicators suggested in this report, showing regional digitalisation or digital preparedness, are currently not available at the regional level.

[3] Similar indicators and few others were suggested by Abonyi et al. (2020) in counting the so-called Regional Industry 4.0+ Readiness Index.

including variations in their origins and way of formation (Miörner et al. 2019b). DIHs were constituted as a regionally anchored instrument, the first regional points of contact for existing industries' demand-side endeavours regarding digital technologies. Therefore, they were also intended to be linked strongly to other EU-wide initiatives supporting policy creation at the regional level. Their actions were supposed to influence the realisation of regional innovation strategies, particularly smart specialisation strategies, an instrument that helps align regional agendas and investments with EU priorities (Rissola, Sörvik 2018; Miörner et al. 2019a).

In the years 2016-2021, the launching and dissemination of DIHs were financially supported by the European Regional Development Fund, national funds, and often by Horizon 2020 research Programme. While basic services provided by DIHs for companies were usually free of charge, more specialised services were often commercialised or sometimes co-funded by public funds and membership fees (Rissola, Sörvik 2018). Also, the online Digital Innovation Hub Tool was launched as a part of the S3 Platform of the EU Joint Research Centre, aiming to facilitate contact between firms and DIHs and DIHs and policy-makers and other DIHs (S3 Platform – DIH tool 2021).

The first evaluations of the impact of DIHs on digital transformations in regions were conducted recently. Actions undertaken by DIHs in Spain seem to influence entrepreneurial discovery processes, networking, learning by interaction, open innovation generation, and new knowledge creation. As a consequence, they influence regional path creation or path modernisation through the cross-fertilisation of regional actors, industries and activities (Hervas-Oliver et al. 2021b). Another study among Italian DIHs proved that they are both knowledge brokers (facilitating access to external knowledge) and knowledge sources (facilitating knowledge transfer). They are embedded in local territories and generate a high level of trust, which helps them to plan individual digitalisation paths (Crupi et al. 2020).

In the years 2022-2027, the new programme enacted at the EU level – The Digital Europe Programme, is intended to foster selected DIHs – henceforth European Digital Innovation Hubs (EDIHs), by providing funding, especially for supercomputing, artificial intelligence, cyber security and advanced digital skills (EC 2021d; DIGITAL 2021). Given the tremendous political interest in supporting Industry 4.0, this paper aims to analyse actions undertaken by regional organisations and Digital Innovation Hubs to facilitate the adoption of I4.0 technologies in manufacturing companies, considering divergent framework conditions for implementing I4.0 technologies in different types of regions.

5. Data and methods

For the analysis, we chose three case studies among European regions: Veneto & Friuli Venezia Giulia regions in Italy, Wielkopolska in Poland and Baden-Württemberg in Germany. We chose the case study as a research method (Yin 2018) because we wanted to investigate how the current state of economy and innovativeness influences digitalisation and I4.0 implementation in the manufacturing sector in regions and how regional authorities are acting to facilitate the dissemination of Industry 4.0 technologies (what kind of actions they are performing to achieve that aim and why). The choice of case studies was purposeful (Swanborn 2010; Yin 2018): we wanted to compare indicators and contemporary actions (treated as cases) fostering Industry 4.0 adoption in selected European regions (three case studies) characterised by different GDP per capita and different innovativeness levels. The substantive criterion for selecting these regions[4] was a possible heterogeneity of digitalisation indicators and approaches towards fostering the dissemination of Industry 4.0 technologies in firms.

The research design consisted of two main steps. First, we performed desk research and analysed framework conditions and digital preparedness – statistics and indicators showing regional readiness to implement Industry 4.0 in manufacturing firms. In the second step, we conducted in-depth interviews (IDI) with representatives of regional entities responsible for Industry 4.0 programs or activities (as part of the innovation policy) and outstanding Digital Innovation Hubs located in each of the three selected

[4] Veneto and Friuli Venezia Giulia are two administrative units bordering each other (with different governing bodies); however, as they are characterised by similar level of socio-economic development and economic structure, and many business support organisations are common for firms located in both areas, we treat them as one case study.

regions (Table 1). To this end, we used an open interview scenario with three general issues: (1). Origins and scope of actions (initiatives, projects) undertaken to create conditions for Industry 4.0 dissemination. (2). Explanation of how the actions facilitated or facilitate the Industry 4.0 implementation in manufacturing companies. (3). Barriers and challenges to the implementation of Industry 4.0 in companies (currently and in the upcoming years), given the regional conditions.

TABLE 1.
The interviewees and codes of interview

Region	Organisation	Code
Baden-Württemberg	Regional Network Allianz Industrie 4.0 Baden-Württemberg (located at the VDMA Baden-Württemberg), International Relationships Management and Startups unit (Stuttgart)	G1
	Cyber Forum DIH, Innovation & Digital Ecosystems unit (Karlsruhe)	G2
Veneto, Friuli Venezia Giulia	Confindustria Veneto, Delegate for Policies of Innovation, Research and Industry 4.0 (Venezia / Padova)	I1
	IP4FVG DIH, Area Science Park, Business and Digitisation Office (Trieste)	I2
Wielkopolska	Wielkopolska Observatory of Innovation, The Marshal Office of the Wielkopolska Region (Poznań)	P1
	DIH4Future, Poznan Science and Technology Park, Commercialization and Business Development Department (Poznań)	P2

The interviews took place between June and December 2021, either in person or via videoconference or telephone. Each lasted around 1 hour, was recorded and then transcribed and analysed (speakers were given a code used later in this paper). After the interviews, the speakers sent additional materials and links via email that were used in the analysis to draw conclusions referring to the research questions (multiple sources of evidence were triangulated, as suggested by Yin 2018).

6. Conditions for the development of Industry 4.0 in manufacturing in Baden-Württemberg, Veneto & Friuli Venezia Giulia and Wielkopolskie: preliminary analysis of regional preparedness

For the purpose of analysis, regions were selected based on their location in Germany, Italy, and Poland – with very different characteristics in terms of Industry 4.0. The similarity between the three countries lies in the strong manufacturing sector (NACE section C), with the share in gross value added and employment exceeding the EU-27 average[5]. However, these countries differ significantly in terms of overall innovativeness and specifically, regarding I4.0 – in the number of industrial robots and hitherto integration of digital technology in firms (Germany – high, Italy – average, Poland – low). In terms of the overall digitalisation of the economy and society (counted by the DESI Index) and the percentage of ICT personnel in total employment, Italy and Poland show similar levels, below the EU average and far behind Germany, which is among the European leaders (Table 2). According to Castelo-Branco et al. (2019), in terms of Industry 4.0 readiness at the country level, measured by interconnectivity (infrastructure) and information transparency (big data maturity), Germany stands out (primarily due to the Industry 4.0

[5] Eurostat data (2021) show that the three countries are among the five principal states concerning employment in manufacturing in the European Union, together employing 50% of all its manufacturing workers.

infrastructure), Italy is somewhere around the European average, while Poland is among the continental laggards.

TABLE 2.
Framework conditions for I4.0 applications in manufacturing in Germany, Italy and Poland

No.	Country / Indicator	G	I	P	EU-27	Source, year of data*
1	Share of manufacturing (NACE section C) in gross value added	35	33	32	29	Eurostat, 2018
2	Share of manufacturing (NACE section C) in employment	26	25	29	23	Eurostat, 2018
3	Innovativeness level	strong innovator	moderate innovator	emerging innovator	---	European Innovation Scoreboard, 2021
4	Number of industrial robots per 10000 employees	322	200	42	144	International Federation of Robotics – IFR, 2019
5	DESI Integration of Digital Technology in firms**	7,9	6,2	5,2	8,3	European Commission – Digital Scoreboard 2020
6	DESI Composite Index**	56,1	43,6	45,0	52,6	European Commission – Digital Scoreboard 2020

* All data (except for no. 3) is available for country-level (not for regional one). Source websites are listed in the bibliography at the end of the paper.
** DESI – explanations concerning the index are included in the text of the previous section of this paper.

The national governors of all three countries adopted strategies and special tools to propagate industry 4.0 and to foster the implementation of its solutions in the manufacturing sector.

Germany is believed to be the country that coined the term Industry 4.0. It occurred in 2011, during the Hannover Trade Fair, after which the Federal Government launched a Strategic Initiative Platform Industry 4.0 (DE: *Industrie 4.0*) – a high-tech strategy underlying the role of interplay between humans and machines and the significance of digital applications in manufacturing and production. It assumed the need for a joint effort of key national stakeholders, such as industry associations and Fraunhofer Institutes, for the industrial change (Kagermann et al. 2013; GTAI 2014; De Propris, Bailey 2020b). Today Germany is one of the leaders in the implementation of I4.0 in Europe (Götz 2021).

Italy's economy, especially in the North-Eastern part, is largely based on industrial districts (clusters), predominantly small and medium enterprises in traditional manufacturing sectors, known in the World and respected as "Made in Italy" products. Not surprisingly, the country is at the forefront of research on the possible impact of the fourth industrial revolution on industrial districts and their firms, with emerging examples, especially from the north part of the country (Bettiol et al. 2020). In 2016, the Italian Government enacted the Industry 4.0 National Plan (IT: *Piano Nazionale Industria 4.0*, later expanded to *Impresa 4.0* and *Transizione 4.0)* to foster I4.0 innovations. One of its first executive instruments was the Voucher for digitising SMEs (*Voucher per la digitalizzazione delle PMI*), governed by the Ministry of Economic Development.

Poland is one of the post-socialist countries in Central and Eastern Europe, characterised by a dynamic GDP growth per capita in the last 30 years, primarily influenced by a strong manufacturing sector and growing export of goods to the EU markets (Rachwał et al. 2009; Rachwał 2015; Dyba et al. 2018). However, with its pre-1990 legacy, the country is below the European average in terms of innovativeness and digitalisation in manufacturing and is characterised by huge domestic differences between the more developed western part of the country and the east (Churski et al. 2021). To facilitate industrial digitalisation, the Polish Ministry of Enterprise and Technology established the Initiative for Polish Industry 4.0 – the Future Industry Platform (PL: *Platforma Przemysłu Przyszłości)* in 2019. Its projects included support for Digital Innovation Hubs acting as role models (FPPP 2021).

The differences in the framework conditions for the development of Industry 4.0 are also visible on the regional level – even if all three regions belong to the most industrialised and affluent in each country, with GDP per capita above the national average (Table 3).

TABLE 3.
General information about the economies of the regions under analysis

No.	Region / Indicator	Baden-Württemberg	Veneto	Friuli Venezia Giulia	Wielkopolskie	Source, year of data
1	Number of inhabitants (mln)	11,1	4,879	1,206	3,479	Eurostat, 2020
2	Persons employed in manufacturing (thous.)	1,461	531,6	105,6	360,3	Eurostat, 2019
3	Number of companies (thous.)	470,5	486,0	88,8	430,4	RIMP, 2019
4	GDP (mln euro)	525 197	164 860	38 772	52 576	Eurostat, 2019
5	GDP per capita PPS (euro)	42800	33 700	32100	24600	Eurostat, 2019
6	GDP per capita PPS (EU27 =100)	137	108	103	79	Eurostat, 2019
7	Innovativeness level	innovator leader	strong innovator	strong innovator	emerging innovator	Regional Innovation Scoreboard 2021

Baden-Württemberg [DE1 in the NUTS classification] is a land in south-western Germany consisting of four sub-regions (Stuttgart, Karlsruhe, Freiburg and Tübingen). For decades it has been one of the most affluent and innovative regions in Europe, characterised by strong manufacturing and institutional setting allowing technology transfer and industrial development (Hassink 1993; Heidenreich, Krauss 1997). The strengths of the regional economy are the automotive industry representing a quarter of the industrial turnover, and mechanical engineering representing 20% of the industrial turnover, followed by the metal and electrical industries. The chemical, pharmaceutical, and optical industries account for much less than the three previous sectors, but their share in the overall national production has increased (RIMP 2016).

Veneto [ITH3] is a region in north-eastern Italy, with the capital city in Venice (other important industrial and service centres include Vicenza, Verona, and Padua). It is one of the leading industrial regional economies that saw an "economic miracle" of development in the 60s and 70s. The highly specialised and competitive manufacturing base is mainly comprised of SMEs operating in mechanics, textiles, agro-food, glasses production, gold and jewellery, electrical appliances and furniture (RIMP 2021). Friuli Venezia Giulia [ITH4] is a region bordering Veneto to the east, with the capital in Trieste and two other important centres in Udine and Pordenone. Its vital manufacturing sectors include the wood-furniture industry; manufacture of metal products; manufacture of machinery and equipment; manufacture of electrical and non-electric household appliances; food and beverage industry; manufacture of other non-metallic mineral processing products; metallurgy; shipbuilding. Some of these sectors converge in supply chains and sectors with a high capacity for growth and innovation: the agri-food chain; the home system supply chain; metalworking; the chemical-pharmaceutical supply chain; nautical, shipbuilding, and off-shore, the Bio sector and cultural and creative enterprises (Chiarvesio, Tabacco 2016; S3 Platform 2021; RIMP 2021).

Wielkopolskie [PL41] is a region in Western Poland, with the capital city of Poznan. Its strong manufacturing sector is based on machinery and equipment, motor vehicles, trailers and semi-trailers (and other transport equipment), furniture production, wood and cork products, paper products, manufacturing of food products and beverages, fabricated metal products as well as textiles, leather and related products (Czyż 2010; Churski et al. 2017; S3 Platform 2021; RIMP 2021).

Notably, all three regions included Industry 4.0 and ICT-related elements among development axes ("economic domains") in their smart specialisation strategies: in Baden Württemberg – under the ICT framework, green and intelligent products, in Veneto and Friuli – as a cross-sector innovation and the priority are advanced technologies for manufacturing, in Wielkopolska – within the priority manufacturing of the future, industry of tomorrow and ICT-based development. All three regions included improving industrial production and technology among the regional "scientific domains" and digital transformation among the "policy objectives" (Eye@RIS3 2021).

The analysis allows showing substantial differences in indicators proving the digital preparedness of the investigated regions (Table 4).

The data shows that the Italian and Polish regions have a similar situation regarding digital infrastructure and human capital. In contrast, Veneto and Friuli Venezia Giulia have more Digital Innovation Hubs (see Table 6), more investments in R&D and GVA in ICT. It suggests the business environment of the Italian regions is more advanced for the implementation of Industry 4.0 than the Polish region.

Considering all the presented indicators, Baden-Württemberg has the highest capacity for adopting further I4.0 technologies. Without substantial financial and organisational support in the Italian and Polish regions, we may expect a slower implementation rate of I4.0 technologies in the following years. As a consequence – we may observe growing disparities between the three regions.

TABLE 4.
Digital preparedness of the investigated regions – selected indicators (data for 2019)

No.	Group, indicators	Region	Baden-Württemberg	Veneto	Friuli Venezia Giulia	Wielkopolskie
1	Digital infrastructure	Households with broadband internet access (in %)	94	90	91	89**
2	Business environment	1. Presence of active Digital Innovation Hubs (listed on the S3 Platform of the EC's JRC)	14	7	4	2
		2. Number of enterprises in ICT (in brackets the number of manufacturing enterprises per 1 ICT enterprise)	21989 (21:1)	10256 (47:1)	2413 (37:1)	10610 (41:1)
3	Investment in R&D	The gross domestic expenditure on R&D (GERD) as % of GDP	5,6	1,39	1,71	0,82
4	Human capital	1. Persons employed in ICT* (number and number of employed in manufacturing per 1 employed in ICT)	205247 (7:1)	43160 (12:1)	8887 (12:1)	28057 (13:1)
		2. Persons with tertiary education (ISCED) and/or employed in science and technology (HRST) in thous. (and as a % of the total workforce)	3454,1 (50,2)	918,4 (35,4)	237,6 (37,6)	725,7 (39,7)
5	Digital economy and services	Gross value added at basic prices in the ICT sector (mln euro)	22 841,64	3535,9	884,4	1382,85

* ICT is a section J in a NACE classification and includes programming and broadcasting activities; wired, wireless and satellite telecommunications activities; computer programming and consultancy activities; information service activities such as data processing, hosting, web portals, news agencies, information search; and also publishing activities as well as motion picture and sound recording activities (the last two less relevant for the digital preparedness in terms of I4.0);
** Data for Makroregion północno-zachodni (województwa zachodniopomorskie, lubuskie i wielkopolskie).
Source: own elaboration based on Eurostat and S3 Platform – DIH tool (for 2.1).

7. Types of regional actions fostering Industry 4.0 adoption in manufacturing firms

The interviews and further information sent or mentioned by interviewees afterwards allowed us to collect and categorise various actions undertaken in regions to foster the adoption of Industry 4.0 in manufacturing firms in recent years. We aggregated these actions into 8 types, corresponding to five component groups of the "digital preparedness" framework (infrastructure – 1, business environment – 2, 3, 4, investments/ funding – 5, human capital – 6, digital economy and services – 7, 8). The scope of actions and their direct link to the I4.0 concept differ between the investigated case studies (Table 5).

TABLE 5.
Typology of regional actions fostering the adoption of Industry 4.0 technologies in manufacturing firms (in the years 2016-2021)

Type	Example of good practice	Description	Case study
1. Investments in the broadband internet infrastructure	Broadband internet expansion (Breitbandausbau)	Project financed from federal funds (in the years 2016-2020), where 2630 broadband projects plus additional 810 expansion projects in counties, cities and municipalities were supported	G
	Strategy for next generation access network (Strategia Nazionale per la Banda Ultra-Larga, SNBUL)*	Italy's national ultra-broadband plan that facilitated the rollout of fibre-based broadband internet networks. Several projects funded from state and EU regional funds were implemented in stages (in the years 2015-2020)	I
	Wielkopolska Broadband Internet Network (Wielkopolska Sieć Szerokopasmowa)	The project was conducted under a public-private partnership (EU regional funds and internet operator) allowed to deliver the next generation access to all communes in the region (basic infrastructure completed in 2015; afterwards, distribution nodes are used to provide the network to further areas and end-users by ICT operators)	P
2. Strategic planning and monitoring of I4.0 development	Allianz Industrie 4.0 (in particular the Steering Committee)	Network initiated and funded by the Ministry of Economics, Labour and Tourism Baden-Württemberg. Partners: high-ranking representatives from politics in Baden-Württemberg, businesses, applied research institutions, chambers and social partners advise on the actions fostering the adoption of Industry 4.0 technologies in companies	G
	Veneto Innovazione, Industry Platform 4 FVG **	Technical structure supporting the regional government in innovation-related activities (exploitation of innovations, organisational support with innovative projects, promotion of innovation)	I
	Regional Council "Industry of the Future" (Wielkopolska Rada 30) and Wielkopolska Innovation Observatory **	Two bodies: council of 30 experts representing regional economic organisations and the regional administration unit - advising regional authorities on strategic documents and initiatives related to the regional economy. The second commissioned two external expert's analyses on the possible impact of I4.0 on the regional job market.	P

TABLE 5. CONT.
Typology of regional actions fostering the adoption of Industry 4.0 technologies in manufacturing firms (in the years 2016-2021)

Type	Example of good practice	Description	Case study
3. Creation of awareness about available I4.0 technologies	Regional website dedicated to Industry 4.0	Dedicated information containing the main terms in Industry 4.0 or basic digital assessment tools	G, I
	Competence Atlas of I4.0	An online tool to find all suitable companies and organisations operating within the area of I4.0 (available in the initial phase of Allianz Industrie 4.0)	G
	Events, webinars, training, and workshops on I4.0 innovations, often followed by individual consultations on digital transformation	In G – Actions of Allianz Industrie 4.0 Baden-Württemberg In all – actions of DIHs	G, I, P
4. Promotion of good practices of I4.0 implementations in firms within the regions	100 locations for Industry 4.0 Baden-Württemberg	Competition promoting "outstanding ideas from business, science and education that fully exploit the potential of I4.0 in Baden-Württemberg"	G
	100 places of Industry 4.0 and sustainability	Competition promoting good examples of I4.0 technology implementations in firms	I
	i-Wielkopolska – innovative for Wielkopolska competition **	Competition aiming at promoting firms that implemented outstanding innovations: yearly editions since 2007, recently including those in the field of I4.0	P
5. Financial support for I4.0 implementations in firms	Funds for innovations in SMEs (grants, vouchers or loans), including dedicated sources for digital innovations* **	Grants or loans under the available funding schemes (including European, national and regional funds). In I and P include dedicated vouchers for digitalisation.	G, I, P
	Tax reductions*	Tax reductions for implementing innovations related to Industry 4.0	I
6. Preparing workers for the demands of I4.0 through education and training	Training centres	Organisations offering courses related to I4.0 for existing companies In all – actions of DIHs	G, I, P
	Learning Hubs 4.0 at Vocational Schools	Establishment of 37 training factories 4.0 at vocational schools – laboratories similar to industrial full-automatic solutions in layout and features, spots to learn and train up basic techniques of application-related processes.	G

TABLE 5. CONT.
Typology of regional actions fostering the adoption of Industry 4.0 technologies in manufacturing firms (in the years 2016-2021)

Type	Example of good practice	Description	Case study
	Industrie 4.0 Talents	Competition promoting training programs for students and apprentices, already introduced in companies	G
7. Supporting I4.0 start-ups	Consultancy of business models for start-ups in the field of I4.0 (or utilising I4.0 technologies) **	Standard consultancy for start-ups in the Knowledge-Intensive Business Services (technology parks, business incubators, chambers of commerce) and DIHs	G, I, P
	Startup the future	Matchmaking event where representatives of start-ups in sectors of Industry 4.0 meet directly with decision makers of industrial companies.	G
8. International promotion and networking of regional firms operating in the field of I4.0	Funding participation of firms in international fairs **	In G – one of the pillars coordinated by Allianz Industrie 4.0 (and dedicated to I4.0) Promotion of companies offering I4.0 on international fairs (financed by regional administration or chambers of commerce)	G, I, P

* Instruments at the national level, conducted in cooperation with regional authorities or promoted at the regional level.
** Activities supporting the adoption and popularisation of any innovative solution in companies (including I4.0, but not exclusively).
Source: own elaboration based on interviews, information sent by the interviewees and internet websites.

The most comprehensive approach towards I4.0 focused on the specific set of technologies included in the I4.0 framework is being implemented in Baden-Württemberg under the framework Allianz Industrie 4.0. The network, founded in 2015, aims "to establish Baden-Württemberg as a leading provider and lead market for Industry 4.0 technologies". As [G1] explains, "*Various projects and purposeful actions fostering Industry 4.0 implementation by regional companies are coordinated by the Allianz Industrie 4.0 Baden-Württemberg. The framework consists of 5 pillars, each with a dedicated project manager*: *Industry 4.0 Initial consultation, Learning & Qualification 4.0, AI & Cybersecurity, International Relationships Management and Startups as well as Networking & Data-based Business Models*". The Allianz Industrie 4.0 Baden-Württemberg is structured as follows: The coordination office, which is responsible for coordinating and implementing activities, is located at the VDMA Baden-Württemberg. Besides there is the core team which oversees operational coordination and alignment. This team consists of representatives from politics, businesses and applied research. In addition, the Allianz Industrie 4.0 works closely together with three main partners (bwcon, microTEC Südwest e.V. and Landesnetzwerk Mechatronik). The strategic orientation of the Allianz Industrie 4.0 is set by the Steering Committee, which consists of high representatives from the Ministry of Economics, Labour and Tourism Baden-Württemberg, businesses and applied research institutions (www1). The various actions undertaken within those 5 pillars are listed in Table 5.

First activities and initiatives facilitating Industry 4.0 development in the investigated Italian and Polish regions (support for Digital Innovation Hubs, financial vouchers for digitalisation) were managed and funded from the central, country level (or funded from external funds, including the EU funds). In Veneto and Friuli Venezia Giulia, the growing interest in the subject is confirmed by the pivotal project undertaken by the regional industrial association (*Confindustria*) – the "100 places of Industry 4.0 and sustainability". It takes the form of events – either via direct contact or online, each presenting one company. *These are promotions of the concrete Industry 4.0 solutions in firms, showing the most innovative* *implementations serving digital and sustainable transformation of companies (…). To encourage participants, each company receives a 2-days consultancy of digital assessment. Therefore, entrepreneurs are happy to show what they do, and each event arouses great interest, gathering up to 200 participants* [I1]. Interestingly, it was undertaken based on the Baden-Württemberg 100 places initiative and proved to be a successful nation-wide initiative (used now by other local industrial associations; www3).

In Wielkopolska, activities fostering Industry 4.0 are an integral part of the regional innovation policy, which aims at fostering designated smart specialisations. As confirmed by [P1], Industry 4.0 technologies (ICT) are cross-sectoral innovations, so they are part of general innovation policy activities. The appointment of the Wielkopolska Council of 30 – Industry of the Future, an advisory body consisting of representatives of the most important regional business support organisations and firms (including experts in Industry 4.0), can be given as an example of good practice (www5).

8. Actions of Digital Innovation Hubs enabling manufacturing companies to adopt Industry 4.0 innovations

There are significant differences between the three case studies in the number of Digital Innovation Hubs and the overall variety of services they provide to regional companies (Table 6).

For the detailed analysis in this paper, we contacted and interviewed representatives of three Digital Innovation Hubs, one from each region: Cyber Forum (G2), IP4FVG (I2) and DIH4Future (P2). The Hubs were indicated by the regional representatives (G1, I1, P1) as active and relevant for the digitalisation and implementation of I4.0 technologies in the three regions. Cyber Forum is a non-profit organisation with a registered office in Karlsruhe. It was set up in 1997 and since then evolved from a network of stakeholders related to the IT industry in the region to become a Digital Innovation Hub in 2017. It received funding from the German Federal Government within the program De Hub as one of the 12 supported organisations in the country (www2). IP4FVG is an Industry Platform for Friuli Venezia Giulia, based in Trieste. It dates back to 2018, when it was set up as an industrial platform, part of Area Science Park, soon to be named a Digital Innovation Hub and receive funding from the regional administration budget (www4). DIH4Future, a consortium led by the Poznań Science and Technology Park in Poland, was established in 2019. In the first years, it received a subsidy from the national Ministry of Development as one of the 5 model Digital Innovation Hubs featured in the country (www6).

The origins and organisational structure of the three DIHs differ (as suggested by Miörner et al. 2019b), but the tasks and services they provide are similar and in line with the guidelines of the European Union (Table 6, as in Kalpaka et al. 2020). In the light of interviews [with G2, I2, P2], DIHs have strong and diverse connections with regional universities, administration, and other DIHs and provide access to specialised equipment and technology providers. Therefore, they are an important part of the regional innovation policy, facilitating the implementation of smart specialisation strategies (as in Rissola, Sörvik 2018).

According to the interviewees, an important role of DIHs is to help companies overcome digitalisation barriers at the firm level. As the interviewee [G2] indicates, "*it is lack of knowledge on the opportunities created by digitalisation and problems with financing. This is where we try to help the most*". The interviewee [I2], apart from these barriers, another barrier is "*necessary changes in business models, comprising a range of elements to be changed, (…) difficult because of the often reluctance to changes among the managers and other workers in many companies*". Finally, the speaker [P2] says that financing and lack of knowledge are problems; however, it is the "*overall human factor in the introduction and use of Industry 4.0 technologies that impede changes in companies. It includes lack of skills, willingness or potential to fully benefit from the introduced digital changes*". According to the speaker, in many regional SMEs, a significant barrier is also technological backwardness, but indeed only companies with a certain level of digitalisation, conscious of the I4.0 potential, use the DIH consultancy. In the light of the conducted research, the barriers to implementing Industry 4.0 technologies in European firms are similar (as in Cugno et al. 2021; Raj et al. 2020), but the lower the level of GDP per capita and innovativeness, the more they are connected with human and technology-related factors and more challenging to overcome.

TABLE 6.
Services provided by the Digital Innovation Hubs in Baden-Württemberg, Veneto & Friuli Venezia Giulia and Wielkopolska

Case study	Name and city	Services provided*														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
G	Mittelstand 4.0-Kompetenzzentrum (Stuttgart)		x				x		x							
	Smart Data Solution Center Baden-Württemberg (Stuttgart)		x	x		x		x	x					x	x	
	Fraunhofer Future Work Lab (Stuttgart)		x	x		x	x	x	x	x				x		x
	Application Center Industrie 4.0 (Stuttgart)	x	x	x		x	x	x	x					x	x	
	Center Digitisation District (Böblingen)	x	x	x		x	x	x	x	x					x	
	University Werk150 (Reutlingen)	x	x	x		x	x	x	x	x		x		x	x	
	Hahn-Schickard (Villingen – Schwenningen)	x	x	x		x		x	x				x	x		
	Cyberforum – Software Cluster (Karlsruhe)		x	x				x	x	x						
	FZI Research Center for Information Technology (Karlsruhe)		x	x		x		x						x		
	Smart Data Innovation Lab (Karlsruhe)		x	x	x	x		x	x	x				x	x	
	Steinbeis-Europa-Zentrum (Karlsruhe)	x	x	x				x	x		x	x			x	
	Institute of Reliable Embedded Systems and Communication Electronics (Offenburg)			x		x			x					x		
	Transfer Platform Industry 4.0 (Aalen)													x		
	Application Center for Automation in Healthcare (Mannheim)	x	x	x		x			x	x		x		x	x	
I	IP4FVG Area Science Park (Trieste)	x	x	x			x	x	x	x	x	x		x	x	
	Lean Experience Factory – DIEX Digital Experience (San Vito al Tagliamento)		x	x			x	x							x	
	Laboratory for Advanced Mechatronics – LAMA FVG (Udine)	x	x	x		x	x		x				x	x	x	
	DIH Udine – Data Analytics & Artificial intelligence (Udine)		x	x			x	x				x			x	
	SMACT Competence Center (Venezia)	x	x	x		x	x	x	x			x		x	x	
	Ecipa Nordest Hub (Venezia)	x	x				x	x	x			x				
	T2i – DIH Triveneto (Treviso)	x	x	x		x	x	x	x	x	x	x		x	x	
	Galileo Digital Innovation Hub (Padova)	x	x	x		x		x	x	x	x	x		x	x	
	Digital Innovation Hub Vicenza (Vicenza)		x	x		x	x	x	x	x	x	x		x	x	
	Speedhub (Verona)	x	x				x	x	x			x			x	
	DIH Belluno Dolomiti (Feltre)	x	x	x			x	x	x	x		x			x	
P	HPC4Poland (Poznan)	x		x		x	x		x	x				x		
	DIH4Future, Poznan Science and Technology Park (Poznan)	x	x	x	x	x	x	x	x	x	x				x	x

* 1. Access to funding and investor readiness, 2. Awareness creation, 3. Collaborative research, 4. Commercial Infrastructure, 5. Concept validation and prototyping, 6. Digital maturity assessment, 7. Ecosystem building, scouting, brokerage, networking, 8. Education and skills development, 9. Incubator / accelerator support, 10. Market intelligence, 11. Mentoring, 12. Pre-competitive series production, 13. Testing and validation, 14. Visioning and Strategy Development for Businesses, 15. Voice of the customer, product consortia.
Source: elaboration based on information on the S3 Platform – DIH tool (2021).

The interviewees in all three regions, representing regional organisations and DIHs, list similar challenges in the further dissemination of I4.0 technologies in the subsequent years. They include the need to: a) create awareness about the potential of I4.0, b) help managers find the best financing strategies for I4.0 implementation and c) shape the digital skills of workers, which among others, may include subsidised training or webinars for employees and changes in the study programs at universities and schools.

9. Conclusions, limitations and further research

The paper aimed to compare actions undertaken to foster the implementation of Industry 4.0 (I4.0) technologies in manufacturing firms in Europe. In particular, we analysed various initiatives and projects coordinated by regional organisations responsible for I4.0-related actions in three regional case studies: Baden-Württemberg in Germany, Veneto & Friuli Venezia Giulia in Italy, and Wielkopolska in Poland. They included activities of Confindustria Veneto (one of the Italian industrial associations), German Engineering Association VDMA (governing the flagship project Allianz Industrie 4.0 in Baden-Württemberg), Wielkopolska Innovation Observatory (unit of the regional administration) as well as three outstanding Digital Innovation Hubs – organisations, set up as a response to the European Commission's innovation policy, advising firms on the best strategies of digitalisation – implementation of I4.0 technologies.

In the first step of the analysis we proved major differences in regional backgrounds for implementing Industry 4.0 in enterprises: different initial GDP, innovativeness levels as well as various digitalisation indicators. Although operating in different conditions, representatives of all investigated organisations acknowledged in the second step the potential created by I4.0 technologies. Indeed it shows that I4.0 may significantly influence manufacturing in all types of regions in Europe (as in Barzotto et al. 2019; Capello, Lenzi 2021). In all investigated regions, the ICT-related elements are included in smart specialisation strategies, which as an I4.0 enabler, indeed should be a cross-sectional, basic element of all innovation policies (Hervas-Oliver 2021b).

Actions fostering the implementation of I4.0 technologies undertaken by regional organisations were divided into the following groups: infrastructural investments, strategic planning and monitoring, awareness creation, promotion of good practices, financial support for I4.0 implementations, preparing future workers for the demands of I4.0 through training and education as well as supporting start-ups and international networking. The most comprehensive approach, fostered by the most significant financial support from the regional budget, was observed in Baden-Württemberg in Germany, where a single organisation coordinates various I4.0 actions. The first activities presented dedicated to I4.0 in Veneto and Friuli Venezia Giulia seem to be the beginning of a comprehensive approach towards I4.0 in manufacturing; however, we should highlight that IP4FVG aims at becoming the point of reference for I4.0 actions in the region, able to coordinate actors and projects in this field. In Wielkopolska, activities are part of an innovation policy in general, and their number and scope have been so far smaller than in the other case studies. Importantly, regional authorities in the investigated Italian and Polish regions are aware of the potential created by Industry 4.0, as proved by the commissioning and funding of the publications: Bondyra, Zagierski (2019) and Potti (2020). Regional organisations including Digital Innovation Hubs have been playing an important role in overcoming I4.0 implementation barriers at the firm level, including lack of knowledge about I4.0 technology, no digitalisation strategy, lack of funds and insufficient skills among workers to implement I4.0 technologies (as in Cugno et al. 2021).

The policy recommendation – strategy to follow by regions less advanced in Industry 4.0 – is the replication of "good practices", that is, actions fostering I4.0 implementation that proved successful in regions in the forefront of this field. Most often, it will not be possible without substantial funds and establishing one entity in charge of I4.0 (like in Baden-Württemberg). As the analysis of indicators showed, there are significant differences in "digital preparedness" between European regions, primarily connected to regional GDP and innovativeness levels. It seems that without the significant financial and organisational involvement in all types of regions (under the industrial policy dedicated to I4.0), the gap in the industry advancement and productivity between the most innovative regions and the less affluent European regions will most likely widen (as in Orłowski, 2014).

We acknowledge that our research showed actions fostering I4.0 implementation that have been undertaken at the regional level recently. Many of their effects may be evaluated only after some time, creating the potential for further research. The paper's conclusion in the second half of 2021 coincided with the time scholars, policymakers and technology providers alike conducted the first analyses of the effect of the COVID-19 worldwide pandemic on the regional economies. It may also impact the further implementation of I4.0 technologies in manufacturing firms. Early evidence (CoR, 2021) shows that the pandemic slowed the pace of significant investments into I4.0 hardware like smart robots or the Industrial Internet of Things, but on the contrary, a higher propensity to implement software-related innovations (cloud solutions allowing remote working and online meetings). Further studies should investigate how the changes induced by the pandemic on the organisation and functioning of firms influenced the needs in terms of their support – and, therefore, what are the implications for the actions supporting the implementation of Industry 4.0 that should be performed under the regional innovation policies.

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Annex

Internet websites of regional organizations, innovation platforms and investigated Digital Innovation Hubs

(www1) Allianz Industrie 4.0 Baden-Württemberg (Stuttgart): https://www.i40-bw.de/

(www2) Cyber Forum (Karlsruhe): https://www.cyberforum.de/

(www3) Industria 4.0 Veneto (Padova, Venezia): https://www.industria40veneto.it/

(www4) IP4FG – Area Science Park (Trieste): https://www.ip4fvg.it/

(www5) Innowacyjna Wielkopolska (Poznań): http://iw.org.pl/

(www6) DIH4Future (Poznań): https://ppnt.poznan.pl/dih/

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Articles

Clubes de convergencia regional en Colombia 2000-2016: un análisis flexible por departamentos

Domingo Rodríguez Benavides, Owen Eli Ceballos Mina***

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Resumen:

Los análisis de convergencia económica en Colombia han mostrado resultados en distintas direcciones; aportar evidencia para enfocar los esfuerzos de política pública en la reducción de las brechas regionales resulta muy pertinente. Usando como variable de análisis el PIB per cápita de los departamentos y la capital del país en el periodo 2000-2016, este artículo evalúa la hipótesis de convergencia total frente a la presencia de clubes regionales por medio de la prueba de Phillips y Sul (2007). Después de excluir del análisis las principales regiones mineras del país se identifican seis clubes de convergencia departamental y un grupo que diverge. Los resultados sugieren la persistencia de la desigualdad en el conjunto nacional, pero múltiples equilibrios o estados estacionarios por grupos de departamentos.

Palabras clave: Crecimiento; convergencia regional; modelos no lineales; Colombia.

Clasificación JEL: O18; O47; C32; C33.

Regional Convergence Clubs in Colombia 2000-2016: A Flexible Analysis by Provinces

Abstract:

Economic convergence studies in Colombia have shown mixed results. It is relevant to provide evidence that allows to focus public policy efforts to reduce the gaps between the country's regions. This paper using Colombian departments and the district capital applies the Phillips and Sul (2007) test to evaluate the hypothesis of total convergence versus the presence of regional clubs in GDP per capita in 2000-2016. We found evidence of divergence for the entire country but multiple steady states and departmental convergence clubs if the main mining regions are excluded from the analysis.

Keywords: Economic-growth; convergence; nonlinear models; Colombia.

JEL Classification: O18; O47; C32; C33.

1. Introducción

Colombia entre las naciones en desarrollo de la región, se ha caracterizado por un crecimiento económico relativamente estable, pero con altos niveles de pobreza y desigualdad (Han y Maisel 2018; Robinson, 2016; Aristizábal y García, 2020); estos fenómenos que no se han distribuido de forma homogénea sobre

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el territorio, se manifiestan como persistentes disparidades regionales en su interior. Las regiones centrales con mayor concentración de población y actividad económica como la capital Bogotá y los departamentos de Antioquia y Valle exhiben mejores indicadores de desempeño económico y social frente a otras periféricas como La Guajira, Chocó y Amazonas, que a decir de varios autores han sido desatendidas por el gobierno nacional (García, 2017; Galvis, Hahn, y Galvis, 2017; OCDE, 2018). En este contexto, no son pocos los intereses por medir el cierre de las brechas regionales en el país.

El estudio empírico de las disparidades socioeconómicas en un país o en una región a lo largo del tiempo, posibilita al menos tres tipos de análisis diferentes para medir el cierre de las brechas: *i*) β-convergencia; *ii*) σ-convergencia; y *iii*) convergencia relativa. La β-convergencia es el concepto más utilizado; fue sugerido a principios de los noventa por Barro y Sala-i-Martin y de aquí se desprenden las definiciones de convergencia absoluta y condicional (Moncayo, 2004). Una forma de referir la β-convergencia es la noción de que las regiones pobres crecerán más rápidamente que las ricas. Si se comparan las tasas de crecimiento de cada economía tomando en cuenta el valor inicial del producto, se estudia su convergencia absoluta; cuando se controla dicho crecimiento por factores adicionales se hace referencia a una convergencia condicional.

Milton Friedman en los años noventa sugirió que la verdadera prueba de la tendencia al cierre de brechas económicas entre países sería mostrar una disminución constante de la varianza de la riqueza; esta idea dio lugar a la σ-convergencia. El concepto conlleva a observar la dispersión de la riqueza a lo largo del tiempo; si dicha dispersión decrece y cada territorio se encuentra más cerca del promedio conjunto, entonces se refiere un proceso de tipo σ. De otro lado, el concepto de convergencia relativa procedente del enfoque de medición de series de tiempo es retomado por Phillips y Sul (2007), que por medio de un modelo no lineal con un componente de variación de tiempo y otro idiosincrático, generan una prueba de convergencia para el conjunto que de forma alternativa permite identificar clubes que convergen o divergen al interior. Esta prueba centrada en la idea de que la razón relativa de algún par de variables converge a la unidad en el largo plazo, constituye una prueba más flexible y precisa en términos econométricos frente a los métodos de convergencia tradicionalmente usados.

No son pocos los estudios que se han remitido al análisis tradicional de las convergencias tipo β y σ en Colombia, pero dichos estudios agrupan un conjunto de resultados que no llegan a ser conclusivos (Galvis *et al.*, 2017; Hahn y Meisel, 2018; Moncayo, 2004). En resumen, hay evidencia mixta en las últimas décadas del siglo xx; previo a los años sesenta se señalan periodos de convergencia, mientras que se identifican procesos divergentes con mayor frecuencia en tiempos más recientes; la evidencia aparece en ambas direcciones, tanto en el caso de las tasas de crecimiento regionales como para la dispersión de la riqueza interdepartamental del país. Sin embargo, hasta donde se ha revisado en este estudio, no se han efectuado pruebas de convergencia relativa y de formación de clubes de convergencia regional en el país.

Este trabajo investiga la aplicación del concepto de convergencia relativa y la posible presencia de clubes departamentales de convergencia en Colombia entre 2000 y 2016. Se emplea la prueba de Phillips y Sul (2007), cuya ventaja es que no requiere el cumplimiento de ninguna condición a priori sobre las propiedades estocásticas de las series que conforman el panel de estudio. Los resultados muestran evidencia de un proceso divergente para el conjunto del país, pero cuando se excluyen las regiones con alta producción minera es posible identificar seis clubes de convergencia y un conjunto de cuatro departamentos que divergen. Los dos primeros clubes agrupan las regiones con mejor desempeño económico y mayor desarrollo; los clubes tres y cuatro agrupan un conjunto de departamentos con desarrollo intermedio, mientras los dos últimos grupos las regiones que convergen a los menores niveles de desarrollo del país.

Este artículo se estructura en cinco apartados incluyendo su introducción; en el segundo apartado se hace una breve revisión de la literatura sobre los estudios de convergencia a nivel internacional y en Colombia. En la tercera sección se presenta el conjunto de datos, algunos descriptivos y se detalla el procedimiento para probar convergencia relativa; en la cuarta se presentan los resultados de convergencia para el conjunto de departamentos y por clubes para Colombia, incluyendo y excluyendo del análisis los departamentos mineros. En la quinta y última sección se presentan las conclusiones del trabajo.

2. Revisión de la literatura

2.1. Convergencia en la literatura internacional

La literatura internacional sobre convergencia ha usado un amplio arsenal de herramientas estadísticas para el análisis de las brechas regionales, avanzando de las pruebas más sencillas hacia técnicas flexibles y con mayor alcance analítico. La prueba Phillips y Sul (2007) posee ventajas como el no depender del supuesto de estacionariedad a un único estado. Es una prueba que permite modelar un gran número de sendas de transición hacia la convergencia; permite introducir la hipótesis de convergencia por subgrupos y posibilita el modelaje de unidades heterogéneas sin ninguna dificultad. Así pues, es una prueba de convergencia relativa suficientemente flexible que permite discernir entre uno o varios estados estacionarios a los que convergen países o regiones.

Cabe mencionar que la metodología de Phillips y Sul (2007) también se ha utilizado para el análisis de convergencia de diferentes mercados. Montagnoli (2015) por ejemplo, aplica esta metodología para el mercado inmobiliario del Reino Unido comprobando la existencia de múltiples clubes de convergencia y no un único equilibrio. Otro caso es el trabajo realizado por Reyna (2014), en el cual se estudia el mercado laboral peruano entre 2001 y 2011 identificando cuatro clubes en los que los miembros suelen encontrarse geográficamente cerca unos de otros. Pese a estas breves menciones, la principal actividad en la que se ha utilizado la metodología de clubes de convergencia son los análisis del crecimiento y sus determinantes.

Por ejemplo, Barrios *et al.* (2017) aplican la prueba Phillips y Sul (2007) para las regiones españolas en el periodo de 1980 a 2008; comprueban la existencia de clubes de convergencia para las variables del PIB per cápita, la productividad laboral y el empleo. Los autores concluyen que existe convergencia conjunta de la productividad laboral, mientras que encuentran tres clubes para el PIB y empleo. Monfort *et al.* (2013) emplean la misma metodología para el continente europeo utilizando el PIB per cápita en el periodo de 1980 a 2009; los autores encuentran dos clubes de convergencia para Europa central y Europa del este, mientras definen que la pertenencia a la zona euro es el determinante para que un país se encuentre en un grupo de ingresos altos o bajos.

Li *et al.* (2018) emplean la misma técnica para el caso chino en el que analizan el PIB per cápita de 2,286 condados en el periodo 1992 a 2010. Los autores también utilizan un modelo probit ordenado espacial dinámico para determinar los factores que afectan en la conformación de clubes. Concluyen que hay seis clubes de convergencia, donde la industrialización, la densidad de población y los activos fijos per cápita afectan positivamente, mientras la productividad laboral y los niveles de capital humano afectan negativamente la constitución de estos clubes. De igual forma, Tian *et al.* (2016) estudian el PIB per cápita para el caso de China en el periodo de 1978 a 2013. Encuentran que las provincias de China convergen en dos clubes. La desigualdad entre los ingresos de un club y otro lo asocian con la inversión en capital físico, humano y con la tasa de crecimiento de la población.

La metodología de Phillips y Sul (2007) también se ha empleado en algunos países de Latinoamérica para analizar la existencia de clubes de convergencia. En particular, Delgado y Rodríguez (2013) para el Perú encontraron tres clubes de convergencia y dos departamentos desvinculados del resto del país en el periodo de 1970 a 2010. En Ecuador, Tinizhañay (2020) emplean esta prueba en el periodo de 2007 a 2008. En el trabajo se llega a la conclusión de que existen cinco clubes de convergencia con una tendencia decreciente en la productividad a lo largo del tiempo, mientras la disparidad entre el grupo más pobre y el rico aumenta. Por otra parte, Aboal *et al.* (2018) estudiaron la convergencia para los 19 departamentos de Uruguay en el periodo de 2008 a 2018 y encuentran tres clubes de convergencia e identifican una tendencia en el desarrollo de los departamentos.

En el caso de México hay tres trabajos que utilizan la metodología propuesta por Phillips y Sul (2007). Rodríguez *et al.* (2016) investigan la convergencia en clubes con el PIB per cápita para el periodo de 1970 a 2012. Sus resultados muestran que los estados de México convergen en seis clubes y que, al excluir los estados productores de petróleo, Campeche y Tabasco, los resultados se mantienen. López y Cermeño (2016) para el periodo de 1940 a 2013 con respecto al PIB per cápita en el caso mexicano mostraron que existen tres clubes de convergencia y vincularon la desigualdad regional con la proporción de la inversión extranjera directa a nivel estatal. Mendoza *et al.* (2020) analizan los patrones de convergencia de la desigualdad interregional y del ingreso per cápita en los estados mexicanos en el periodo 1940-2015; estos autores no logran probar convergencia al mismo equilibrio de largo plazo, pero aportan evidencia de clubes para la desigualdad y el ingreso per cápita.

2.2. Los estudios de convergencia en Colombia

La reducción de las disparidades en Latinoamérica ha sido tema central de la agenda de investigación económica en la región. Los estudios de convergencia regional en Colombia no han sido la excepción; la literatura especializada en el tema documenta alrededor de dos décadas de estudios regionales en los que diferentes metodologías han sido implementadas para medir el comportamiento en el tiempo de las diferencias económicas entre las regiones del país (Galvis *et al.*, 2017). Un gran número de mediciones de convergencia absoluta y condicional tipo β enfocados en periodos de finales del siglo xx y unos pocos en series más largas hacia atrás, presentan evidencias diferenciadas en favor de la hipótesis de convergencia o de su rechazo.

Entre los primeros trabajos en el país y uno de las más discutidos sobre el tema es el de Cardenas, Pontón y Trujillo (1993), quienes afirman que la β-convergencia para el periodo 1950-1989 fue de 4,22% y de 3.2% si se excluye del análisis los años 50; en opinión de los autores, estas tasas superiores a las de países desarrollados como Estados Unidos, Europa y Japón en el mismo lapso evidencian un exitoso proceso de convergencia en Colombia. Tras esta primera referencia, un importante número de estudios usando información de las décadas previas al año 2000, han aportado evidencia en favor de la convergencia interdepartamental tipo β (Gómez, 2006; León y Benavides, 2015; Royuela y García, 2015), pero junto con esta creciente bibliografía, también emergieron importantes críticas en contrasentido.

Los primeros cuestionamientos sobre la dirección del proceso de convergencia en el país emergen con Meisel (1993), Mora y Salazar (1994) y Bastidas (1996) que haciendo centro en los argumentos de Cardenas *et al.* (1993) discuten la validez de sus hallazgos. Con un periodo más largo Bonet y Meisel (1999) agrupan su análisis en dos tramos temporales y refieren que, aunque las brechas interdepartamentales se redujeron entre 1926 y 1960, a partir de los años 60 y hasta 1995 el análisis de las series del PIB no aporta elementos para referir convergencia. Varios autores se suman en la dirección que prueba un proceso de divergencia condicional o absoluta en este periodo; el mismo Bonet (1999), usando el método *shift-share* concluye que entre 1980 y 1996 las desigualdades en el crecimiento departamental se acentuaron; Rocha y Vivas (1998) también verifican la hipótesis de desigualdad persistente en el período 1980-1994; Lotero, Restrepo y Franco (2000) para 1985-1997 refieren divergencia en la productividad industrial; Galvis y Meisel (2001) usando los depósitos bancarios como *proxy* del PIB en las ciudades más grandes, también refieren un proceso divergente entre 1973 y 1998.

Un grupo de estudios más recientes continúan aportando evidencia en dirección del rechazo de la hipótesis convergencia en Colombia (Acevedo, 2003; Barón, 2003; Bonet y Meisel, 2007; Branisa y Cardozo, 2009; Franco y Raymond, 2009; Martínez, 2006; Hahn y Meisel, 2018). Entre los más recientes Galvis *et al.* (2017) para el periodo entre 1995 y 2016 afirman que si se excluyen los departamentos mineros de Putumayo, Arauca y Casanare no hay evidencia de convergencia absoluta en el país y que en términos de la convergencia condicional a pesar de la evidencia en favor de la hipótesis, es más preciso controlar por factores espaciales como lo hacen Galvis y Hahn (2016) quienes concluyen que dado los efectos indirectos de las derramas espaciales no existe un proceso de convergencia condicional en los municipios del país para el periodo entre 1993 y 2012.

Con centro en los trabajos de Quah (1993, 1995, 1996, 1997) y sus críticas a las mediciones tradicionales de convergencia tipo β y σ en Colombia también se ha constituido una línea alternativa de estudios que analiza el cambio en la distribución de riqueza y si las economías regionales convergen a diferentes estados estacionarios como en el caso de los "clubes de convergencia" (Mora, 2003). Entre las primeras referencias Birchenall y Murcia (1997) basándose en los modelos de dinámica distribucional concluyen que el país exhibe un claro proceso de persistencia que ha mantenido las distancias entre los ingresos de los departamentos y sus posiciones desde la década de los 60; varios autores que han explorado esta perspectiva coinciden en que la distribución de riqueza ha sufrido muy pocos cambios a través del tiempo (Ardila, 2004; Birchenall y Murcia, 1997; Bonet y Meisel, 2007; Branisa y Cardozo, 2009; Franco y Raymond, 2009; Gómez, 2006; Martínez, 2006; Royuela y García, 2015).

Bajo este enfoque Bonet y Meisel (2007) en torno a la distribución de ingresos depertamentales en el periodo 1975-2000 describen el proceso de polarización regional y remarcan la posición de Bogotá como capital del pais con un ingreso percápita que duplica la media nacional y una posición que se ha consolidado a lo largo del tiempo frente a las regiones periféricas. Gómez (2006) para el período 1960-2000 por medio de un Kernel Gaussiano identificó en los años ochenta posibles clubes de convergencia con tendencia a la polarización, aunque afirma que en la década de los noventa las disparidades regionales parecen disminuir. Franco y Raymond (2009) para el periodo 1975-2005 usando panel de efectos fijos y mediante el cálculo de estados estacionarios de equilibrio departamentales definen cuatro clubes de convegencia dos para los departementos más desarrollados y otros dos para los de mayor rezago; en general, sugieren que tres de los cuatro clubes (dos desarrollados y el club de los más pobres) convergen al interior, pero no encuentran evidencia de que los clubes se acerquen entre si por lo que concluyen que las desigualdades regionales en el pais se estan acentuando.

En un estudio reciente, Aristizabal y Garcia (2020) analizan la relación entre las instituciones y el crecimiento económico en un nivel intra-regional en Colombia a través de la estimación de modelos de crecimiento económico aumentado con variables institucionales y efectos espaciales. Sus resultados muestran que las instituciones tienen un fuerte impacto positivo en el crecimiento económico regional, mientras que los efectos de desbordamiento espacial de los factores institucionales de una región muestran un efecto negativo sobre el crecimiento económico de las regiones vecinas, resultado que atribuyen a los altos niveles de heterogeneidad y fragmentación institucional encontrados en las regiones de Colombia.

3. Datos y modelo de convergencia relativa

Este apartado hace una primera referencia descriptiva al conjunto de datos y a los detalles metodológicos del modelo para la prueba de convergencia. Los datos empleados en este análisis provienen de la información pública disponible provista por las Cuentas Departamentales de la Dirección de Síntesis y Cuentas Nacionales del Departamento Administrativo Nacional de Estadística (DANE) del Gobierno colombiano en 2020. La prueba de convergencia relativa utilizada se basa en el modelo semiparamétrico propuesto por Phillip y Sul (2007) y el algoritmo en cuatro pasos para probar la existencia de clústeres o clubes de convergencia.

3.1. Datos y descriptivos

La información para el análisis de este artículo corresponde al producto interno bruto (PIB) per cápita departamental entre 2000 y 2016 a precios constantes de 2005[1]; el periodo de análisis se determinó principalmente por la disponibilidad de datos recientes sobre este indicador. El cuadro 1 presenta el comportamiento del PIB per cápita corriente por departamento para el primer y el último año de análisis, la tasa media de crecimiento y su varianza. Para el año 2000, Casanare fue el departamento con mayor nivel de ingresos per cápita con 25.7 millones y Chocó el de menor con apenas 1.6 por habitante; en el año 2016, el de mayor ingreso fue Santander con 31.2 millones de pesos mientras el de menor fue Vaupés con 5.2 millones. En el caso de los departamentos de mayor ingreso per cápita vale destacar que ambos se encuentran entre los departamentos mineros del país.

[1] De manera oficial el DANE presenta el PIB per cápita departamental en términos corrientes, pero también brinda información sobre el PIB departamental agregado en términos corrientes y constantes, por lo que es posible estimar el número de habitantes de cada departamento en el periodo muestral y finalmente calcular el PIB per cápita departamental en términos constantes.

Cuadro 1.
PIB per cápita departamental 2000 y 2016, tasa de crecimiento y varianza

Departamentos	PIB per cápita de 2000	PIB per cápita de 2016	Tasa de crecimiento (2000-2016)	Varianza de la tasa de crecimiento
Amazonas	2.626	7.926	7.19%	0.0009
Antioquia	5.436	18.336	7.93%	0.0008
Arauca	8.774	15.981	5.91%	0.0492
Atlántico	4.424	14.603	7.80%	0.0011
Bogotá D. C.	8.769	27.564	7.43%	0.0003
Bolívar	3.939	16.723	9.68%	0.0051
Boyacá	4.633	20.131	9.70%	0.0020
Caldas	3.667	13.158	8.36%	0.0011
Caquetá	2.365	8.528	8.41%	0.0015
Casanare	25.701	30.194	2.14%	0.0264
Cauca	2.313	11.017	10.28%	0.0009
Cesar	3.398	15.321	10.13%	0.0060
Chocó	1.639	7.311	10.29%	0.0115
Córdoba	3.053	8.815	7.16%	0.0068
Cundinamarca	5.282	16.753	7.50%	0.0005
Guainía	2.623	6.671	6.41%	0.0087
Guaviare	2.707	6.819	6.12%	0.0040
Huila	4.181	13.072	7.56%	0.0041
La Guajira	3.595	8.744	6.29%	0.0132
Magdalena	2.472	8.714	8.25%	0.0012
Meta	5.812	26.278	11.47%	0.0382
Nariño	2.180	7.898	8.42%	0.0009
Norte Santander	3.064	10.731	8.21%	0.0013
Putumayo	2.610	8.391	8.64%	0.0236
Quindío	4.036	12.032	7.17%	0.0023
Risaralda	3.826	13.713	8.35%	0.0011
San Andrés y Providencia	4.906	16.926	8.13%	0.0020
Santander	6.255	31.165	10.72%	0.0036
Sucre	2.265	8.130	8.36%	0.0011
Tolima	3.754	13.148	8.22%	0.0016
Valle	5.774	17.991	7.39%	0.0006
Vaupés	1.964	5.218	6.41%	0.0026
Vichada	2.761	6.296	5.40%	0.0026

Nota: PIB per cápita en millones de pesos a precios constantes de 2015.
Fuente: Elaboración propia con datos del DANE.

Es notable que los departamentos con extracción petrolera proseen gran varianza en el comportamiento de sus ingresos mostrando importantes saltos en el PIB per cápita de sus habitantes en el periodo de análisis (son los de mayor varianza en las tasas de crecimiento; por ejemplo, Casanare, Arauca, Meta y Putumayo). En particular, para el año 2000 el desempeño de Casanare muestra una marcada diferencia frente Bogotá D.C. (segundo PIB per cápita más alto con apenas 8.76 millones de pesos) y frente al resto de departamentos del país. En 2016 la dispersión general del PIB per cápita departamental parece menor; pese a esto último, se debe notar que en ambos años las mayores diferencias en el PIB per cápita se encuentran en la parte alta de la distribución, mientras los departamentos de menores ingresos como Chocó, Vaupés, Vichada, Nariño, Guaviare y Amazonas parecen permanecer agrupados.

La tabla 1 también presenta las tasas de crecimiento promedio del PIB per cápita y la varianza de las tasas anuales por cada departamento. Los departamentos con mayores tasas de crecimiento promedio entre 2000 y 2016 son Meta, Santander, Chocó, Cauca y Cesar con promedios entre 10% y 11.5%; de estos departamentos Chocó y Meta presentan una gran varianza en el periodo. Sólo Santander y Meta corresponden a departamentos con PIB per cápita de nivel alto, mientras Chocó, Cauca y Cesar se encuentran entre los departamentos con menor nivel de ingresos. Por otro lado, Casanare que se encuentra entre los departamentos con mayor nivel de ingreso posee baja tasa de crecimiento; en general, los de menor crecimiento son los departamentos que se conocen como las antiguas intendencias al oriente del país como Arauca, Guainía, Guaviare, Vaupés, Vichada, y en el norte La Guajira.

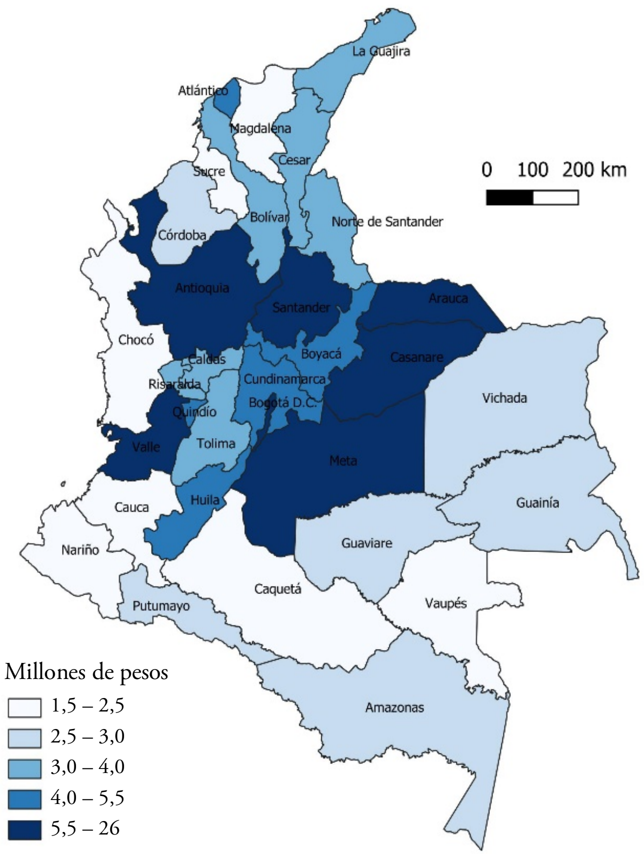
Los departamentos con menor varianza en la tasa de crecimiento anual del PIB per cápita entre 2000 y 2016 son Amazonas, Antioquia, Bogotá D.C., Cauca, Cundinamarca y Valle; entre estos, Amazonas y Cauca son de ingreso bajo, mientras el resto de los departamentos se encuentran entre los de ingreso per cápita medio y alto. Esta breve descripción sobre el comportamiento del PIB per cápita departamental es complementada por una primera visualización de la localización de los departamentos. El mapa 1 presenta el PIB per cápita por departamento en 2000 y 2016. Una primera observación relevante es que los departamentos con un mayor nivel de PIB per cápita tienden a concentrarse en la zona centro del país manteniendo el desempeño entre 2000 y 2016.

En el año 2000 (panel izquierdo del mapa 1) los departamentos de Antioquia, Arauca, Bogotá D.C., Casanare, Meta, Santander y Valle poseen los niveles de ingreso per cápita más alto, seguidos de Boyacá, Cundinamarca, Huila, Quindío, demarcando la región central del país en tonos más oscuros del mapa. Esta situación parece mantenerse para el año 2016 (panel derecho); los departamentos con mayor riqueza per cápita se siguen concentrando en el centro, con pequeños cambios entre los de ingreso medio e ingreso alto; Boyacá se introduce en el grupo de los departamentos de ingreso alto, mientras que Arauca es desplazado al segmento de ingresos medios.

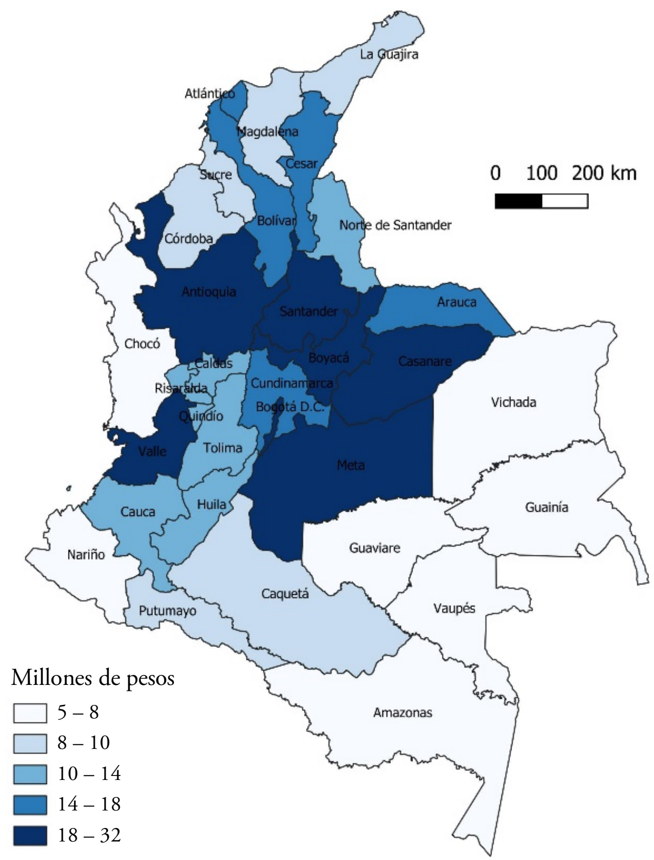
En la dinámica del mapa 1 entre 2000 y 2016 se observa claramente que, si bien en el centro del país se mantiene una concentración de los departamentos de ingresos altos y medios, la periferia concentra departamentos de ingreso per cápita bajo. En el año 2016 los departamentos de Amazonas, Cauca, Guaviare, Guainía y Vichada pasaron a formar parte al segmento de menor ingreso consolidando la periferia de menor ingreso per cápita en las zonas del pacífico, el oriente y el sur del país; esta sugerencia de segregación espacial del PIB per cápita de los departamentos podría sugerir un comportamiento por grupos de crecimiento y la posibilidad de clubes de convergencia.

Mapa 1.
PIB per cápita por departamentos

a) Colombia en 2000



b) Colombia en 2016



Fuente: Elaboración propia con información del DANE.

3.2. Prueba de convergencia y de agrupamiento en Clubes

El punto de partida del modelo es la descomposición del panel de datos X_{it} como:

$$X_{it} = g_{it} + a_{it} \tag{1}$$

donde g_{it} representa los componentes sistemáticos tales como los componentes permanentes comunes mientras que a_{it} incorpora los componentes transitorios. Con el fin de separar los componentes comunes de los idiosincrásicos, es posible transformar la ecuación (1) de la siguiente forma:

$$X_{it} = \left(\frac{g_{it}+a_{it}}{u_t}\right)u_t = \delta_{it}u_t \tag{2}$$

donde δ_{it} es un elemento idiosincrático que varía en el tiempo y u_t es un solo componente común. La ecuación (2) es un modelo de factor dinámico donde u_t captura algunos componentes determinísticos o el comportamiento de tendencia estocástica; mientras el factor de ajuste variante en el tiempo δ_{it} mide la distancia idiosincrática entre el componente de tendencia común u_t y X_{it}. En general, no es posible estimar de manera directa el modelo sin imponer algunas restricciones sobre δ_{it} y u_t, por lo que Phillips y Sul (2007) proponen remover el factor común de la siguiente manera:

$$h_{it} = \frac{X_{it}}{\frac{1}{N}\sum_{i=1}^{N} X_{it}} = \frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N} \delta_{it}} \tag{3}$$

donde h_{it} es llamado el parámetro de transición relativa el cual mide el coeficiente de ajuste relativo a la media del panel en el tiempo t. En otras palabras, h_{it} traza una ruta de transición de cada elemento i en relación con el promedio del panel. La ecuación (3) indica la media de sección cruzada de h_{it}. De esta forma, h_{it} captura la desviación relativa de la región i de la ruta de crecimiento de estado estable común μ_t.

Para formular la hipótesis nula de convergencia, Phillips y Sul (2007) proponen un modelo semiparamétrico para el comportamiento variable en el tiempo de δ_{it} como el siguiente:

$$\delta_{it} = \delta_i + \sigma_i \xi_{it} L(t)^{-1} t^{-\alpha} \quad t = 1, \dots, T \tag{4}$$

donde ξ_{it} es un componente especifico de cada región que se distribuye de manera idéntica e independiente con media 0 y varianza unitaria entre las i pero débilmente dependiente a través del tiempo, y $L(t)$ es una función que varía lentamente en la que $L(t) \longrightarrow \infty$ en la medida que $t \longrightarrow \infty$. Phillips y Sul (2007) asumen que la función $L(t)$ es una función logarítmica de t. La magnitud de α determina el comportamiento (convergencia o divergencia) de δ_{it}. Esta formulación asegura la convergencia del parámetro de interés para todo $\alpha \geq 0$, la cual es la tasa de decaimiento. Ellos consideran la convergencia expresada como:

$$lim_{k\to\infty}\left(y_{it+k}/y_{jt+k}\right) = 1 \;\; para\ todo\ i\ y\ k \tag{5}$$

La cual es denominada convergencia relativa. Esta condición es equivalente a:

$$lim_{k\to\infty}\delta_{it+k} = \delta \;\; para\ todo\ i \tag{6}$$

Esta definición de convergencia permite diversos patrones de transición. De igual forma esta definición de convergencia y el concepto de cointegración están relacionadas, pero tienen características distintas. Ningún concepto es suficiente ni necesario para el otro. Por ejemplo, la noción de convergencia que se prueba a través del enfoque por pares se basa en la prueba de raíz unitaria; es decir, la cointegración con restricciones de parámetros. La convergencia en el sentido de Phillips y Sul (2007) y la convergencia basada en el enfoque por pares están relacionadas, pero no son equivalentes. Phillips y Sul consideran el caso en el que dos series de tiempo no están cointegradas, incluso cuando las dos series de tiempo convergen en el sentido en el que ellos la definen.

La evaluación de convergencia se realiza a través de una prueba $\log t$ por medio de las siguientes hipótesis:

$$H_0 \colon \delta_i = \delta \quad para\ todo\ i\ y\ a \geq 0 \tag{7}$$

$$H_1 \colon \delta_i \neq \delta \quad para\ alg\acute{u}n\ i\ o\ a < 0 \tag{8}$$

Phillips y Sul muestran que la hipótesis nula de convergencia se puede probar a través de la siguiente ecuación:

$$\log(H_1/H_t) - 2\log L(t) = a + b\log t + u_t \quad t = T_0, \dots, T, \tag{9}$$

donde $H_t = \frac{\sum_{i=1}^{N}(h_{it}-1)^2}{N}$; $T_0 = [rT]$ para algún r; y $\log(H_1/H_t)$ es el diferencial de transición de sección transversal cuadrático medio y mide la distancia del panel del límite común. Phillips y Sul (2007) sugieren $r = 0.3$ con base en sus experimentos de simulación. También sugieren usar $\log(t)$ para $L(t)$. La selección de la fracción de la muestra inicial r puede influir en los resultados de la regresión anterior (Du, 2017). Los experimentos de Monte Carlo indican que eligiendo $r \in [0.2,0.3]$ se obtiene un buen resultado. De manera más específica, se sugiere establecer $r = 0.3$ para una muestra de tamaño pequeño o moderado (≤ 50) y hacer $r = 0.2$ para un tamaño de muestra más grande (≥ 100).

Phillips y Sul (2007) demuestran además que $b = 2\alpha$ y que H_0 se prueba convenientemente a través de la desigualdad débil $\alpha \geq 0$. Lo que implica una prueba t unilateral. Bajo algunos supuestos técnicos, la distribución límite del estadístico t de regresión es:

$$t_b = \frac{\hat{b}-b}{S_b} \Rightarrow N(0,1) \tag{10}$$

donde $\hat{b}$ es el estimador del coeficiente b y S_b es el error estándar de largo plazo. La ecuación (10) implica que la hipótesis nula de convergencia se rechaza al nivel de significancia del 5% si $t_b \leq 1.65$. Es preciso aclarar que antes de aplicar la prueba al conjunto de datos bajo estudio, Phillips y Sul (2007) sugieren filtrar los datos con el filtro de Hodrick-Prescott con el fin de eliminar algunos componentes meramente transitorios de las series. Ellos muestran que la hipótesis de convergencia se prueba a través de una prueba t de un solo lado con el parámetro $b \geq 0$ donde:

$$S_b^2 = \widehat{l\,\dot{\mathrm{var}}(\hat{u}_t)} \left[\sum_{t=[rT]}^{T} \left(\log(t) - \frac{1}{T-[rT]+1}\sum_{t=[rT]}^{T} \log(t)\right)^2\right]^{-1} \tag{11}$$

y $\widehat{l\,\dot{\mathrm{var}}(\hat{u}_t)}$ es una estimación de HAC convencional formada a partir de los residuos de regresión.

El rechazo de la hipótesis nula de convergencia para todo el panel no puede descartar la existencia de convergencia en los subgrupos al interior. Para investigar la posibilidad de clústeres de convergencia, Phillips y Sul desarrollaron un algoritmo basado en los datos, el cual consta de cuatro pasos. En el primer paso, los individuos se clasifican en el panel en orden decreciente de acuerdo con las observaciones del último período. Si hay una volatilidad sustancial en las series de tiempo, la clasificación puede basarse en el promedio de la serie de tiempo de las últimas observaciones $[rT]$, con $r = 1/2$ o $1/3$.

El segundo paso consiste en la formación del grupo central de k^* individuos. En este paso, el primer subgrupo de k individuos o regiones (G_k) se selecciona ejecutando la regresión $\log t$ y se calcula el estadístico de prueba de convergencia t_k para este subgrupo con $t_k > -1.65$, si no hay k que cumpla la condición de que $t_k > -1.65$ se termina el algoritmo y se concluye que no existen subgrupos que converjan en el panel. Por el contrario, si se cumple la condición de que $t_k > -1.65$, una vez que se han seleccionado los primeros k individuos en el panel, el grupo central de tamaño k^* se obtiene maximizando t_k sobre k de acuerdo con el criterio $k^* = \arg max_k$ sujeto a min $\{t_k\} > -1.65$.

En el tercer paso, los individuos del panel que no están incluidos en el primer grupo principal se agregan de uno en uno al grupo principal con k^* miembros y la prueba $\log t$ se ejecuta nuevamente. El individuo en cuestión debe incluirse en el club de convergencia si el estadístico t asociado es mayor que el valor crítico c.

En el último paso, se forma un subgrupo con los individuos restantes que no cumplen el criterio de inclusión en el paso tres. La prueba $\log t$ se ejecuta para este grupo. Si el estadístico es mayor que -1.65, este subgrupo forma otro club de convergencia. De lo contrario, se repiten los pasos 1 a 3 para ver si este segundo subgrupo se puede subdividir en grupos de convergencia más pequeños.

4. Resultados

El cuadro 2 presenta los resultados de la prueba de convergencia $\log t$ aplicada a los 32 departamentos y la capital del país en su conjunto; el cuadro reporta el coeficiente $\hat{b}$, el error estándar y el estadístico t estimados en la prueba. Dado que el valor del estadístico t es -219.97 y por tanto menor de -1.65, la hipótesis nula de convergencia para el conjunto del país y su capital entre 2000 y 2016 se rechaza al nivel del 5%.

Cuadro 2.
Prueba de Convergencia Total en Colombia (2000 – 2016). Todos los departamentos

Variable	$\hat{b}$	Error estándar	Estadístico-t
$\log(t)$	-0.8785	0.0040	-219.97

Nota: Incluye 32 Departamentos y Bogotá D.C.
Fuente: Elaboración propia con datos del DANE.

Pese al rechazo de la hipótesis de convergencia para el conjunto del país, se procede a identificar los clubes de convergencia a través del proceso iterativo de la prueba. Los resultados del procedimiento en el cuadro 3 permiten identificar cuatro clubes; el primer club en el que se encuentra la capital del país y los dos últimos con los departamentos menos desarrollados incluyendo las antiguas intendencias, son evidencia de múltiples estados estacionarios de convergencia; sin embargo, en el segundo club conformado por más de la mitad de los departamentos, (con signos de divergencia) es un resultado estadísticamente no significativo. Hasta aquí el ejercicio muestra la dificultad de identificar convergencia departamental en la parte central de la distribución para el conjunto de análisis cuando se incluyen todos los departamentos.

Con la finalidad de averiguar si hay clubes que potencialmente se puedan fusionar, aplicamos la prueba de fusión propuesta por Schnurbus *et al.* (2017), cuyos resultados se presentan en el cuadro 4. Las estimaciones revelan que no es posible fusionar los clubes de convergencia sucesivos 1 y 2, 2 y 3 y 3 y 4 ya que en todos los casos el estadístico t de prueba es menor que -1.65.

En el análisis de convergencia es una práctica común excluir algunas regiones cuyas actividades económicas predominantes pueden generar sesgos en los resultados; en el caso colombiano se suelen excluir los principales departamentos mineros, por lo que de manera análoga a Galvis *et al.* (2017) se excluyen de la prueba los departamentos mineros de Putumayo, Arauca y Casanare. La prueba de convergencia total para el conjunto del país excluyendo los mencionados departamentos se muestran en el cuadro 5. Los resultados confirman los obtenidos en el cuadro 2; es decir, aun excluyendo las regiones mineras hay evidencia para rechazar la hipótesis de convergencia en el PIB per cápita; el conjunto del país diverge mostrando evidencia en favor de la persistencia de las disparidades regionales.

CUADRO 3.
Prueba de Clubes de Convergencia en Colombia (2000 – 2016). Todos los departamentos

Club	$\hat{b}$	Estad-t	Número de Departamentos	Miembros del Club
1	0.933	4.429	4	Bogotá D. C., Casanare, Meta, Santander
2	-0.041	-0.812	17	Antioquia, Arauca, Atlántico, Bolívar
				Boyacá, Caldas
				Cauca, Cesar, Cundinamarca, Huila
				Norte Santander, Putumayo
				Quindío, Risaralda
				San Andrés y Providencia, Tolima, Valle
3	0.517	6.367	8	Amazonas, Caquetá, Chocó, Córdoba
				La Guajira, Magdalena
				Nariño, Sucre
4	0.739	4.646	4	Guainía, Guaviare, Vaupés, Vichada

Nota: Incluye 32 Departamentos y Bogotá D.C.
Fuente: Elaboración propia con datos del DANE.

CUADRO 4.
Prueba de fusión de Clubes de Convergencia en Colombia (2000 – 2016) Todos los departamentos

Grupos Iniciales	Pruebas de fusión			Grupos Finales
Club 1 [4]	Club 1+2			[4]
	-0.579			
	-80.025			
Club 2 [17]		Club 2+3		[17]
		-0.561		
		-32.740		
Club 3 [8]			Club 3+4	[8]
			-0.570	
			-43.715	
Club 4 [4]				[4]

Nota: Incluye 32 Departamentos y Bogotá D.C. Los números entre corchetes es el número de miembros al interior de cada club.
Fuente: Elaboración propia con datos del DANE.

CUADRO 5.
Prueba de Convergencia Total en Colombia (2000 – 2016) excluyendo Putumayo, Arauca y Casanare

Variable	$\hat{b}$	Error estándar	Estadístico-t
$\log(t)$	-1.2044	0.0024	-504.1714

Fuente: Elaboración propia con datos del DANE.

Tras rechazar la hipótesis de convergencia total excluyendo los departamentos mineros, también se aplica el procedimiento iterativo para identificar la posible presencia de clubes departamentales igual que en el primer caso. Los resultados se presentan en el cuadro 6; se encuentran seis clubes de convergencia y un grupo divergente. Estos resultados sugieren mayor divergencia en el sentido de que hay un mayor número de clubes (6 en lugar de 4) además de la presencia de un club que diverge. Asimismo, la composición de los miembros pertenecientes a cada club cambia notablemente con respecto al análisis con todos los departamentos en el cuadro 3; la capital se mantiene en el grupo líder; sin embargo, despunta el departamento de Santander como seguidor en la parte alta de los grupos que convergen.

CUADRO 6.
Prueba de Clubes de Convergencia en Colombia (2000 – 2016) excluyendo Putumayo, Arauca y Casanare

Club	$\hat{b}$	estad-t	Número de Departamentos	Miembros del Club
1	8.329	2.861	2	Bogotá D. C., Santander
2	0.206	4.212	6	Antioquia, Boyacá, Cesar
				Cundinamarca
				San Andrés y Providencia, Valle
3	0.771	5.040	3	Caldas, Cauca y Tolima
4	0.218	3.865	3	Huila, Norte Santander, Quindío
5	0.517	6.367	8	Amazonas, Caquetá, Chocó, Córdoba
				La Guajira, Magdalena, Nariño, Sucre
6	0.739	4.646	4	Guainía, Guaviare, Vaupés, Vichada
7	-2.312	-196.734	4	Atlántico, Bolívar, Meta, Risaralda
			(*Divergente*)	

Fuente: Elaboración propia con datos del DANE.

Un resultado relevante es que bajo este análisis que excluye la distorsión de las regiones mineras, es posible identificar clubes de convergencia claramente definidos para los departamentos de desempeño económico intermedio. En la parte alta de la distribución en un segundo club con Antioquia, Boyacá, Cesar, Cundinamarca, San Andrés y Providencia y Valle, seguido de dos clubes que convergen con departamentos con niveles de desarrollo intermedio. Los dos clubes con las regiones con mayor rezago y que convergen en la parte baja de la distribución se conforman de departamentos que tradicionalmente podrían considerarse menos articulados con la región central del país. Finalmente, los departamentos de Atlántico, Bolívar, Meta y Risaralda conforman un grupo de regiones divergentes en términos del comportamiento de su PIB per cápita en el periodo de análisis.

También se aplicó la prueba de fusión de clubes excluyendo los departamentos mineros y los resultados se presentan en el cuadro 7. Los estadísticos t de las pruebas de fusión los clubes iníciales 1 y 2, así como en los clubes 2 y 3, son menores que -1,65, revelando la imposibilidad de fusionarse. Sin embargo, el estadístico t de la prueba para los clubes 3 y 4 es 5.365, lo que significa que pueden fusionarse en un nuevo club 3, con lo cual ahora este club posee 6 miembros. La prueba sugiere entonces que cuando se excluyen los departamentos de Putumayo, Arauca y Casanare, las 30 regiones restantes del país pueden clasificarse en cinco clubes de convergencia y un grupo divergente.

En general, estos resultados sobre convergencia departamental en Colombia son evidencia de la flexibilidad y bondades de análisis que ofrece la prueba de Phillips-Sul (2007). En particular, pese a la evidencia del rechazo de la hipótesis de convergencia para el conjunto del país, los resultados sugieren la importancia de excluir regiones que generan distorsiones en el ordenamiento de la distribución (en este caso las regiones mineras) para encontrar evidencia de los múltiples equilibrios de convergencia regional. La conformación de clubes de convergencia en Colombia en este ejercicio muestra la amplitud de la distribución y es evidencia de la persistencia de las desigualdades al interior del país.

Como un ejercicio de contraste frente al mapa 1 del apartado de descriptivos, el mapa 2 presenta geográficamente los clubes de convergencia de la tabla 3 incluyendo todos los departamentos (panel izquierdo) y de la tabla 5 excluyendo a Arauca, Casanare y Putumayo (panel derecho). El mapa 2 en el panel izquierdo para sólo cuatro clubes de convergencia confirma el comportamiento de la región central del país en la que se encuentran los clubes con los departamentos de ingreso per cápita alto y medio. A excepción de Bogotá D.C., los departamentos del primer Club corresponden a regiones asociadas con la extracción petrolera, mientras la región andina del país concentra a los departamentos del segundo Club que pueden asociarse con un nivel de ingreso per cápita medio. Los dos clubes de menor ingreso se ubican de forma periférica en la misma forma que lo sugería el mapa 1 de los descriptivos.

Cuando se excluye Arauca, Casanare y Putumayo la estructura espacial de clubes muestra mayor dispersión sin perder la lógica de que el centro concentra los departamentos en los clubes con mayor ingreso per cápita mientras la periferia concentra a los departamentos de los clubes 5 y 6 con menor ingreso. En general, es evidente que los mapas excluyendo o no los departamentos mineros sugieren la existencia de ciertas proximidades espaciales de los departamentos en los clubes encontrados. Pese a que la prueba de Phillips Sul (2007) no posee ninguna información referente a las vecindades de los departamentos, ni pretende a priori inferir algún aspecto de econometría espacial, la evidencia gráfica sugiere que la localización de los departamentos y su distribución espacial son un determinante fundamental de los clubes de convergencia.

Cuadro 7.
Prueba de fusión de Clubes de Convergencia en Colombia (2000 – 2016) Excluyendo Putumayo, Arauca y Casanare

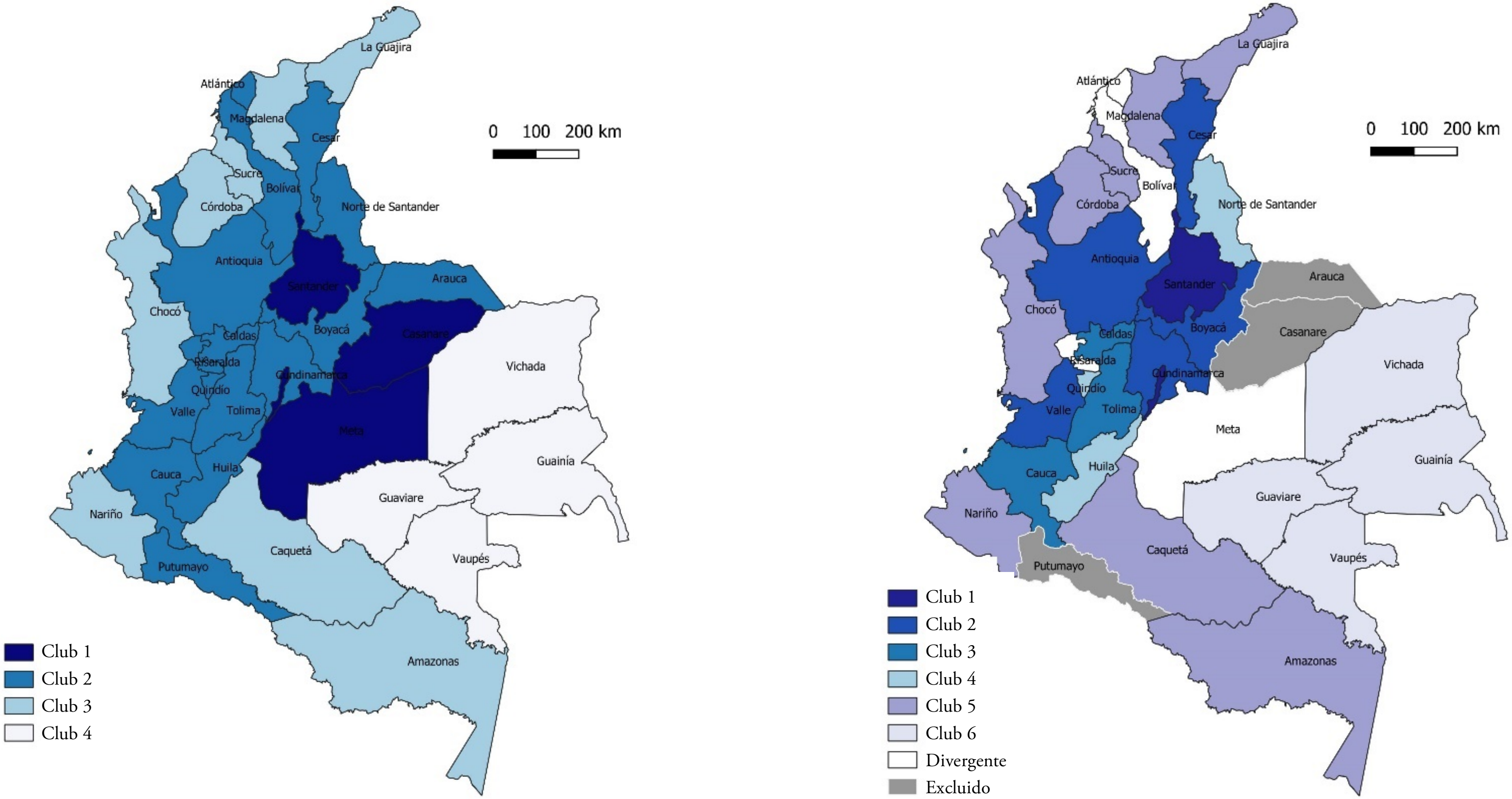
Grupos Iniciales	Pruebas de fusión						Grupos Finales
Club 1 [2]	Club 1+2						[2]
	-0.756						
	-52.773						
Club 2 [6]		Club 2+3					[6]
		-0.523					
		-19.919					
Club 3 [3]			Club 3+4				[6]
			0.530				
			5.365				
Club 4 [3]				Club 4+5			[8]
				-0.152			
				-5.969			
Club 5 [8]					Club 5+6		[4]
					-0.570		
					-43.715		
Club 6 [4]						Club 6+G7	[-]
						-1.684	
						-2180.367	
Grupo 7 [4]							[4]

Nota: Incluye 32 Departamentos y Bogotá D.C. Los números entre corchetes es el número de miembros al interior de cada club.
Fuente: Elaboración propia con datos del DANE.

MAPA 2.
Clubes de convergencia del ingreso per cápita 2000-2016

a) Cuatro clubes para 32 departamentos y Bogotá D.C.

b) Siete clubes excluyendo Arauca, Putumayo y Casanare



Fuente: elaboración propia con información del DANE.

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5. Conclusiones

En las últimas décadas se ha incrementado el interés por probar la hipótesis de convergencia en Colombia; no obstante, el interés se ha concentrado principalmente en algunas técnicas tradicionales y se han dejado de lado algunas metodologías relativamente novedosas que pueden arrojar luz sobre el proceso de convergencia en el país. En este trabajo se emplea la propuesta de Phillips y Sul (2007) para probar la hipótesis de convergencia relativa a nivel departamental en el periodo 2000-2016.

La metodología utiliza un modelo no lineal con un factor común y un componente idiosincrásico, entre sus beneficios se encuentra la posibilidad de incorporar el progreso técnico heterogéneo de las regiones analizadas, el no requerir ningún supuesto respecto a la estacionariedad o no de las series consideradas, además de ser una técnica extremadamente flexible para modelar una gran cantidad de sendas de transición hacia la convergencia, así como el evitar obstáculos en el modelado de unidades heterogéneas. Entre las limitaciones o áreas de oportunidad del ejercicio, se debe reconocer que la metodología por sí misma no considera aspectos geográficos; no obstante, el incorporar dicho factor en términos descriptivos permitió realzar la importancia de los comportamientos espaciales en los análisis de convergencia regional.

Los resultados muestran que los departamentos de Colombia no convergen a un solo grupo sino en distintos clubes. Cuando se considera la totalidad de los departamentos, a pesar de que la prueba de convergencia total se rechaza, se encuentra evidencia de cuatro clubes de convergencia de modo que la capital Bogotá está en el primer club, pero hay un segundo grupo con la mayoría de los departamentos, en el que los resultados no son significativos. Cuando la prueba se realiza excluyendo las principales regiones mineras del país se identifican seis clubes de convergencia y un grupo con los departamentos de Atlántico, Bolívar, Meta y Risaralda que divergen en el periodo de estudio.

Enfrentar las disparidades del conjunto regional en Colombia es una tarea de coordinación estratégica que debe conducir el estado colombiano generando condiciones iniciales adecuadas para la autonomía y sustentabilidad. Por un lado, se requiere de mejores condiciones en materia de infraestructura física en los departamentos que tradicionalmente no han sido rentables para la inversión privada; aumentar la inversión pública en infraestructura de las regiones periféricas alentaría la generación de empleo, el crecimiento económico y contribuiría al cierre de brechas. De igual forma, se debe impulsar la productividad de los clubes de departamentos con menores niveles de desarrollo por medio de la inversión en capital humano y mayores niveles educativos. No menos importante, se debe procurar la calidad de las instituciones en materia de corrupción, burocracia y escasa rendición de cuentas, variables que en estudios relacionados con este objeto, han demostrado constreñir el crecimiento y que mientras no sean atendidas perpetúan las disparidades.

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Articles

The Income-Inequality Relationship within US Metropolitan Areas 1980-2016

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Abstract:

Economic growth might both increase and decrease income inequality, also at the city level. This paper examines the income-inequality relationship within US metropolitan areas and finds that it changes over time. A higher average income per capita level was associated with a lower inequality level in earlier years, but this association vanished later. For the 1980-2000 panel, increases in the average income per capita are associated with decreases in inequality. In contrast, increases in the average income per capita are associated with increases in inequality in the 2006-2016 panel. The obtained results hint at polarization resulting from technological change substituting middle-skill routine tasks.

Keywords: Inequality; income; metropolitan areas; United States.

JEL classification: D31; O18; R11.

La Relación Ingresos-Desigualdad en las Áreas Metropolitanas de los EE.UU.

Resumen:

El crecimiento económico puede tanto aumentar como disminuir la desigualdad de ingresos, también al nivel de ciudades. Este artículo examina la relación entre ingresos y desigualdad en las áreas metropolitanas de los EE.UU. y descubre que cambia con el tiempo. Un mayor nivel de ingreso per cápita medio se asoció con un menor nivel de desigualdad en los primeros años, pero esta asociación desapareció posteriormente. Para el panel de 1980—2000, los aumentos del ingreso per cápita medio se asocian con disminuciones de la desigualdad. En cambio, un aumento del ingreso per cápita medio se asocia con un aumento de la desigualdad en el panel 2006—2016. Los resultados obtenidos insinúan a una polarización resultante del cambio tecnológico que sustituye a las tareas rutinarias de cualificación media.

Palabras clave: Desigualdad; ingresos; áreas metropolitanas; Estados Unidos.

Clasificación JEL: D31; O18; R11.

1. Introduction

The income-inequality relationship has been a question of debate since the seminal work of Kuznets, who proposed the Kuznets curve: inequality first increases and then decreases with increasing national income (Kuznets, 1955). However, the income-inequality relationship at the city level does not necessarily follow

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that at the national level. Some channels from the national level, such as credit market mechanisms and redistribution policies, do not translate directly to the city level (Glaeser et al., 2009; Royuela et al., 2019). The latter is characterized by more in- and out-migration and the less political maneuver room it has. Other factors level out at the national level, such as segregation. At the same time, income inequality is most visible and prominent in cities due to the spatial proximity of different income levels (Partridge & Weinstein, 2013). Comparatively little is still known about the income-inequality relationship at the city level, mainly due to data limitations. To close this gap, this study assesses this relationship within US metropolitan statistical areas (MSAs) from 1980-2016.

Few studies have analyzed the income-inequality relationship at this scale. For US MSAs, a negative income-inequality relationship has been found for 1980 and 2000: higher income levels are associated with lower inequality levels in MSAs based on cross-section regressions (Glaeser et al., 2009). For European regions, determinants of inequality at the regional level have been analyzed using annual panels over the 1990s and 2000s. These studies find a positive income-inequality relationship: income increases are associated with inequality increases (Rodríguez-Pose & Tselios, 2009; Castells-Quintana et al., 2015).

To assess these opposing results further, the present paper employs both cross-section and fixed effects (FEs) panel regression analyses for one geographic unit (MSAs) over several decades (1980-2016). This procedure provides a consistent background for comparing the results for different techniques and years. The analyses are based on two distinct data sets. The first is an annual panel over 2006-2016 using data from the American Community Surveys (ACSs) (Ruggles et al., 2018; US Census Bureau, n.d.-a). The second is a decennial panel over 1980-2000 using US Census data (Manson et al., 2017; Ruggles et al., 2018). This paper thereby expands the time horizon for local-level studies on the income-inequality relationship up to 2016.

This paper finds that the income-inequality relationship changes over time. A higher average income per capita level is associated with a lower within-MSA inequality level in the earlier years. However, this association stopped being statistically significant in 2000 and remains insignificant for all the following years. For the 1980-2000 panel, average income per capita increases are accordingly associated with decreases in inequality. In contrast, an increase in average income per capita is associated with an increase in inequality in the 2006-2016 panel. The income-inequality relationship changed direction. These results are robust to the use of various inequality measures.

This change in sign might be due to differences in MSA delineations and time dimensions across the two panels. However, it could also originate from qualitative changes in the income-inequality relationship over time, potentially reflecting globalization and specialization. Notably, this study finds hints for polarization in line with the Autor & Dorn (2013) hypothesis of technological change substituting middle-skill routine tasks. However, these explanations cannot be completely distinguished with the data sets at hand. Thus, further research is required.

The following section reviews in greater detail the literature on how income and inequality are linked at the city level. Section 3 describes the data sources used and provides the empirical framework. Section 4 presents the cross-section results on the income-inequality relationship, while section 5 details the panel results. Section 6 presents robustness checks using alternative inequality measures and section 7 discusses potential reasons for the change in sign of the income-inequality relationship. Section 8 concludes.

2. City-Level Links between Income and Inequality

Increases in mean income might both increase and decrease inequality depending on the circumstances. The Kuznets curve theory hypothesizes that the income-inequality relationship follows an inverted-U-shaped curve: inequality first increases and then decreases with increasing income (Kuznets, 1955). The N-shape hypothesis augments this theory, stating that after a certain point, inequality starts increasing again with income for highly-developed economies (Conceição & Galbraith, 2001; Castells-Quintana et al., 2015).

Trade and labor market phenomena such as specialization, technological change substituting middle-skill routine tasks, deunionization, and flexible labor market regulations might lead to a positive income-inequality relationship. They might engender both economic growth and increased inequality (Rigby & Breau, 2008; Autor & Dorn, 2013; Partridge & Weinstein, 2013). On the contrary, theories about residential segregation and disamenities such as crime and sociopolitical unrest predict a negative association: inequality decreases with income. For instance, residential segregation is associated with lower economic growth and higher inequality (Li et al., 2013; Florida & Mellander, 2015). Crime and sociopolitical unrest hinder economic growth while leading to and reinforcing inequality, resulting in vicious circles (Glaeser et al., 2009; Partridge & Weinstein, 2013).

These theories consider implicitly a medium- to long-run perspective where agents can adjust to a new situation. To the best of the author's knowledge, no explicitly short-run theory about the income-inequality relationship exists. However, the relationship between income and inequality might differ between the short, medium, and long run. Transmission channels differ in their manifestation rapidity, with purely economic factors typically realizing faster than sociopolitical ones (Halter et al., 2014).

An MSA's population size, education level, and the sectoral structure of its economy influence within-MSA inequality as well (Glaeser et al., 2009). Studies on the city size-inequality relationship typically identify a positive relationship: larger cities are ceteris paribus more unequal (Glaeser et al., 2009; Baum-Snow & Pavan, 2012; Castells-Quintana et al., 2020). Education proxies for differences in skills and the degree of specialization, which leads to dispersed incomes (Glaeser et al., 2009). Higher education levels are associated with higher levels of inequality (Perugini & Martino, 2008; Glaeser et al., 2009). Shifts in the economy's sectoral structure might influence inequality due to differences in the associated income structure (Bolton & Breau, 2012; Castells-Quintana et al., 2015). Deindustrialization tends to increase inequality (Bolton & Breau, 2012; Partridge & Weinstein, 2013).[1]

Several studies on MSA-level determinants of inequality exist, but they only employ cross-section regression analyses. A higher median income level is related to a lower level of inequality for 1980 and 2000 (Glaeser et al., 2009). Similarly, a higher average income level is associated with lower income inequality for 2010 when wage inequality is controlled for (Florida & Mellander, 2016). Higher income per capita growth appears to lead to lower end-of-period inequality in 1990 (Bhatta, 2001). For 11 OECD countries, including the US, a trend towards a negative income-inequality relationship at the city level emerges in pooled cross-sections over 2000—2014 with year and country FEs (Castells-Quintana et al., 2020). Higher average income per capita is associated with lower inequality. However, this association is not always statistically significant. Furthermore, the results hint at an inverse-U-shape income-inequality relationship (Castells-Quintana et al., 2020).

Cross-sections typically only capture the situation at one point in time and hence incorporate all the past influences leading to differences across MSAs (Forbes, 2000; Partridge, 2005). In this sense, they have rather a long-term perspective. This contrasts with panel studies that assess how changes in income levels result in inequality changes for a given MSA (Partridge, 2005; Atems, 2013). Panel studies have rather a short- to medium-term perspective. Therefore, cross-section and panel results are not directly comparable (Atems, 2013). This study will use both techniques, cross-section and panel analyses, to gain a complete picture of the income-inequality relationship at hand.

Some studies of European regions have analyzed the income-inequality relationship in annual panel frameworks with city FEs. Income per capita changes appear to be positively related to inequality changes for European NUTS I and II regions over 1995-2000 based on FEs, random effects, and GMM techniques (Rodríguez-Pose & Tselios, 2009). A U-shaped relationship is found over the 1993-2011 period for NUTS I regions but only when using the GINI as inequality measure (Castells-Quintana et al., 2015). The latter interprets this as inequality having increased more in regions with higher relative increases in income, hence a positive income-inequality relationship as well (Castells-Quintana et al., 2015). However, these results are not directly transferable to US MSAs due to the differing labor market and institutional

[1] The demographic and racial composition of an MSA might influence inequality levels as well. However, the related variables have proved not statistically significant in the regressions. They have been omitted from the presented analysis for clarity.

context, influencing the income-inequality relationship. Furthermore, MSAs provide smaller and more homogeneous regions than the NUTS regions. The present study's sample size is also larger, with up to 399 MSAs available for the analysis.

This paper expands the time horizon for studies on the income-inequality relationship by using data spanning from 1980 to 2016, although with gaps and changes in between as detailed in the next section. This enables assessing whether this relationship changed over time.

3. Data Sources and Empirical Framework

The study unit of this paper is the MSA.[2] MSAs are suitable units for studying regional economic activity and income inequality, as they encompass both the city core and suburbs related through commuting (Madden, 2000). MSAs form a functional economic unit encompassing production and consumption activities (Madden, 2000). Although the concept of MSAs has changed little over time, their county composition does change. A major change in MSA delineations occurred in 2013. Data within the 1990 MSA delineations are available for 1980, 1990, and 2000. Data within the 2013 MSA delineations are available from 2006 onward.

Hence, this study employs two distinct data sets: one with decennial data for 1980-2000 and one with annual data from 2006-2016. For the 2006-2016 data set, the data stems from the 1-year ACSs collected by the US Census Bureau. The data for all the main variables was retrieved from FactFinder (US Census Bureau, n.d.-a). This data includes the pretax household income GINI at the MSA level. Figure 1 shows the MSAs and their respective inequality levels in 2010. All ACS income variables are for the past 12 months prior to the interview moment, which is not publicly disclosed (US Census Bureau, 2009; Peters, 2013; IPUMS-USA, n.d.-b). This paper converts all original income variables into 2010 US-$ using the conversion factors provided by the Integrated Public Use Microdata Series USA (IPUMS) to adjust for inflation (IPUMS-USA, n.d.-b). Table 1 presents descriptive statistics. The resulting panel data set consists of 399 MSAs and 11 years. It is unbalanced due to slight further delineation changes over the time period.

Table 1.
Descriptive Statistics 2006-2016 Data Set

	Obs.	Mean	St. Dev.			Min	Max
			Overall	Between	Within		
Gini	4069	0,450	0,027	0,023	0,015	0,355	0,561
Income per capita	4069	24738	4423	4223	1175	12572	51661
Mean household income	4069	63444	11527	11193	2938	42026	139718

The statistics are for all observations of all MSAs over the entire 2006-2016 period pooled together. The within standard deviation is within MSAs.
Source: FactFinder as well as own calculations.

[2] An MSA is a geographic entity delineated by the Office of Management and Budget for use by US statistical agencies. MSAs consist of the county or counties associated with at least one urbanized area of at least 50,000 inhabitants plus adjacent counties having a high degree of social and economic integration with the core as measured through commuting ties (US Census Bureau, n.d.-b).

FIGURE 1.
MSAs' Inequality Levels 2010

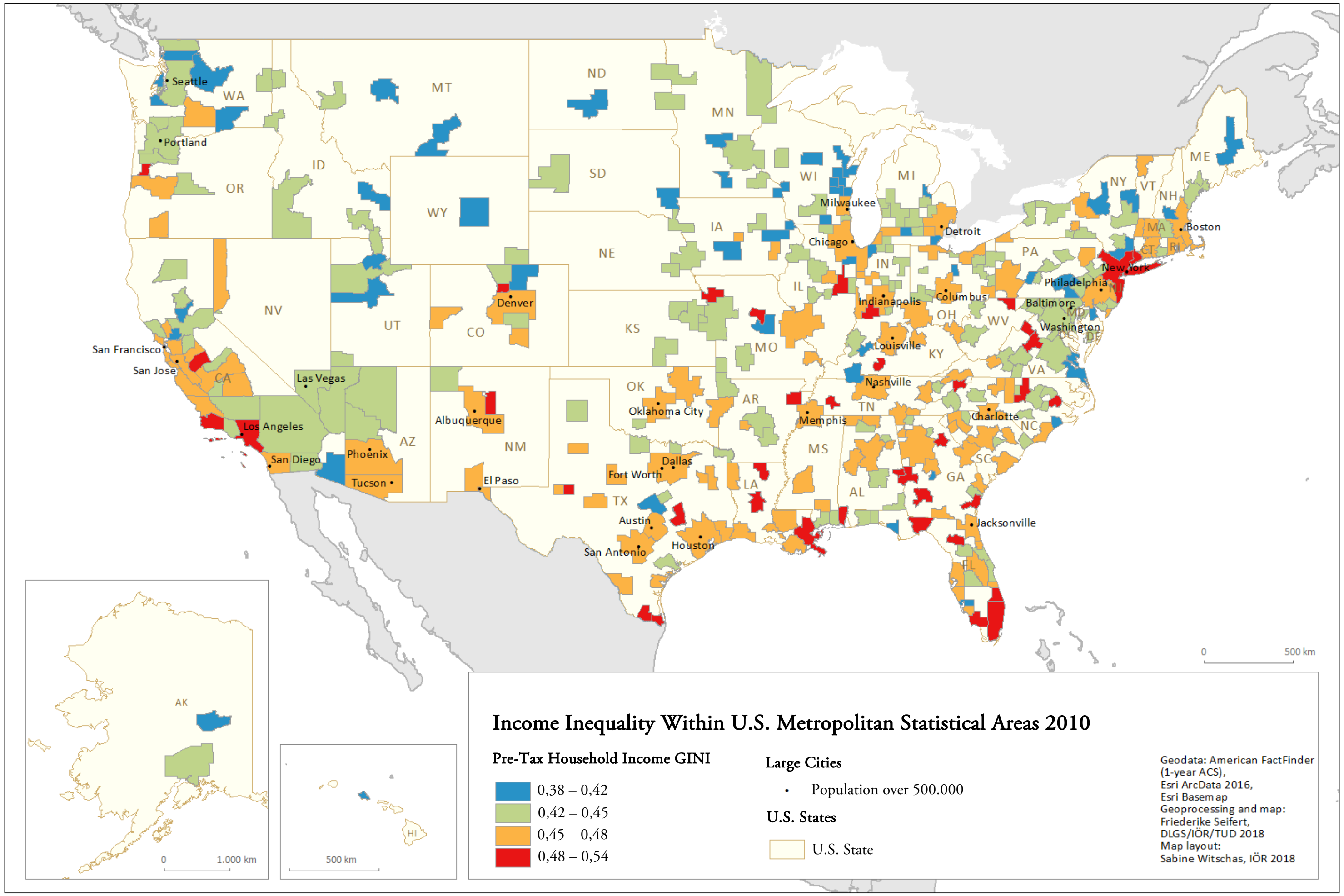

TABLE 2.
Descriptive Statistics 1980-2000 Data Set

	Obs.	Mean	St. Dev.			Min	Max
			Overall	Between	Within		
Gini	735	0,416	0,033	0,024	0,024	0,333	0,532
Income per capita	735	23906	4379	3742	2425	11664	42928

The statistics are for all observations of all MSAs over the entire 1980-2000 period pooled together. The within standard deviation is within MSAs.
Source: NHGIS and IPUMS as well as own calculations.

For the 1980-2000 data set, the data stems from the US Census via NHGIS and IPUMS (Manson et al., 2017; Ruggles et al., 2018). NHGIS offers aggregated data at the MSA level for all main variables except the GINI. The latter is calculated from IPUMS, which offers household-level data. There are drawbacks to using IPUMS data to calculate the GINI compared to variables provided by NHGIS or FactFinder directly. First, MSA populations are incompletely identified in the IPUMS data sets (IPUMS-USA, n.d.-a). Second, data confidentiality issues in smaller MSAs reduce the sample size. Third, household income is bottom-coded and the reported incomes are rounded in all years (IPUMS-USA, n.d.-b).[3] The correlation between the 2010 FactFinder and IPUMS-calculated GINIs is nonetheless over 0.9 and statistically significant at the 1% level. Table 2 presents descriptive statistics. The resulting unbalanced panel data set for 1980-2000 consists of 260 MSAs and 3 years.

This paper estimates the income-inequality relationship in cross-sections and panel frameworks using MSA and time FEs. The latter approach controls for time- and MSA-invariant variables. It also allows studying dynamics of change within short time series (Rodríguez-Pose & Tselios, 2009). However, FEs might lead to less variation than in cross-sectional studies as only within variation is considered (Royuela et al., 2019). This effect might be especially relevant for the 2006-2016 panel analysis as inequality is believed to change only slowly over time (Glaeser et al., 2009; Royuela et al., 2019).

This paper regresses inequality on mean income in the same year. The empirical model is as follows:

$$g_{it} = \alpha + \beta y_{it} + \gamma \boldsymbol{X}_{it} + \mu_i + \tau_t + \varepsilon_{it} \tag{1}$$

where g_{it} is a measure of inequality for MSA i at time t, y_{it} is an income measure (in logs), $\boldsymbol{X}_{it}$ is a vector of control variables, μ_i and τ_t are respectively MSA and time FEs, and ε_{it} is the error term. Standard errors are clustered at the MSA level.[4] The cross-sections exclude the MSA and time FEs and are only estimated for a given t.

Controls for population, education (population share with a bachelor's degree or higher, respectively with a high school diploma or higher, in percent), and sector employment shares (share of persons 16 years and over employed in agriculture, respectively in the manufacturing sector, in percent) are included to avoid confounding factors. They have been shown to influence within-city inequality, as previously discussed. Furthermore, some regressions include quadratic income terms to test for a nonlinear income-inequality relationship. Still, unobservable factors might influence the income-inequality relationship, potentially leading to omitted variable bias. The panel regressions account for time-invariant MSA characteristics, reducing this issue compared to the cross-sections.

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[3] A negative income is possible because both the Census and the ACSs include self-employment income from own businesses, that is, net income after business expenses. Furthermore, they include income from an estate or trust, interest, and dividends, which can be negative as well (IPUMS-USA, n.d.-b).
[4] Neither state FEs nor standard errors clustered at the state level can be included. Several MSAs cross state borders and belong to more than one state (not necessarily in equal parts). Furthermore, the number of MSAs per state is limited with several states only having one or two MSAs.

Reverse causality between income and inequality constitutes an issue in these regressions, leading to endogeneity. Income influences inequality, but inequality, in turn, affects income and income growth. Convincing instruments for income have not yet been proposed in this context. Therefore, the obtained coefficients have to be interpreted as associations rather than causal effects of income on inequality. However, this income-inequality association is interesting in its own right and relevant for policy debate.

4. Cross-Section Results

This section presents cross-section results using both data sets. These results constitute a starting point to assess the income-inequality relationship across time. To gain a first impression, Appendix Figures I—III present scatterplots of the GINI and logarithmized income. They all show a slight upward trend, that is, a positive income-inequality relationship: inequality increases with income. Similarly, the income per capita coefficient is positive and statistically significant at the 1% level in pooled cross-section regressions without any control variables included (Appendix Table I). However, these simple regressions do not account for year specificities or the influence of several relevant control variables.

Table 3 presents cross-section results by year, including controls. The first three columns report regression results for 2016, 2010, and 2006. These regressions use the 2013 MSA delineations. The data stems from the ACSs via FactFinder. The last three columns report regression results for 2000, 1990, and 1980. These regressions use the 1990 MSA delineations. The data stems from the Census via NHGIS and IPUMS.

Table 3.
Cross-Section Results Regressing Inequality on Income

	(1)	(2)	(3)	(4)	(5)	(6)
	2016	**2010**	**2006**	**2000**	**1990**	**1980**
	Gini	**Gini**	**Gini**	**Gini**	**Gini**	**Gini**
ln (income per capita)	-0,003 (0,016)	0,001 (0,014)	0,016 (0,015)	-0,032 (0,022)	-0,048*** (0,018)	-0,038*** (0,014)
ln (population)	0,000 (0,002)	-0,001 (0,001)	-0,001 (0,001)	0,001 (0,002)	0,002 (0,002)	0,001 (0,001)
Share bachelor's degree	0,001*** (0,000)	0,002*** (0,000)	0,002*** (0,000)	0,077** (0,036)	0,101*** (0,038)	0,050** (0,023)
Share high school diploma	-0,003*** (0,000)	-0,003*** (0,000)	-0,003*** (0,000)	-0,223*** (0,063)	-0,236*** (0,049)	-0,170*** (0,028)
Share agriculture	-0,002*** (0,001)	-0,002** (0,001)	-0,002*** (0,001)	-0,249*** (0,088)	-0,140** (0,069)	-0,097*** (0,035)
Share manufacturing sector	-0,001*** (0,000)	-0,001*** (0,000)	-0,001*** (0,000)	-0,126*** (0,025)	-0,070*** (0,023)	-0,129*** (0,013)
Constant	0,711*** (0,124)	0,676*** (0,125)	0,545*** (0,126)	0,969*** (0,178)	1,082*** (0,140)	0,916*** (0,114)
MSAs	382	366	359	251	245	239
R^2	0,232	0,311	0,305	0,310	0,338	0,496

The first three columns report results for 2016, 2010, and 2006 respectively. They use 2013 MSA delineations and ACS data from FactFinder. The last three columns report results for 2000, 1990, and 1980 respectively. They use 1990 MSA delineations and Census data from NHGIS and IPUMS. Robust standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder, NHGIS and IPUMS as well as own calculations.

For the years 2000, 2006, 2010, and 2016, the income coefficient is not statistically significant even at the 10% level. Income per capita levels appear not to influence inequality levels in these years: either positively or negatively. The income coefficient is statistically significant at the 1% level and negative in 1980 and 1990. Higher income per capita levels appear to be associated with reduced inequality levels in these years. A 1% increase in income per capita involves ceteris paribus a decrease in the GINI by 0.0004 (1980) respectively 0.0005 points (1990) for a given MSA. This decrement is equivalent to a decrease by about 0.1% at the mean of the GINI. These negative coefficients correspond to the previous findings in the literature for MSAs. Section 7 discusses in detail the reasons for the divergent results across years.

The control variables' coefficients are typically of the expected signs. Only population surprises with a statistically insignificant coefficient. Thus, the MSA size does not seem to influence the inequality level in the considered context, contrary to the existing literature (Glaeser et al., 2009; Baum-Snow & Pavan, 2012; Castells-Quintana et al., 2020). The divergent results in the present study might stem from including other control variables than in previous studies. Still, the coefficient remains in four out of six cases of positive sign as expected.

The control variables do not drive the results as similar results are obtained when excluding them from the regression (Appendix Table II). The statistically significant negative income-inequality relationship persists for 1980 and 1990. The same now applies to 2000. For 2006, 2010, and 2016, the income per capita coefficient remains not statistically significant, as previously. The switch in significance is hence also observed without controls included. The positive coefficient of pooling all 1980-2000 observations together without controls vanishes in the by-year regressions and turns negative. It is probably due to a time trend. The switch in significance is also observed in pooled cross-sections with controls, albeit the other way round. The income coefficient is always negative but only statistically significant for the 2006-2016 panel (Appendix Table I).

When adding quadratic income terms, a similar pattern to that of the main regressions appears (Appendix Table III). In the cross-sections for 2006, 2010, and 2016, neither the linear nor the quadratic income coefficient is statistically significant at the 10% level. For 1980, 1990, and 2000, both are statistically significant at the 1% level. The linear one is positive and the quadratic one negative, indicating an inverted-U-shaped relationship as expected. Most MSAs are situated in the downward sloping part of the curve according to their observed incomes per capita. This pattern indicates that higher-income MSAs have over-proportionally low inequality levels in these years, while a negative income-inequality relationship holds for most MSAs.

5. Panel Results

This section presents panel results using both data sets. They permit evaluating the impact of changes in income per capita on inequality and provide a comparison point to the cross-section results. In addition, they reduce the issue of unobserved heterogeneity in time-invariant MSA characteristics compared to cross-sections.

Table 4 presents the results. The first two columns show the annual 2006-2016 panel results. Column one uses income *per capita* while column two employs *mean household* income. The third column shows the decennial 1980-2000 panel results employing income *per capita*.[5]

For the 2006-2016 panel, the income coefficient is statistically significant at the 1% level and positive in both regressions. Income increases appear to be associated with inequality increases. A 1% increase in per capita (mean household) income involves, ceteris paribus, an increase in the GINI by 0.0015 (0.0014) points for a given MSA. This increment is equivalent to an increase by about 0.3% at the mean

[5] Mean household income is not available for 1980 and 1990. Its cross-section results for the remaining years are very similar to the income per capita ones (available upon request).

of the GINI. These results correspond to the ones obtained for European regions in annual panels over the 1990s and 2000s (Rodríguez-Pose & Tselios, 2009; Castells-Quintana et al., 2015).

For the 1980-2000 panel, the income coefficient is statistically significantly negative. An increase in income seems to have decreased inequality. The absolute size of the income coefficient is smaller than previously. A 1% increase in income per capita involves, ceteris paribus, a decrease in the GINI by 0.0007 points for a given MSA. This decrement is equivalent to a decrease by about 0.2% at the mean of the GINI. However, the within-R^2 increases considerably from 0.29 to 0.85. Section 7 discusses the reasons for these divergent results.

TABLE 4.
Panel Results Regressing Inequality on Income

	2006-2016		**1980-2000**
	(1)	**(2)**	**(3)**
	Gini	**Gini**	**Gini**
ln (income per capita)	0,149*** (0,009)		-0,072*** (0,017)
ln (mean household income)		0,135*** (0,010)	
ln (population)	-0,020*** (0,004)	-0,023*** (0,005)	-0,013** (0,006)
Share bachelor's degree	-0,001** (0,000)	-0,000* (0,000)	0,150** (0,059)
Share high school diploma	-0,001*** (0,000)	-0,001*** (0,000)	-0,043 (0,035)
Share agriculture	-0,001 (0,000)	-0,000 (0,000)	-0,000 (0,072)
Share manufacturing sector	-0,001*** (0,000)	-0,000** (0,000)	-0,084*** (0,027)
Constant	-0,674*** (0,107)	-0,628*** (0,126)	1,302*** (0,161)
MSA & Time FE	yes	yes	yes
N	4069	4069	735
MSAs	399	399	260
T	11	11	3
Within-R^2	0,288	0,267	0,849

The first two columns report the 2006-2016 annual panel results, while the third column reports the 1980-2000 decennial panel results. Standard errors clustered at the MSA level in parentheses; * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder resp. NHGIS and IPUMS as well as own calculations.

From the control variables, population sticks out again. It now exhibits a statistically significant negative coefficient. Thus, increases in MSA size seem to decrease inequality for a given inequality and city size level, whereas the population level per se does not affect an MSA's inequality level. The observed difference in results probably stems from these differing interpretations and foci of cross-section and MSA FEs panel regressions. The existing literature estimates cross-sections or panels without city FEs, rendering the obtained results not directly comparable with those of the MSA FE.

The obtained results are robust to excluding all control variables from the regression while keeping the MSA and sometimes time FEs (Appendix Table IV). The statistically significant positive income-inequality relationship in the 2006-2016 panel persists. For the 1980-2000 panel, the income coefficient remains negative and significant when both MSA and time FEs are included. When only MSA FEs are included, the coefficient turns positive while remaining statistically significant, showing again the importance of controlling for time specificities in this long-term panel.

When adding quadratic income terms, the switch in signs between the two panels is again observed (Appendix Table V). Only the linear income term is statistically significant in the 2006-2016 panel with income per capita. It is positive as previously. With mean household income, both income terms are statistically significant. The linear one is positive, and the quadratic one is negative, indicating an inverse-U-shaped income-inequality relationship. However, all MSAs are located within the upward-sloping part of the curve according to their observed incomes, hence exhibiting a positive income-inequality relationship. For the 1980-2000 panel, both income terms are statistically significant but now of the opposite sign. The linear one is negative while the quadratic one is positive. Thus, the income-inequality relationship is U-shaped. Most MSAs are located within the downward-sloping part of the curve, hence exhibiting a negative income-inequality relationship. Thus, the same pattern as in the linear-only regressions reappears.

6. Employing Alternative Inequality Measures

The obtained opposing results for the two data sets might stem from a peculiarity of the GINI. Therefore, the previous regressions were repeated with several other inequality measures to test the results' robustness. The robustness check sections only present results for the panel regressions as they exhibit most clearly the pattern of switching signs. Furthermore, they can be considered the more reliable results as they abstract from MSA-specific unobservable characteristics, which might bias the cross-section results.[6]

The calculated alternative inequality measures for within-MSA inequality are as follows:

- the GE(0) (Generalized Entropy index with a=0, that is, the mean log deviation),[7]
- the 90/10, 90/50, and 50/10 percentile ratios, and
- the s1, the income share of the top 1% incomes in an MSA.

The GE(0) is an overall inequality measure as the GINI, providing a direct comparison point. The 90/10 percentile ratio is also an overall measure, but it excludes the extreme values at the top and bottom of the income distribution. The 90/50 percentile ratio measures the inequality within top incomes, while the 50/10 percentile ratio measures the inequality within bottom incomes. The s1 indicates the evolution of the very top incomes compared to the rest.

The alternative inequality measures are calculated for both data sets from IPUMS as it offers household-level data. This procedure reduces the number of observations in the 2006-2016 data set to 2,856 (from 4,069 before) and in the 1980-2000 data set to 700 (735 before). The alternative inequality measures replace the GINI as the dependent variable in the regressions. Table 5 presents the 2006-2016 panel results, and Table 6 the 1980-2000 panel results.

For the 2006-2016 panel, GE(0) shows a very similar result to the GINI one: a statistically significant and positive income coefficient. The income coefficient is also statistically significantly positive for s1, while it is not statistically significant in the regressions with the percentile ratios. For the 1980-2000

[6] Robustness checks have also been run for the cross-sections with similar results, indicating that their results are overall robust as well (Appendix Tables VI—X).

[7] Regressions have also been run for the GE(2) (Generalized Entropy index with a=2, that is, half the squared coefficient of variation). The obtained results are very similar to the GE(0) ones. The results have been omitted due to space considerations but are available upon request.

panel, all income coefficients are statistically significant and negative as with the GINI except for the 50/10 percentile ratio and s1. In the latter cases, the coefficient is not statistically significant.

Overall, the regressions with alternative inequality measures confirm the results obtained with the GINI. The oppositional signs of the two panels' income coefficients appear again for the GE(0). The other measures exhibit mixed results. This corresponds to expectations as they only consider parts of the income distribution.

TABLE 5.
Alternative Inequality Measures in the 2006-2016 Panel

	(1)	(2)	(3)	(4)	(5)	(6)
	Gini	**Ge0**	**p90p10**	**p90p50**	**p50p10**	**s1**
ln (income per capita)	0,126*** (0,011)	0,037** (0,016)	-1,097 (0,961)	0,027 (0,100)	-0,480 (0,317)	0,052*** (0,007)
Controls	yes	yes	yes	yes	yes	yes
MSA & Time FEs	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
N	2856	2856	2856	2856	2856	2856
MSAs	293	293	293	293	293	293
Within-R^2	0,289	0,248	0,062	0,141	0,028	0,090

Standard errors clustered at the MSA level in parentheses; * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder and IPUMS as well as own calculations.

TABLE 6.
Alternative Inequality Measures in the 1980-2000 Panel

	(1)	(2)	(3)	(4)	(5)	(6)
	Gini	**ge0**	**p90p10**	**p90p50**	**p50p10**	**s1**
ln (income per capita)	-0,073*** (0,018)	-0,102*** (0,023)	-3,811*** (0,927)	-0,744*** (0,113)	-0,277 (0,284)	0,012 (0,014)
Controls	yes	yes	Yes	yes	yes	yes
MSA & Time FEs	yes	yes	Yes	yes	yes	yes
Constant	yes	yes	Yes	yes	yes	yes
N	700	700	700	700	700	700
MSAs	254	254	254	254	254	254
within-R^2	0,857	0,852	0,349	0,770	0,140	0,756

Standard errors clustered at the MSA level in parentheses; * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder and IPUMS as well as own calculations.

The use of these alternative inequality measures also allows distinguishing between two hypotheses, which have been discussed for the rising inequality in the US: a rise in the top income share and polarization (Piketty & Saez, 2003; Autor et al., 2006; Essletzbichler, 2015). Income per capita has, on average, increased over the study period. Thus, both channels would result in a positive income coefficient for s1 and the 90/50 percentile ratio. Polarization would additionally lead to a negative coefficient for the 50/10 percentile ratio, while the 90/10 ratio should remain relatively unchanged. Notably, the 2006-2016 panel should exhibit this pattern as it captures the time of technological change substituting middle-skill routine tasks, leading to polarization.

The obtained results hint towards both rises in top incomes and polarization but cannot substantiate these hypotheses unambiguously. The income coefficient for s1 is positive and significant in the new panel compared to being insignificant, albeit already positive, in the old panel. This indicates that the income per capita increases disproportionally benefited the very top incomes. Concurrently, the 90/50 percentile ratio turns insignificantly positive from being significantly negative before. Thus, increasing top incomes played a role in the increasing inequality and switching signs of the income-inequality relationship across the panels. In addition, the 90/10 exhibits an insignificant coefficient in the newer panel, while being significantly negative before, consistent with polarization. However, the coefficient of the 50/10 percentile ratio is not significant but negative in both panels, which questions an income redistribution from the middle to bottom incomes, as suggested by the polarization hypothesis.

7. Reasons for the Change in the Income-Inequality Relationship

There are four possible reasons why the income-inequality relationship changes its sign across panels: differences in the database, changes in the MSA delineations, the different time gaps in the panels, and qualitative changes in the relationship.

First, changes in the underlying data and its aggregation between FactFinder and IPUMS might lead to differing results. The 1980-2000 panel is based on Census data, while the 2006-2016 one uses the ACS. However, both data products are produced by the US Census Bureau according to similar standards. Furthermore, the 2006-2016 results persist when using IPUMS-calculated inequality measures, as shown in the alternative inequality measures regressions. Thus, the differences in the databases cannot account for the changing sign of the income-inequality relationship.

Second, MSA delineation changes result in different MSAs being considered across the two data sets. These changes lead to a clear difference in the number of MSAs available: 260 in the 1980-2000 data set versus 399 in the 2006-2016 one. The increase in sample size due to the number of MSAs alone is considerable. However, 260 MSAs are a large enough number of observations for regression analyses. Furthermore, the panel and cross-section results remain unchanged when restricting the 2006-2016 sample to only those MSAs already existing in 2000 (Appendix Table XI). Besides, one can calculate both the GINI and mean household income from IPUMS for 2000 and 2010 for both MSA delineations. If one then regresses the GINI on the income, the obtained results are qualitatively the same regarding significance levels and signs (Appendix Table XII). Thus, delineation and sample size changes might play a role in the diverging results, but they appear unlikely to be the sole cause of the opposing results.

Third, the time gaps and time dimensions of the panels differ. The 2006-2016 panel is an annual one with observations for 11 different years. The 1980-2000 panel is a decennial one with observations for only three years. Both might result in statistical issues. There might not be enough within-variation in the former for proper estimation, while the number of observations per MSA might be too small in the latter. The 10-year gap between observations in the latter results in a more medium-run perspective than the short-run one of the annual panel. Transmission channels differ in their manifestation rapidity, as discussed in section 2. Purely economic factors typically realize faster than sociopolitical ones (Halter et al., 2014). The former include trade and labor market phenomena, which result in a positive income-inequality relationship. The latter comprise segregation, crime, and sociopolitical contrast and hence exactly those factors leading to a negative income-inequality relationship. Annual panel studies for European regions found likewise positive income-inequality relationships for 1994-2001 (Rodríguez-Pose & Tselios, 2009), respectively 1993-2011 (Castells-Quintana et al., 2015).

The 2006-2016 panel can be transformed into one with 5-year gaps and observations for three years (2006, 2011, and 2016). This approaches the time gap between observations to the one of the 1980-2000 panel and results in the same number of observation years (three). When regressing the GINI on income and the usual controls in this panel, the income coefficient remains statistically significant and positive for both per capita and mean household income. However, its size diminishes by about one-third. A similar reduction is observed when basing the 5-year panel on the MSAs already existing over 1980-2000 (Appendix Table XIII). Thus, there appears to be something special about the 2006-2016 time period other than the time gap between observations and the number of observed years resulting in the positive income-inequality relationship. However, the 10-year gaps cannot be simulated due to the 2006-2016 panel's limited time dimension.

Forth, the income-inequality relationship might have changed qualitatively over the years, especially between 2000 and 2006, according to the panel results. [8] The cross-section results also reflect this change. The negative income-inequality association stops in 1990 and no longer exists for 2000 and further years. This timing corresponds to the sharp rise in inequality generally observed in the US in the 1980s and beyond (Piketty & Saez, 2003). This increase in inequality is also observed in the MSA-level data employed in the present study. Apparently, it was not only inequality that increased but also its relationship with income changed. The changed sign of the income-inequality relationship also hints at economic growth having become less inclusive over the years.[9]

The influence of factors resulting in a negative income-inequality relationship might have decreased over time while the influence of those leading to a positive relationship increased. Factors resulting in a negative income-inequality relationship include residential segregation, crime, and sociopolitical unrest, as detailed in section 2. Crime rates have indeed declined for several offenses since the 1980s (Asher, 2017), but residential segregation increased during the considered period (Bischoff & Reardon, 2014). Thus, the evidence for a decline in the "negative" factors is mixed.

Factors leading to a positive income-inequality relationship include specialization, technological change substituting middle-skill routine tasks, trade, deunionization, and flexible labor market regulations. Trade and specialization have increased since the 1980s due to globalization and technological change substituting middle-skill routine tasks (Autor et al., 2006; Rigby & Breau, 2008; Autor & Dorn, 2013). Unionization rates declined over the last decades (Hu & Hanink, 2018). All these developments would strengthen a positive income-inequality relationship. Combined, they might have led to the observed change in the sign of the income-inequality relationship if the importance of these positive factors were stronger relative to the negative factors, especially residential segregation.

Given the available data, it is impossible to distinguish data-related issues neatly from qualitative changes in the income-inequality relationship. Thus, one cannot exclude the possibility that the differences in the data and the analysis setup are responsible for the observed change in sign of the relationship. This would require a longer annual panel over at least 20 years to evaluate results for panels of different lengths based on a single, consistent data set. Consequently, further research is required on this topic.

8. Conclusion

This paper analyzed the income-inequality relationship within MSAs using two data sets: a decennial one over 1980-2000 based on the Census and an annual one over 2006-2016 based on the ACS. These data sets enable study of the income-inequality relationship within MSAs over a more extended period than was previously possible, as well as employing both cross-section and panel regression techniques.

A higher income per capita level is still associated with a lower within-MSA inequality level in the earlier years. However, this association stops being statistically significant in 2000 and remained so until 2016. For the 1980-2000 panel, income per capita increases are accordingly associated with inequality decreases. In the 2006-2016 panel, income per capita increases are associated with inequality increases. The income-inequality relationship changes direction over time.

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[8] The European panel studies finding a positive income-inequality relationship analyzed the 1990s and 2000s (Rodríguez-Pose & Tselios, 2009; Castells-Quintana et al., 2015).

[9] The economic crisis of 2008 might also have influenced the income-inequality relationship. However, the change is already visible in the 2000 cross-section, where the income coefficient is insignificant for the first time. Furthermore, the positive income-inequality association also appears in the 2012-2016 panel, starting after the crisis years.

The main explanations for this change in sign are MSA delineation changes and different time dimensions in the panels, as well as qualitative changes in the income-inequality relationship. The latter are probably due to polarization resulting from technological change substituting middle-skill routine tasks in line with Autor & Dorn (2013). However, these explanations cannot be completely distinguished with the data sets at hand.

Therefore, further research is required to solve this puzzle. On the one hand, studies using a more extended annual panel are needed to evaluate the income-inequality relationship in panels with different time dimensions and time gaps. On the other hand, more research on the transmission channels of the income-inequality relationship at the MSA levels might enlighten the influence of specific factors on this relationship in different periods.

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Appendix

Figures

FIGURE I.
Scatterplot of the GINI against ln (income per capita) 2006-2016

FIGURE II.
Scatterplot of the GINI against ln (mean household income) 2006-2016

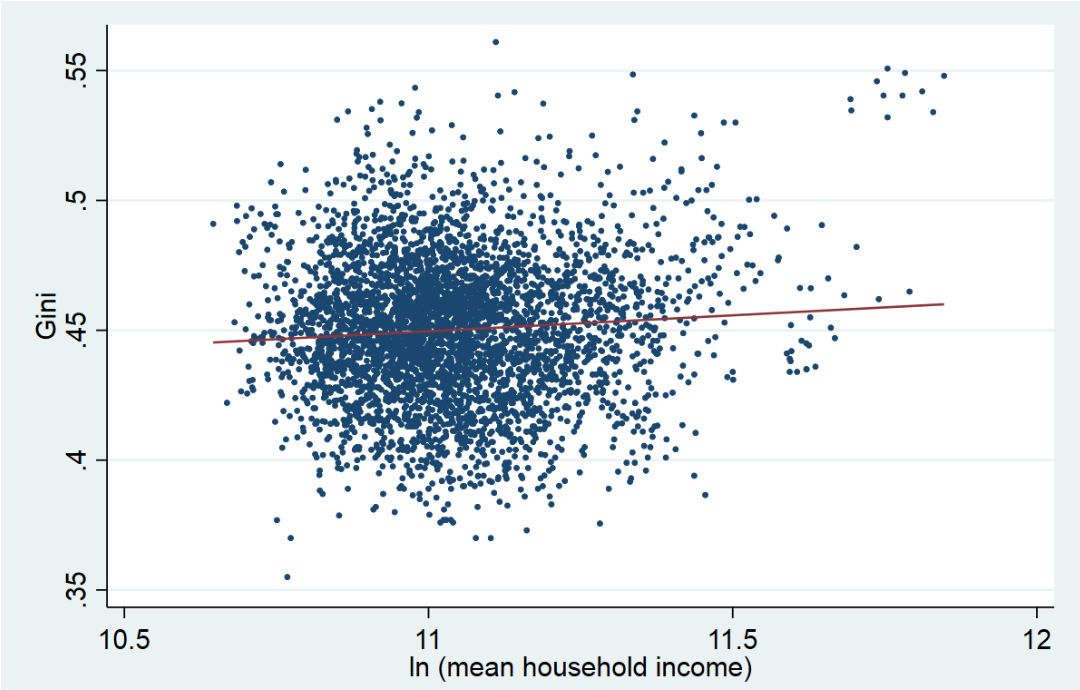
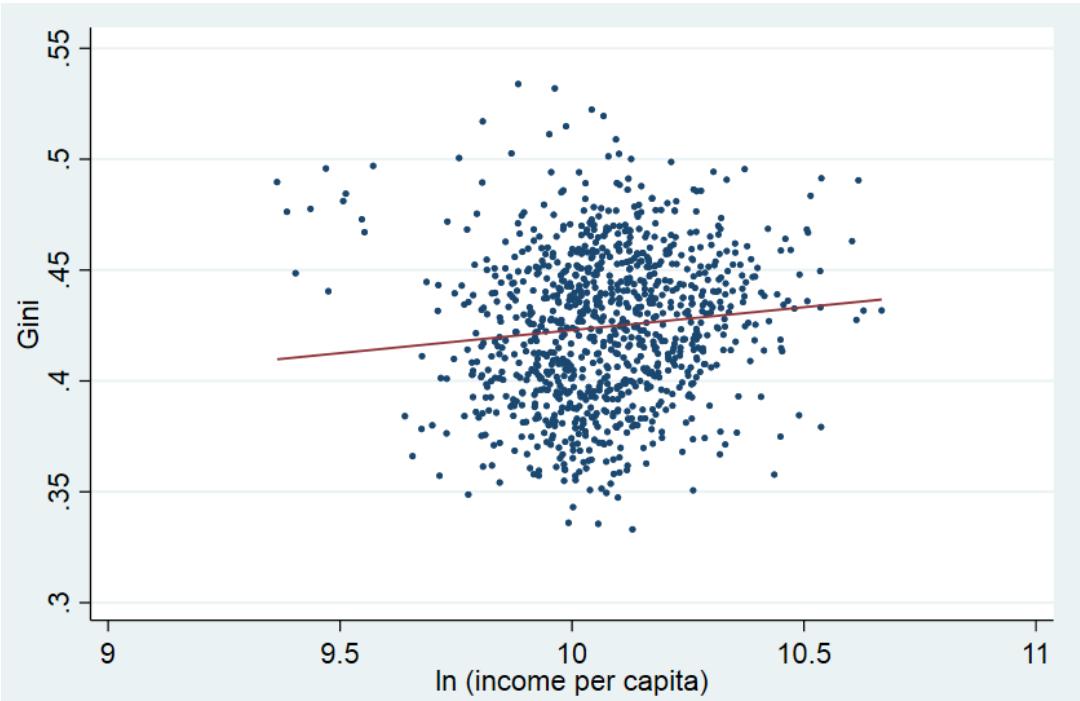


FIGURE III.
Scatterplot of the GINI against ln (income per capita) 1980-2000



Tables

Table VII.
Pooled Cross-Sections Without and With Control Variables Included

	2006-2016			1980-2000	
	(1)	(2)	(3)	(4)	(5)
	Gini	Gini	Gini	Gini	Gini
ln (income per capita)	0,011*** (0,003)	0,011*** (0,003)	-0,013*** (0,004)	0,022*** (0,008)	-0,020 (0,013)
Controls	no	no	yes	no	yes
MSA & Time FEs	no	no	no	no	no
Constant	yes	yes	yes	yes	yes
N	4070	4069	4069	735	735
MSAs	399	399	399	260	260
R^2	0,005	0,005	0,244	0,014	0,270

The first three columns report results for cross-sections pooling all observations over 2006-2016 together, that is, without including MSA and time FEs. Column 1 presents the results for an unrestricted sample without control variables included. Column 2 is restricted to those observations with data for the control variables without including them into the regression. Column 3 then includes control variables. These regressions use 2013 MSA delineations and ACS data from FactFinder. The last two columns report results for cross-sections pooling all observations over 1980-2000 together, without including MSA and time FEs. Column 4 presents the results without control variables included and column 5 with them included. (The sample size is, in this case, unaffected by the inclusion of control variables.) These regressions use 1990 MSA delineations and Census data from NHGIS and IPUMS. Robust standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder, NHGIS and IPUMS as well as own calculations.

Table VIII.
Cross-Section Results Without Control Variables Included

	(1)	(2)	(3)	(4)	(5)	(6)
	2016	2010	2006	2000	1990	1980
	Gini	Gini	Gini	Gini	Gini	Gini
ln (income per capita)	0,011 (0,009)	0,008 (0,010)	0,011 (0,011)	-0,031*** (0,010)	-0,057*** (0,010)	-0,068*** (0,010)
Constant	0,348*** (0,094)	0,364*** (0,101)	0,334*** (0,114)	0,755*** (0,107)	0,990*** (0,096)	1,061*** (0,104)
MSAs	382	366	359	251	245	239
R^2	0,005	0,003	0,004	0,039	0,142	0,173

The first three columns report results for 2016, 2010, and 2006 respectively. They use 2013 MSA delineations and ACS data from FactFinder. The last three columns report results for 2000, 1990, and 1980 respectively. They use 1990 MSA delineations and Census data from NHGIS and IPUMS. No control variables are included in these regressions. Robust standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder, NHGIS and IPUMS as well as own calculations.

TABLE III.
Quadratic Cross-Section Results

	(1)	(2)	(3)	(4)	(5)	(6)
	2016	**2010**	**2006**	**2000**	**1990**	**1980**
	Gini	**Gini**	**Gini**	**Gini**	**Gini**	**Gini**
ln (income per capita)	0,847 (0,777)	1,072 (0,885)	0,569 (0,888)	2,262** (0,900)	2,286*** (0,702)	1,636*** (0,434)
squared ln (income per capita)	-0,042 (0,038)	-0,053 (0,044)	-0,027 (0,044)	-0,112** (0,044)	-0,116*** (0,035)	-0,084*** (0,022)
Controls	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
MSAs	382	366	359	251	245	239
R^2	0,237	0,317	0,308	0,337	0,376	0,511

The first three columns report results for 2016, 2010, and 2006 respectively. They use 2013 MSA delineations and ACS data from FactFinder. The last three columns report results for 2000, 1990, and 1980 respectively. They use 1990 MSA delineations and Census data from NHGIS and IPUMS. The usual linear control variables are included in these regressions. Robust standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder, NHGIS and IPUMS as well as own calculations.

TABLE IV.
Panel Results Without Control Variables Included

	2006-2016				**1980-2000**	
	(1)	(2)	(3)	(4)	(5)	(6)
	Gini	**Gini**	**Gini**	**Gini**	**Gini**	**Gini**
ln (income per capita)	0,065*** (0,008)	0,135*** (0,009)			0,184*** (0,006)	-0,056*** (0,012)
ln (mean household income)			0,069*** (0,008)	0,124*** (0,009)		
Controls	no	no	no	no	no	no
MSA FEs	yes	yes	yes	yes	yes	yes
Time FEs	no	yes	no	yes	no	yes
Constant	yes	yes	yes	yes	yes	yes
N	4069	4069	4069	4069	735	735
MSAs	399	399	399	399	260	260
T	11	11	11	11	3	3
Within-R^2	0,044	0,268	0,047	0,250	0,579	0,836

The first four columns report the 2006-2016 annual panel results, while the fourth and fifth column reports the 1980-2000 decennial panel results. All regressions do not include control variables but include MSA FEs. The pair columns (2, 4, and 6) additionally include time FEs. The sample is restricted to those observations that have observations for all control variables. The unrestricted (full sample) results are identical. Standard errors clustered at the MSA level in parentheses; * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder resp. NHGIS and IPUMS as well as own calculations.

TABLE V.
Quadratic Panel Results

	(1)	(2)	(3)
	2006-2016		**1980-2000**
	Gini	**Gini**	**Gini**
ln (income per capita)	0,716** (0,345)		-1,248*** (0,464)
Quadratic ln (income per capita)	-0,028 (0,017)		0,059** (0,023)
ln (mean household income)		1,700*** (0,477)	
Quadratic ln (mean household income)		-0,071*** (0,022)	
Controls	yes	yes	yes
MSA and Time FEs	yes	yes	yes
Constant	yes	yes	yes
N	4069	4069	735
MSAs	399	399	250
T	11	11	3
within-R^2	0,289	0,272	0,851

The first two columns report the 2006-2016 annual panel results, while the third column reports the 1980-2000 decennial panel results. Standard errors clustered at the MSA level in parentheses; The usual linear control variables are included in these regressions. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder resp. NHGIS and IPUMS as well as own calculations.

TABLE VI.
Cross-Section Results regressing GE(0) on Income

	(1)	(2)	(3)	(4)	(5)	(6)
	2016	**2010**	**2006**	**2000**	**1990**	**1980**
	ge0	**ge0**	**ge0**	**ge0**	**ge0**	**ge0**
ln (income per capita)	-0,023 (0,031)	-0,035 (0,036)	-0,052 (0,036)	-0,071* (0,038)	-0,116*** (0,032)	-0,057*** (0,018)
Controls	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
MSAs	260	261	259	251	225	229
R^2	0,233	0,352	0,270	0,280	0,385	0,518

The first three columns report results for 2016, 2010, and 2006 respectively. They use 2013 MSA delineations and ACS data from FactFinder. The last three columns report results for 2000, 1990, and 1980 respectively. They use 1990 MSA delineations and Census data from NHGIS and IPUMS. The usual controls are included. Robust standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder, NHGIS and IPUMS as well as own calculations.

TABLE IX.
Cross-Section Results regressing the 90/10 Percentile Ratio on Income

	(1)	(2)	(3)	(4)	(5)	(6)
	2016	**2010**	**2006**	**2000**	**1990**	**1980**
	p90p10	**p90p10**	**p90p10**	**p90p10**	**p90p10**	**p90p10**
ln (income per capita)	-7,982 (5,427)	-4,235** (2,091)	-4,711*** (1,787)	-3,089* (1,611)	-4,768*** (1,256)	-1,355 (0,824)
Controls	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
MSAs	260	261	259	251	225	229
R^2	0,115	0,323	0,286	0,246	0,351	0,400

The first three columns report results for 2016, 2010, and 2006 respectively. They use 2013 MSA delineations and ACS data from FactFinder. The last three columns report results for 2000, 1990, and 1980 respectively. They use 1990 MSA delineations and Census data from NHGIS and IPUMS. The usual controls are included. Robust standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder, NHGIS and IPUMS as well as own calculations.

TABLE XIII.
Cross-Section Results regressing the 90/50 Percentile Ratio on Income

	(1)	(2)	(3)	(4)	(5)	(6)
	2016	**2010**	**2006**	**2000**	**1990**	**1980**
	p90p50	**p90p50**	**p90p50**	**p90p50**	**p90p50**	**p90p50**
ln (income per capita)	0,075 (0,167)	-0,085 (0,187)	-0,144 (0,183)	0,002 (0,214)	-0,568*** (0,121)	-0,358*** (0,080)
Controls	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
MSAs	260	261	259	251	225	229
R^2	0,245	0,322	0,330	0,376	0,537	0,574

The first three columns report results for 2016, 2010, and 2006 respectively. They use 2013 MSA delineations and ACS data from FactFinder. The last three columns report results for 2000, 1990, and 1980 respectively. They use 1990 MSA delineations and Census data from NHGIS and IPUMS. The usual controls are included. Robust standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder, NHGIS and IPUMS as well as own calculations.

TABLE IX.
Cross-Section Results regressing the 50/10 Percentile Ratio on Income

	(1)	(2)	(3)	(4)	(5)	(6)
	2016	**2010**	**2006**	**2000**	**1990**	**1980**
	p50p10	**p50p10**	**p50p10**	**p50p10**	**p50p10**	**p50p10**
ln (income per capita)	-2,690 (1,648)	-1,223** (0,543)	-1,424*** (0,462)	-1,000** (0,406)	-0,981*** (0,353)	0,066 (0,315)
Controls	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
MSAs	260	261	259	251	225	229
R^2	0,107	0,241	0,228	0,145	0,216	0,195

The first three columns report results for 2016, 2010, and 2006 respectively. They use 2013 MSA delineations and ACS data from FactFinder. The last three columns report results for 2000, 1990, and 1980 respectively. They use 1990 MSA delineations and Census data from NHGIS and IPUMS. The usual controls are included. Robust standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder, NHGIS and IPUMS as well as own calculations.

TABLE X.
Cross-Section Results regressing the Top 1% Income Share on Income

	(1)	(2)	(3)	(4)	(5)	(6)
	2016	**2010**	**2006**	**2000**	**1990**	**1980**
	s1	**s1**	**s1**	**s1**	**s1**	**s1**
ln (income per capita)	-0,013* (0,007)	0,008 (0,006)	-0,000 (0,007)	-0,026*** (0,004)	-0,013*** (0,005)	0,051*** (0,010)
Controls	yes	yes	yes	yes	yes	yes
Constant	yes	yes	yes	yes	yes	yes
MSAs	260	261	259	251	225	229
R^2	0,144	0,100	0,076	0,442	0,274	0,442

The first three columns report results for 2016, 2010, and 2006 respectively. They use 2013 MSA delineations and ACS data from FactFinder. The last three columns report results for 2000, 1990, and 1980 respectively. They use 1990 MSA delineations and Census data from NHGIS and IPUMS. The regressions include the usual controls. Robust standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder, NHGIS and IPUMS as well as own calculations.

TABLE XI.
2006-2016 Panel Restricted to the 1980-2000 MSAs Results

	(1)	(2)	(3)	(4)	(5)
	Annual panel		**2016**	**2010**	**2006**
	Gini	**Gini**	**Gini**	**Gini**	**Gini**
ln (income per capita)	0,119*** (0,011)		0,000 (0,021)	-0,016 (0,019)	-0,004 (0,015)
ln (mean household income)		0,107*** (0,010)			
Controls	yes	yes	yes	yes	yes

TABLE XI. CONT.
2006-2016 Panel Restricted to the 1980-2000 MSAs Results

	(1)	(2)	(3)	(4)	(5)
	Annual panel		2016	2010	2006
	Gini	Gini	Gini	Gini	Gini
MSA & time FEs	yes	yes	-	-	-
Constant	yes	yes	yes	yes	yes
N	2600	2600	-	-	-
MSAs	240	240	232	238	240
T	11	11	-	-	-
(within-) R^2	0,289	0,274	0,270	0,348	0,325

The table reports regression results for the annual panel 2006-2016 (columns 1 and 2) and the cross-sections for 2016, 2010, and 2006 (columns 3-5). In all these regressions, the sample is reduced to those MSAs, in 2013 MSA delineations, that already existed in 2000, resulting in at most 240 MSAs. This number is slightly smaller than the 251 MSAs available for 2000 because some MSAs grew between 2000 and 2006 in such a way that they fused with other MSAs, reducing their number. After 2006, some further slight MSA changes occurred, reducing their number in later years. The regressions include the usual controls. Standard errors clustered at the MSA level in parentheses; * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder as well as own calculations.

TABLE XII.
Cross-Section Results for 2000 and 2010 with Different MSA Delineations

	(1)	(2)	(3)	(4)	(5)	(6)
	2010 old IPUMS	2010 new IPUMS	2010 aggregated	2000 aggregated	2000 old IPUMS	2000 new IPUMS
	Gini	Gini	Gini	Gini	Gini	Gini
ln (mean household income)	0,015 (0,012)	0,015 (0,011)	0,014 (0,010)	-0,054*** (0,009)	-0,000 (0,000)	-0,019 (0,013)
Controls	no	no	no	no	no	no
Constant	yes	yes	yes	yes	yes	yes
MSAs	283	261	366	251	283	258
R^2	0,011	0,010	0,007	0,115	0,000	0,015

The table reports results for regressing the GINI on log mean household income without control variables included. The first three columns report results for 2010. The regression of the first column uses the 1990 MSA delineations together with mean household income calculated from IPUMS micro data. The regression of the second column also calculates from IPUMS but uses the 2013 MSA delineations. The regression of the third column then uses the aggregated FactFinder data for the GINI and the mean household income and the 2013 MSA delineations as in the main regressions. The last three columns report results for 2000. The regression of the fourth column uses the aggregated Census NHGIS data for mean household income and the 1990 MSA delineations as in the main regressions. The regression of the fifth column also uses the 1990 MSA delineations but calculates mean household income from IPUMS. The regression of the third column then uses the 2013 MSA delineations while calculating the mean household income from IPIMS. The GINI is in these regressions always calculated from IPUMS. Robust standard errors are in parentheses. * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder, NHGIS and IPUMS as well as own calculations.

TABLE XIII.
5-Year-Period Panels 2006-2016 Results

	(1)	(2)	(3)	(4)
	All MSAs		Only 2000 MSAs	
	Gini	Gini	Gini	Gini
ln (income per capita)	0,099*** (0,013)		0,071*** (0,017)	
ln (mean household income)		0,094*** (0,014)		0,060*** (0,017)
Controls	yes	yes	yes	yes
MSA & Time FE	yes	yes	yes	yes
Constant	yes	yes	yes	yes
N	1106	1106	710	710
MSAs	397	397	240	240
T	3	3	3	3
within-R^2	0,330	0,322	0,350	0,338

The table reports regression results for a 5-year-period subpanel of the 2006-2016 one. Thus, it includes observations from 2006, 2011, and 2016 only. The first two columns report results for the full sample, while the last two columns present the results for restricting the sample to only those MSAs, in 2013 MSA delineations, that have already existed in 2000 (as in Appendix Table XI). The regressions include the usual controls. Standard errors clustered at the MSA level in parentheses; * p<0.1, ** p<0.05, *** p<0.01.
Source: FactFinder as well as own calculations.

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Articles

La seguridad alimentaria en la encrucijada de las desigualdades regionales de México

Felipe Torres Torres, Agustín Rojas Martínez***

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Resumen:

El propósito del presente trabajo es analizar las dimensiones regionales de la seguridad alimentaria, vista como problema estructural del desarrollo en México durante el periodo 2000-2020. La hipótesis es que la apertura comercial implementada en el país bajo un marco de desarrollo económico asimétrico, amplió sus desigualdades socio-territoriales y con ello la brecha de la inseguridad alimentaria. Para investigar este fenómeno, aplicamos los métodos Análisis de Componentes Principales (ACP) y estratificación Dalenius-Hodges, con los cuales construimos un índice de medición a escalas municipal y regional. Los resultados obtenidos señalan que, visto tanto por número de regiones como de proporción de población, más de la mitad de los mexicanos enfrenta algún grado de inseguridad alimentaria. Revertir esta situación implica desplegar una política alimentaria orientada a recuperar la autosuficiencia en la producción de granos básicos y garantizar el acceso a los alimentos, principalmente mediante el mejoramiento del ingreso entre la población ubicada en los rangos de pobreza y pobreza extrema.

Palabras clave: Seguridad alimentaria; desigualdades regionales; política agrícola; índice de seguridad alimentaria municipal y regional; método de análisis de componentes principales.

Clasificación JEL: B41; C02; F60; O13; P25; Q12; Q17; Q18; R11.

Food security at the crossroads of regional inequalities in Mexico

Abstract:

The purpose of this paper is to analyze the regional dimensions of food security, seen as a structural problem of development in Mexico during the period 2000-2020. The hypothesis is that the commercial opening implemented in the country under a framework of asymmetric economic development, widened its socio-territorial inequalities and with it the food insecurity gap. To investigate this phenomenon, we applied the Principal Component Analysis (PCA) and Dalenius-Hodges stratification methods, with which we built a measurement index at municipal and regional scales. The results obtained indicate that, seen both by number of regions and population proportion, more than half of Mexicans face some degree of food insecurity. Reversing this situation implies deploying a food policy aimed at recovering self-sufficiency in the production of basic grains and guaranteeing access to food, mainly by improving income among the population located in the ranges of poverty and extreme poverty.

Keywords: Food security; regional inequalities; agricultural policy; municipal and regional food security index; principal component analysis method.

JEL Classification: B41; C02; F60; O13; P25; Q12; Q17; Q18; R11.

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1. Introducción

Desde mediados de la década de los ochenta del siglo XX en el que México adopta un modelo de desarrollo basado en la apertura comercial, el país enfrenta problemas asociados con la producción y el consumo de alimentos que han repercutido en las condiciones de seguridad alimentaria a lo largo de su territorio. Destacan la pérdida de la soberanía alimentaria, dependencia de las importaciones de productos estratégicos, el deterioro de la calidad de la alimentación, así como las crisis económicas recurrentes que han deteriorado el poder adquisitivo y con ello las posibilidades de acceso a los alimentos, principalmente en estratos de bajos ingresos y condiciones de pobreza extrema. Ello, ha incrementado la proporción de mexicanos en inseguridad alimentaria.

Los diversos diagnósticos (CONEVAL, 2010; López y Sandoval, 2018; Mundo-Rosas et al., 2018; Urquía-Fernández, 2014) sobre la situación de la seguridad alimentaria en México ubican al déficit en la producción de alimentos o las desigualdades en su acceso como causales del deterioro. Sin embargo, el espectro de análisis es restringido en términos conceptuales y metodológicos, al igual que sus indicadores y escala de análisis, por lo que resultan insuficientes para estudiar a la seguridad alimentaria y sus implicaciones, principalmente en cuanto a manifestaciones territoriales, ya que se expresan en promedios que esconden las particularidades del consumo en zonas urbanas, regiones rurales y grupos sociales dispersos en municipios.

Esas limitaciones impiden explicar, por ejemplo, la importancia que tiene para la vulnerabilidad alimentaria el efecto de un tipo de desarrollo económico asimétrico, que genera desigualdades e inhibe las capacidades de respuesta social y regional al problema de la producción y acceso a los alimentos. Medir los alcances de la seguridad alimentaria, asumiendo que esta no afecta por igual a todos los individuos en el territorio, resulta necesario para el diagnóstico integral de una problemática de corte estructural.

Desde la perspectiva territorial, son escasas las investigaciones que han analizado las dimensiones regionales de la seguridad alimentaria. Aquellas que examinan el caso de México (Cruz y Pérez, 2018; Díaz-Carreño et al., 2019) no explican su relación con las asimetrías del desarrollo económico, ni con el deterioro de la calidad de la alimentación o las condiciones de salud, además de que no incorporan indicadores a escala regional como el Producto Interno Bruto Per Cápita municipal o la Prevalencia de talla baja en prescolares en esa misma escala.

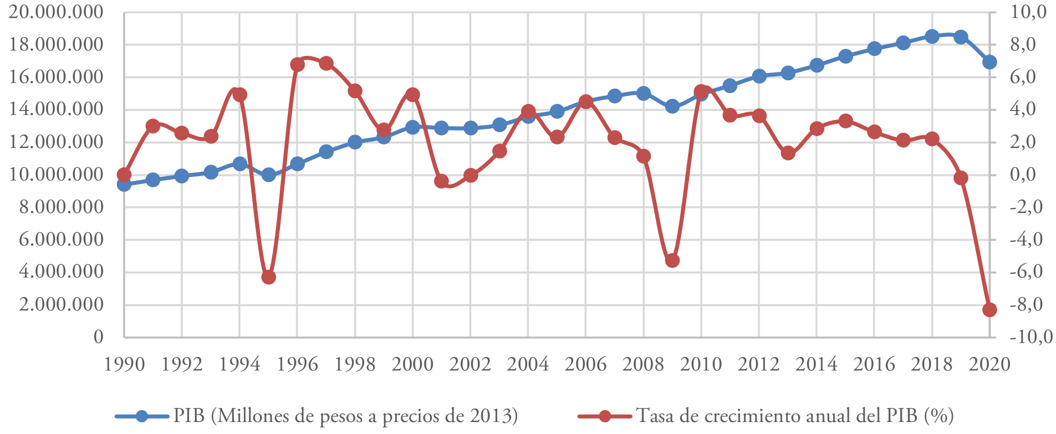
Por tanto, la pregunta que guía esta investigación estriba en dar respuesta a por qué las inequidades del desarrollo económico se expresan en México en desigualdades de la seguridad alimentaria de sus regiones, dentro de entornos productivos agroalimentarios poco atendidos por la política sectorial interna. Partimos de la hipótesis de que la apertura comercial y el desarrollo asimétrico ahondaron los problemas estructurales relacionados con la producción y consumo de alimentos lo cual ha repercutido en inseguridad alimentaria en las regiones de México. El objetivo de nuestro trabajo es explicar las magnitudes del problema de la seguridad alimentaria a escala regional en México utilizando un espectro más amplio de indicadores en ese nivel.

La respuesta a la pregunta de investigación ha requerido el desarrollo y aplicación de una metodología diseñada desde el enfoque territorial que parte de la elaboración de un Índice de Seguridad Alimentaria Municipal y Regional, empleando los métodos de Análisis de Componentes Principales (ACP) y la estratificación de Dalenius-Hodges, este último para medir el número de regiones y población en situación de (in)seguridad alimentaria, tomando como base el periodo 2000–2020.

2. La vulnerabilidad alimentaria de México como reflejo del desarrollo económico.

En el periodo 1990-2020, el Producto Interno Bruto (PIB) de México mantuvo una tasa de crecimiento promedio anual de apenas 2% que ha resultado insuficiente para fortalecer la economía y alcanzar el bienestar social de manera sostenida; además, registró cifras negativas en los periodos de crisis económica (1994-1995; 2008-2009; 2020) lo que amplió la desigualdad social y vulneró la situación de la seguridad alimentaria en las regiones del país (véase gráfica 1).

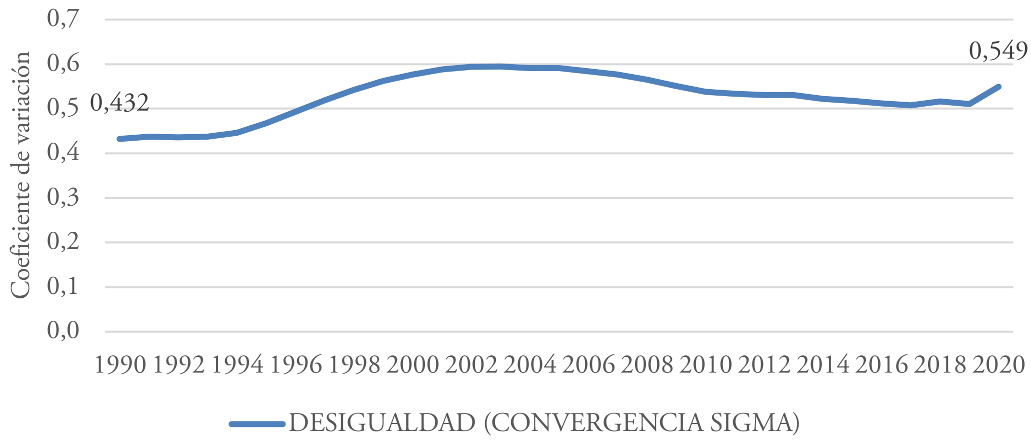
GRÁFICA 1.
México: evolución del Producto Interno Bruto Total, 1990-2020 (Millones de pesos a precios de 2013 y porcentaje)



Fuente: Elaboración propia con base en el Banco de Información Económica (BIE) del Instituto Nacional de Estadística y Geografía (INEGI).

Diversas investigaciones (Diaz-Pedroza et al., 2009; Esquivel, 1999; Luna y Colín, 2017) refieren que entre 1970 y 1985, México presentó convergencia económica regional. Sin embargo, a partir de 1986 con la incorporación del país al Acuerdo General sobre Aranceles Aduaneros y Comercio (GATT por sus siglas en ingles), se revierte esta tendencia al aumentar el coeficiente de variación que amplía la brecha de desigualdad en años más recientes (**Valdez, 2019**). Esto expresa el efecto nocivo de la apertura comercial en lo que se refiere al crecimiento regional, sus asimetrías territoriales y la desigualdad social (véase gráfica 2).

GRÁFICA 2.
México: evolución de la desigualdad entre las entidades federativas a partir del análisis de convergencia-sigma, 1990-2020

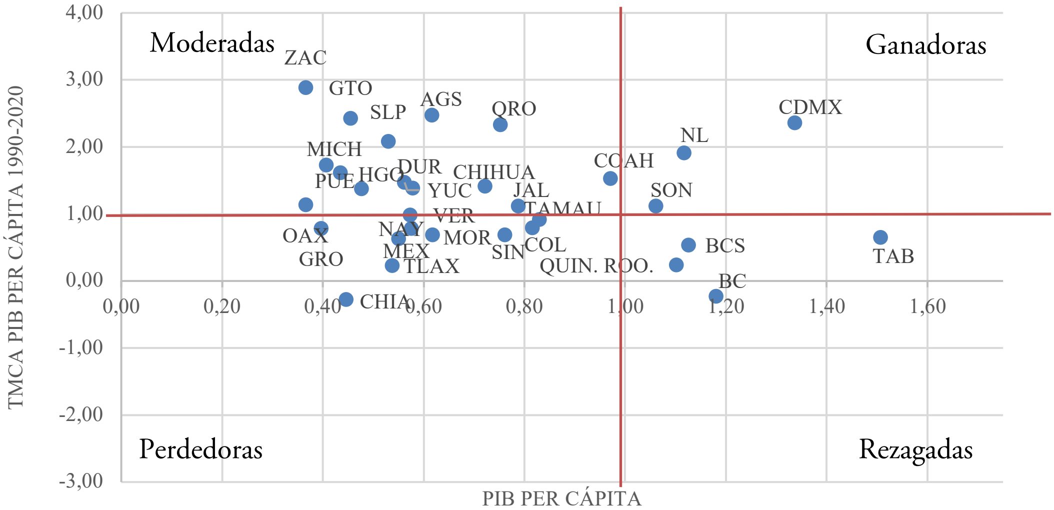


Fuente: Elaboración propia con base en el BIE del INEGI e INEGI (2000; 2005; 2010a; 2015; 2020).

El crecimiento del PIB Per Cápita refleja igualmente el deterioro del ingreso en las entidades a partir de la apertura comercial respecto a los años previos en que operaba el denominado modelo de Industrialización por Sustitución de Importaciones. La clasificación por estados de acuerdo con su PIB Per Cápita en 1990, así como la tasa de crecimiento promedio anual del mismo entre 1990 y 2020, permite elaborar un cuadrante de desempeño económico que identifica entidades ganadoras, moderadas, rezagadas y perdedoras.

En el lapso 1990-2020 la CDMX, Nuevo León y Sonora se ubicaron en el cuadrante de ganadoras. En contraste, las entidades históricamente marginadas se situaron como perdedoras, tal es el caso de Oaxaca, Guerrero, Tlaxcala, Chiapas, Veracruz o Hidalgo. En el de Moderadas, cuyas economías registran bajo PIB Per Cápita, pero altas tasas de crecimiento, se ubican Aguascalientes, Coahuila, Guanajuato, Michoacán, Puebla, Querétaro, San Luis Potosí y Zacatecas. Finalmente, en el de rezagadas, caracterizadas por alto PIB Per Cápita, pero bajas tasas de crecimiento, se encuentran Baja California, Baja California Sur, Quintana Roo, y Tabasco (véase gráfica 3).

Gráfica 3.
México: clasificación de las entidades federativas según crecimiento económico a partir del análisis de convergencia-beta, 1990-2020



Fuente: Elaboración propia con base en el BIE del INEGI e INEGI (2000; 2005; 2010a; 2015; 2020).

Por ello, los cambios del modelo de desarrollo económico ampliaron las desigualdades sociales y regionales, lo que repercutió en niveles salariales, nivel de empleo y pérdida del poder adquisitivo. En el periodo 1990-2020, la composición salarial del país se afectó en términos absolutos; el 56.9% de la población ocupada mantuvo bajo rangos de ingreso de uno a tres salarios mínimos mensuales, lo que dista mucho de los requerimientos mínimos para cubrir las necesidades básicas de la población, particularmente en materia alimentaria. Aunado a ello, la tasa de desocupación nacional presentó incrementos importantes en este mismo lapso: en 1990 registró hasta 6.1%, y aunque en años posteriores osciló por debajo de 4%, a partir de 2008, por efectos de la crisis económica mundial y la intensificación de las políticas de libre mercado, repuntó por arriba de 4.5%, pero en los últimos tres años del periodo promedió 3.7% (INEGI, Banco de Información Económica).

Otro factor que explica la ampliación de las desigualdades sociales es la pérdida del poder adquisitivo. La contención del crecimiento salarial por debajo de los incrementos inflacionarios constituye la causa estructural que explica la pérdida del poder de compra y las restricciones al gasto de los hogares. Este disminuyó 41% en términos reales en el periodo señalado que resulta paralelo al incremento de los niveles de pobreza (INEGI, Banco de Información Económica).

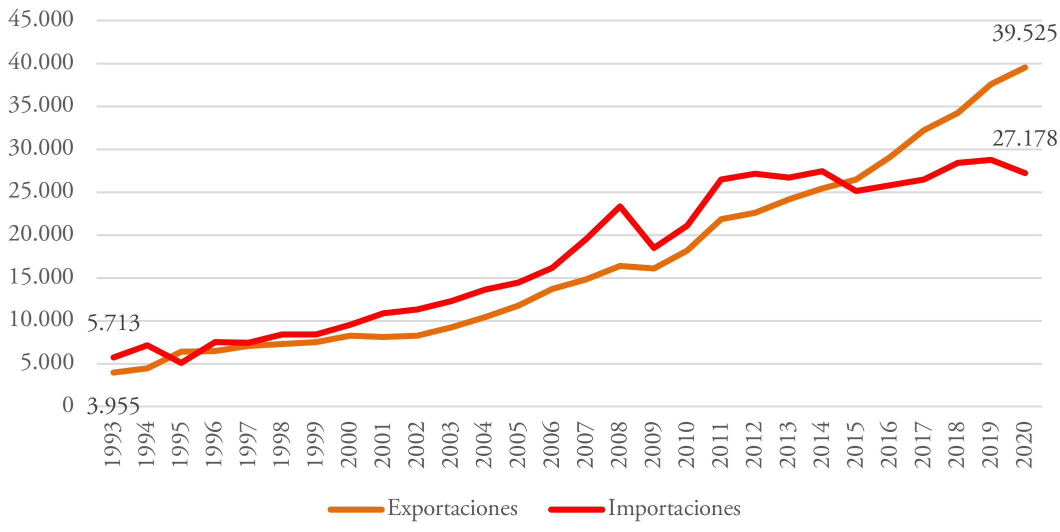
En tal caso, el deterioro de las condiciones alimentarias es resultado de los impactos de las crisis económicas que afectaron el poder adquisitivo de los mexicanos y que se acompañó de la pérdida de la autosuficiencia y soberanía alimentarias, junto a la dependencia de las importaciones de alimentos, principalmente granos básicos.

Asimismo, la crisis económica mundial de 2008-2009 que desató una crisis alimentaria internacional, incrementó los precios internos de los alimentos y provocó mayores niveles de inseguridad alimentaria entre la población y las regiones del territorio nacional (Torres, 2010), lo que se agravó recientemente como consecuencia de la pandemia por el Coronavirus SARS-Cov-2 (COVID-19), la cual se considera que contribuyó a un incremento de entre 8.9 y 9.8 millones el número de mexicanos con un ingreso inferior a la línea de pobreza por ingresos (CONEVAL, 2021).

Los cambios en el modelo de desarrollo provocaron también que la producción de los alimentos estratégicos registrara crecimientos negativos. Entre ellos el arroz, maíz, frijol, trigo. El sorgo y la soya, que son insumos esenciales para la producción de carne, leche y huevo mantienen una situación similar. A diferencia de las frutas, hortalizas y otros productos denominados comerciales como el café o la caña de azúcar que incrementaron sus crecimientos (Torres y Rojas, 2021).

En el periodo 1993-2020 las exportaciones totales de alimentos reportaron una evolución favorable al pasar de 3,955 a 39,525 millones de dólares. Sin embargo, debe entenderse como una situación artificial, ya que incorpora productos como la cerveza y el tequila. En contraste, las importaciones totales de alimentos mostraron una tendencia creciente en el mismo periodo de análisis al pasar de 5,713 a 27,178 millones de dólares, lo que agravó la dependencia externa y se convirtió en un factor importante de los desequilibrios, tanto de la economía como de la seguridad alimentaria interna (véase gráfica 4).

GRÁFICA 4.
México: variación en valor de las exportaciones e importaciones totales de alimentos, 1993-2020 (Millones de dólares)



Fuente: Elaboración propia con base en el BIE del INEGI.

La dependencia alimentaria externa del país también abarcó a otros productos como carnes frescas o refrigeradas, semillas de soya, cebada y algodón, además de granos básicos como el sorgo, trigo, maíz, frijol. Estos productos registran aumentos importantes en valor y volumen, pero por sus encadenamientos productivos se ha extendido hacia rubros como la carne de bovino, porcino y huevo. Si bien mejora relativamente la situación en la leche fresca, la leche en polvo ocupa los primeros lugares de dependencia (Torres y Rojas, 2021).

Durante las últimas tres décadas, la importación de alimentos representa uno de los principales problemas para la seguridad alimentaria porque su crecimiento refleja la orientación negativa tanto de las políticas de producción interna, como del efecto de las oscilaciones de precios internacionales de alimentos. El incremento en las importaciones implica transferir la demanda al exterior y constituye un freno para el crecimiento de la economía en su conjunto. El valor acumulado de las importaciones en los últimos 28 años alcanzó 489,905 millones de dólares, 17,497 millones de dólares en promedio anual, lo que representa un impacto para el balance externo si consideramos que es casi el equivalente a la renta petrolera.

En 2020 el país dependía casi en un 45% de las compras externas de alimentos. Las importaciones de granos básicos alcanzaron por si solo el 31% del consumo interno. Una situación similar ocurrió con la compra de carne de cerdo y pollo que se incrementaron 16.7% y 11.8%, respectivamente, lo que implicó destinar más de 26 mil millones de dólares al pago de las importaciones alimentarias que inhibieron un mejor desarrollo del sector y de la economía en su conjunto (Torres y Rojas, 2021).

3. Metodología para el diagnóstico de la seguridad alimentaria: una perspectiva estructural desde las asimetrías regionales

El debate conceptual actual de la seguridad alimentaria trasciende los planteamientos de organismos multilaterales de las décadas de los setenta y los ochentas, para erigirse como elemento necesario para la formulación estrategias por los gobiernos de todo el mundo, especialmente entre los que carecen de ella (Aulestia-Guerrero y Capa-Mora, 2020; Ibarrola-Rivas y Galicia, 2017; Neira, 2003; Rodríguez et al, 2016; Ruíz-Chico et al., 2017; Ruíz-Chico et al., 2019; Shamah-Levy et al., 2017).

El concepto más difundido por la Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO por sus siglas en inglés) sobre seguridad alimentaria, se enfoca al diagnóstico general de la problemática por países y las posibilidades de cobertura se mantienen como aspiración individual. Entre las recomendaciones no consideran los factores estructurales que inhiben el desempeño de las economías locales (Neira, 2003). En lo general sus estrategias son casuísticas o coyunturales.

Con base en el planteamiento de dicho organismo, el concepto de seguridad alimentaria empleado en esta investigación se refiere al acceso de todas las personas a una alimentación inocua y nutritiva que les permita llevar en todo momento una vida sana. Se integra por cuatro dimensiones: acceso, disponibilidad, estabilidad del suministro y óptima utilización biológica (FAO, 2009). Pero también por los alcances de la oferta, disponibilidad o estabilidad de alimentos adecuados, sin fluctuaciones o escasez estacional, ni restricciones de acceso a los alimentos inocuos y de calidad causados por la incapacidad financiera para adquirirlos (Clay, 2003; Ruíz-Chico et al., 2019; Salazar, 2016).

La mayoría de los diagnósticos sobre seguridad alimentaria ubican el déficit en la producción de alimentos o las desigualdades en el acceso como causales de la vulnerabilidad (Crovetto y Uauy, 2008; Rodríguez-González et al., 2015). En los últimos treinta años, las estrategias gubernamentales aplicadas en México para el tratamiento del problema se enmarcan en la política social a través de programas focalizados que buscan atenuar los efectos adversos provocados por el modelo de desarrollo económico, que afectan las condiciones alimentarias de la población y generan marginación y pobreza (CONEVAL, 2010; López y Gallardo, 2015).

Aunque el sustento de los diagnósticos representa un avance para el conocimiento sobre la problemática de la seguridad alimentaria, al incorporar el criterio de medición de la pobreza por carencia de cobertura de la Canasta Básica Alimentaria, su espectro es de todas formas limitado en términos conceptuales y metodológicos, además de que resulta insuficiente para tratar la seguridad alimentaria con sus diversas implicaciones. Medir los alcances de la seguridad alimentaria, asumiendo que esta no afecta por igual a todos los individuos en su territorio se convierte en una condición para el diagnóstico integral del problema.

Recientemente han surgido otras propuestas de medición para el diagnóstico como el Índice Global de Seguridad Alimentaria Familiar (Morón y Schejtman, 1997), o el Índice Global de Seguridad Alimentaria desarrollado por la Unidad de Inteligencia de The Economist y DuPont (2017), que incluyen también indicadores para entender sus magnitudes a partir de la prevalencia de factores de obesidad y desperdicio de alimentos, si bien todavía se presentan en cálculos agregados que no dan cuenta de las condiciones que prevalecen en escalas territoriales más pequeñas.

Más allá de las escalas agregadas, surge la necesidad de desarrollar una metodología que permita la construcción de un indicador de mayor representatividad espacial que refleje tal vulnerabilidad, tomando en cuenta la compleja recurrencia de factores de medición, la dificultad de incorporar su desagregación, su dispersión-agrupación espacial en un mismo territorio o la evolución del concepto asociado a la complejidad social.

La propuesta aquí vertida sobre medición y diagnóstico parte de la elaboración de un Índice de Seguridad Alimentaria Municipal y Regional, empleando el método de ACP, el cual permite combinar información de diversas variables en una medida única que sintetiza tres de las cuatro dimensiones asociadas a la seguridad alimentaria: acceso, disponibilidad y utilización biológica. Su representación implica la elaboración de mapas de vulnerabilidad para todo el territorio mexicano a través del método de estratificación Dalenius-Hodges, lo que puede servir para la planeación y evaluación de la política alimentaria.

Las escalas de análisis para la presente investigación son municipal y regional. Esta última parte del nivel de región media que han utilizado los Planes Estatales de Desarrollo para fines de planeación en los estados de México y agrupan al total de municipios en las 214 regiones consideradas. Su utilidad radica en identificar zonas rurales y urbanas de alta y baja especialización económica y niveles de producción, diferenciación de espacios con problemáticas comunes y heterogéneas y, además, el conocimiento sobre la magnitud de los desequilibrios internos provocados por las asimetrías del desarrollo económico. En síntesis, cuantifica la situación que guarda la seguridad alimentaria desde una dimensión regional.

Para la construcción del Índice de Seguridad Alimentaria Municipal y Regional seleccionamos indicadores que miden la situación regional de la seguridad alimentaria, más allá de escalas nacionales o estatales, ya que esta debe abordarse de acuerdo con los distintos niveles de desarrollo humano en su escala territorial y en el contexto de su desarrollo económico, atendiendo a tres de las cuatro dimensiones propuestas por la FAO antes referidas.

Debido a que el análisis de la seguridad alimentaria debe ubicarse también en una perspectiva multifactorial-territorial donde confluyen múltiples factores internos y externos que la vulneran y se manifiestan de manera asimétrica en el territorio, no es posible medirla con una sola variable. Dicha consideración llevó a la selección de 13 indicadores con información desagregada por municipio en los cinco cortes transversales temporales (2000, 2005, 2010, 2015 y 2020). Ello nos permite analizar los cambios en la situación de la seguridad alimentaria a través del comportamiento del índice en el tiempo. Otro criterio de selección radicó en que dicho periodo se sitúa en el vértice de la apertura comercial y la consolidación del modelo de desarrollo actual, donde la seguridad alimentaria presenta una dinámica distinta en comparación con las décadas previas.

A continuación, presentamos la forma de cálculo de los indicadores empleados en la construcción del índice. Si bien la clasificación responde a la propuesta de la FAO en tres de sus cuatro dimensiones, nuestra propuesta considera sus posibilidades de análisis a escala regional (véanse cuadros 1, 2 y 3):

CUADRO 1.
Indicadores de acceso económico a los alimentos

Nombre	Definición operacional	Unidad de medida	Nivel de aplicación	Fuentes de información
Producto Interno Bruto Per Cápita	[PIB municipal[1] / Población municipal]	Millones de pesos (2013=100)	Municipal	Sánchez (2021)
	[PIB por Región Media / Población por Región Media]		Región Media	
Porcentaje de población en situación de pobreza alimentaria	[Personas en pobreza alimentaria[2] por municipio / Población total por municipio] * 100	Porcentaje	Municipal	CONEVAL (2017; 2021)
	[Personas en pobreza alimentaria por Región Media / Población total por Región Media] * 100		Región Media	INEGI (2000; 2005; 2010a; 2015;2020)

Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SIAP-SADER).

CUADRO 2.
Indicadores de disponibilidad de alimentos

Nombre	Definición operacional	Unidad de medida	Nivel de aplicación	Fuentes de información
Porcentaje de suficiencia de granos básicos: arroz, frijol, maíz, trigo	[Disponibilidad Municipal (producción/población) / Consumo Municipal (consumo per cápita*población)] * 100	Porcentaje	Municipal	Sistema de Información Agroalimentaria y Pesquera (SIAP-SADER)
	[Disponibilidad por Región Media (producción/población) / Consumo por Región Media (consumo per cápita*población)] * 100		Región Media	INEGI (2000; 2005; 2010a; 2015;2020)
Porcentaje de suficiencia de carnes: bovino, porcino, ave	[Disponibilidad Municipal (producción/población) / Consumo Municipal (consumo per cápita*población)] * 100	Porcentaje	Municipal	Sistema de Información Agroalimentaria y Pesquera de la Secretaria de Agricultura y Desarrollo Rural (SADER)
	[Disponibilidad por Región Media (producción/población) / Consumo por Región Media (consumo per cápita*población)] * 100		Región Media	INEGI (2000; 2005; 2010a; 2015; 2020)

Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

[1] Los cálculos provienen de Sánchez (2021).
[2] Las cifras de los años 2000, 2005 y 2010 se tomaron de la variable pobreza alimentaria de la metodología de la pobreza por ingreso. La cifra para el año 2015 corresponde a la variable de "Población con ingreso inferior a la línea de bienestar mínimo" de la metodología de pobreza multidimensional. Para 2020 se considera Coneval (2021).

Cuadro 3.
Indicadores de utilización biológica de alimentos

Nombre	Definición operacional	Unidad de medida	Nivel de aplicación	Fuentes de información
Porcentaje de prevalencia de talla baja en niños de primer año de primaria	Talla baja < 2σ	Porcentaje[3]	Municipal	DIF–SEP–INCMNSZ (1994; 1997; 2004); DIF–SEP–SSA–INCMNSZ (2006); Ávila A, Juárez-Martínez L, Del Monte-Vega M, Ávila Arcos MA, Galindo-Gómez C, Ambrocio-Hernández R (2016)[4]
	Talla baja < 2σ		Región Media	
Porcentaje de población de 15 años y más analfabeta	[Población de 15 años y más analfabeta por Municipio / Población total de 15 años por Municipio] * 100	Porcentaje	Municipal	INEGI (2000; 2005; 2010a; 2015; 2020)
	[Población de 15 años y más analfabeta por Región Media / Población total de 15 años por Región Media] * 100		Región Media	
Porcentaje de población derechohabiente a servicios de salud en el IMSS	[Población derechohabiente al IMSS por Municipio / Población total por Municipio] * 100	Porcentaje	Municipal	INEGI (2000; 2005; 2010a; 2015; 2020)
	[Población derechohabiente al IMSS por Región Media / Población total por Región Media] * 100		Región Media	
Porcentaje de viviendas con piso de tierra	[Viviendas con piso de tierra por Municipio / Total de viviendas particulares habitadas por Municipio] * 100	Porcentaje	Municipal	INEGI (2000; 2005; 2010a; 2015; 2020)

[3] Las cifras de Prevalencia de talla baja por municipio se presentan en porcentaje. Para el caso de Región Media, se obtiene el valor promedio del conjunto de municipios que la integran (se presentan en porcentaje).
[4] Debido a que los puntos de interés son los años 2000, 2005, 2010, 2015 y 2020, se realizó una interpolación lineal con los datos de Prevalencia de talla baja en niños de primer grado de primaria en cada uno de los municipios a partir de los datos reportados en 1994, 1999, 2004 y 2016. Se utilizan dos pendientes para estas interpolaciones: 1) una pendiente constante entre los años 1999 y 2004; y 2) una pendiente constante entre los años 2004 y 2016. Esta última pendiente constante se empleó para efectuar una extrapolación lineal y obtener el valor de 2020.

CUADRO 3. CONT.
Indicadores de utilización biológica de alimentos

Nombre	Definición operacional	Unidad de medida	Nivel de aplicación	Fuentes de información
	[Viviendas con piso de tierra por Región Media / Total de viviendas particulares habitadas por Región Media] * 100		Región Media	
Porcentaje de viviendas que no disponen de drenaje	[Viviendas que no disponen de drenaje por Municipio / Total de viviendas particulares habitadas por Municipio] * 100	Porcentaje	Municipal	INEGI (2000; 2005; 2010a; 2015; 2020)
	[Viviendas que no disponen de drenaje por Región Media / Total de viviendas particulares habitadas por Región Media] * 100		Región Media	
Porcentaje de viviendas que no disponen de excusado o sanitario	[Viviendas particulares habitadas sin excusado o sanitario por Municipio / Total de viviendas particulares habitadas por Municipio] * 100	Porcentaje	Municipal	INEGI (2000; 2005; 2010a; 2015; 2020)
	[Viviendas particulares habitadas sin excusado o sanitario por Región Media / Total de viviendas particulares habitadas por Región Media] * 100		Región Media	
Porcentaje de viviendas que no disponen de agua entubada de la red pública	[Viviendas sin agua entubada por Municipio / Total de viviendas particulares habitadas por Municipio] * 100	Porcentaje	Municipal	INEGI (2000; 2005; 2010a; 2015; 2020)
	[Viviendas sin agua entubada por Región Media / Total de viviendas particulares habitadas por Región Media] * 100		Región Media	
Porcentaje de viviendas que no disponen de electricidad	[Viviendas sin electricidad por Municipio / Total de viviendas particulares habitadas por Municipio] * 100	Porcentaje	Municipal	INEGI (2000; 2005; 2010a; 2015; 2020)

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CUADRO 3. CONT.
Indicadores de utilización biológica de alimentos

Nombre	Definición operacional	Unidad de medida	Nivel de aplicación	Fuentes de información
	[Viviendas sin electricidad por Región Media / Total de viviendas particulares habitadas por Región Media] * 100		Región Media	
Porcentaje de viviendas que no disponen de refrigerador	[Viviendas sin refrigerador por Municipio / Total de viviendas particulares habitadas por Municipio] * 100	Porcentaje	Municipal	INEGI (2000; 2005; 2010a; 2015; 2020)
	[Viviendas sin refrigerador por Región Media / Total de viviendas particulares habitadas por Región Media] * 100		Región Media	

Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

Una vez realizado el cálculo, recurrimos al ACP para la construcción del Índice de Seguridad Alimentaria Municipal y Regional. Esta técnica de estadística permite obtener una unidad de medida sintética para evaluar el impacto global de un conjunto de variables, conservando al máximo la información que cada una de ellas aporta al conjunto (Hair et al. 2014). Para ello, se consideró el total de municipios del país para cada corte transversal temporal: 2443 en el año 2000; 2454 en 2005; 2456 en 2010; 2457 en 2015; y 2469 en 2020. Se mantuvo la clasificación de 214 regiones medias, haciendo consistente el análisis independientemente de la incorporación de nuevos municipios.

Para obtener el índice, se construyó una base de datos que incluye la información de los indicadores seleccionados en los municipios donde se aplicó el ACP. El primer paso consistió en estandarizar los indicadores a fin de hacerlos comparables, es decir, homogeneizar las disparidades de longitud, promedio y desviación. En el arreglo matricial, cada municipio o región media, dependiendo de la escala, representa un caso observado y ocupa un renglón. En las columnas de cada renglón aparecen los valores de los 13 indicadores.

Para el Índice de Seguridad Alimentaria por Región Media[5], la estandarización se efectuó mediante la fórmula: $Z_{i,j} = \frac{I_{i,j}-I_j}{ds_j}$, donde:

$Z_{i,j}$: es el indicador j estandarizado de la región media i,

$I_{i,j}$: es el indicador socioeconómico j de la región media i,

$\underline{I}_j$: es el promedio aritmético de los valores del indicador j, y

ds_j: es la desviación estándar insesgada del indicador j,

Como resultado se obtuvo la matriz estandarizada de indicadores:

$$z = \left[z_{1,1}\ z_{1,2}\ \dots\ z_{1,13}\ z_{2,1}\ z_{2,2}\ \cdots\ z_{2,13}\ \vdots \vdots \vdots \vdots\ z_{n,1}\ z_{n,2}\ \cdots\ z_{n,13} \right]$$

Posteriormente, a partir de Z, se construyó la matriz de correlaciones, la cual muestra la relación existente entre los indicadores y las nuevas variables; sus valores oscilan entre 0 y 1.

$$Corr: \left[1_{1,1}\ q_{1,2}\ \dots\ q_{13,1}\ q_{1,2}\ 1_{2,2}\ \cdots\ q_{13,2}\ \vdots \vdots \vdots \vdots\ q_{13,1}\ q_{13,2}\ \cdots\ 1_{13,13} \right]$$

De esta matriz, se obtuvieron los valores propios $\omega_{1,k}$ para cada uno (las letras minúsculas w expresan un vector k con peso para cada indicador). Posteriormente, establecimos un orden jerárquico:

$$\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq \lambda_4 \geq \lambda_5 \geq \lambda_6 \geq \lambda_7 \geq \lambda_8 \geq \lambda_9 \geq \lambda_{10} \geq \lambda_{11} \geq \lambda_{12} \geq \lambda_{13} > 0.$$

A partir de los valores propios se consiguieron los vectores propios o componentes:

$$y_1 = \omega_{1,1} z_1 + \omega_{1,2} z_2 + \dots + \omega_{1,13} z_{13}\ y_2 = \omega_{2,1} z_1 + \omega_{2,2} z_2 + \dots + \omega_{2,13} z_{13}\ \vdots\ y_{13} = \omega_{13,1} z_1 + z_{13,2} z_2 + \dots + \omega_{13,13} z_{13}$$

En función de lo anterior, se pondera la importancia de cada componente por la proporción que representa del total, es decir, por la varianza explicada. Finalmente, para la construcción del índice, el primer vector propio se multiplica por la matriz: $\underline{\omega}'_{1*}\underline{z}$.

Al índice elaborado mediante ACP, se aplicó el método de estratificación Dalenius-Hodges para determinar los rangos de seguridad alimentaria por municipio y región media, los cuales se categorizaron en: seguridad alimentaria, inseguridad alimentaria leve, inseguridad alimentaria moderada e inseguridad alimentaria severa. De acuerdo con la metodología (INEGI, 2010b), para la conformación de estratos,

[5] Este procedimiento se replicó para la construcción del Índice de Seguridad Alimentaria Municipal.

sean N el número de observaciones y L el número de estratos se ordenaron las observaciones de manera ascendente, para agruparlas después en J clases, donde J=min(L*10, n). Una vez obtenidas las clases, calculamos los límites para cada una de la siguiente manera:

$$Ck = \{X(i)\} + (k-1) * \frac{\{X(i)\} - min\,\{X(i)\}}{J}$$

$$Ck = \{X(i)\} + (k) * \frac{\{X(i)\} - min\,\{X(i)\}}{J}$$

A partir de dichos límites, se obtuvo la frecuencia de casos en cada clase *fi (i*= 1, …, *J)*; después, se calculó la raíz cuadrada de la frecuencia de cada clase y luego se acumuló la suma de la raíz cuadrada de las frecuencias, es decir:

$$Ci = \sum_{h=1}^{i} \sqrt{fh}(i = 1, \dots, J)$$

Se dividió el ultimo valor acumulado entre el número de estratos: $Q = \frac{1}{L}Cj$. Los puntos de corte de cada estrato los tomamos sobre el acumulado de la raíz cuadrada de las frecuencias en cada clase de acuerdo a lo siguiente: *Q, 2Q, …, (h – 1) Q*. El criterio consistió en que si el valor Q quedaba entre dos clases se toma como punto de corte la clase que presente la misma distancia a *Q*. Finalmente, los límites de los *h* estratos conformados serían los correspondientes a los límites inferior y superior de las clases comprendidas en cada estrato.

Los resultados obtenidos de la aplicación del método de ACP y de la estratificación de Dalenius-Hodges a los valores del Índice de Seguridad Alimentaria Municipal y de Región Media se presentan a continuación.

4. Dimensiones de la seguridad alimentaria como problema estructural del desarrollo en México: un enfoque regional

Los resultados obtenidos muestran que, del total de municipios delimitados administrativamente al inicio del periodo referido, sólo el 25.2% de ellos alcanzaron el rango de seguridad alimentaria y 18.7% se ubicaron en inseguridad alimentaria severa, 29.5% en inseguridad alimentaria leve y 26.6% en inseguridad alimentaria moderada. Sin embargo, esta condición de rezago debido a problemas estructurales dentro del modelo de desarrollo económico, se profundizó a partir del 2020 a causa de la crisis económica generada por el coronavirus SARS-Cov2 (COVID-19): el número de municipios en seguridad alimentaria disminuyó a 311, lo que representa una pérdida de 304 municipios en esta condición respecto al 2000; sin embargo, el número aumentó a 932 en inseguridad alimentaria severa, por lo que las condiciones críticas de la seguridad alimentaria se incrementaron incluso de manera proporcional (véase tabla 1).

Según nuestros resultados, la población en situación de seguridad alimentaria localizada en los municipios se incrementó en más de tres millones en términos absolutos, en términos porcentuales se contrajo 12.2%, al pasar de 65.7% a 53.5%. En contraste, la población con algún grado de inseguridad alimentaria aumentó en esa misma proporción, aunque destaca el crecimiento del estrato de población en inseguridad alimentaria severa, el cual aumentó 5.1% al pasar de 5.3% a 10.4% en el periodo (véase tabla 2).

Tabla 1.
México: municipios y su situación de seguridad alimentaria, 2000-2020 (Número y porcentaje)

Grado de (in)seguridad alimentaria / Año	2000		2005		2010		2015		2020	
	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)
Seguridad alimentaria	615	25,2	520	21,2	579	23,6	556	22,6	311	12,6
Inseguridad alimentaria leve	720	29,5	894	36,4	848	34,5	873	35,5	571	23,3
Inseguridad alimentaria moderada	651	26,6	683	27,8	549	22,4	702	28,6	655	26,5
Inseguridad alimentaria severa	457	18,7	357	14,5	480	19,5	326	13,3	932	37,6
Total	2443	100	2454	100	2456	100	2457	100	2469	100

Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

Tabla 2.
México: población total por municipios y su situación de seguridad alimentaria 2000-2020 (Número y porcentaje)

Grado de (in)seguridad alimentaria / Año	2000		2005		2010		2015		2020	
	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)
Seguridad alimentaria	64,086,651	65,7	65,667,305	63,6	71,631,313	63,8	77,487,069	64,8	67,381,107	53,5
Inseguridad alimentaria leve	18,327,672	18,8	22,806,819	22,1	25,178,142	22,4	26,943,191	22,5	27,992,305	22,2
Inseguridad alimentaria moderada	9,946,671	10,2	10,562,125	10,2	9,560,558	8,5	10,998,189	9,2	17,538,894	13,9
Inseguridad alimentaria severa	5,122,418	5,3	4,227,139	4,1	5,966,525	5,3	4,102,304	3,4	13,107,718	10,4
Total	97,483,412	100	103,263,388	100	112,336,538	100	119,530,753	100	126,014,024	100

Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

Tabla 3.
México: regiones medias y su situación de seguridad alimentaria, 2000-2020 (Número y porcentaje)

Grado de (in)seguridad alimentaria / Año	2000		2005		2010		2015		2020	
	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)
Seguridad alimentaria	59	27,6	63	29,4	63	29,4	43	20,1	37	17,3
Inseguridad alimentaria leve	64	29,9	61	28,5	66	30,8	84	39,3	67	31,3
Inseguridad alimentaria moderada	54	25,2	55	25,7	53	24,8	56	26,2	59	27,6
Inseguridad alimentaria severa	37	17,3	35	16,4	32	15	31	14,5	51	23,8
Total	214	100	214	100	214	100	214	100	214	100

Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

Tabla 4.
México: población total por regiones medias y su situación de seguridad alimentaria 2000-2020 (Personas y porcentaje)

Grado de (in)seguridad alimentaria / Año	2000		2005		2010		2015		2020	
	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)	Absoluto	(%)
Seguridad alimentaria	48,821,787	50,1	53,478,742	51,8	60,624,800	54	49,127,255	41,1	47,437,538	37,6
Inseguridad alimentaria leve	20,993,339	21,5	21,760,223	21,1	23,446,870	20,9	40,592,943	34	38,040,216	30,2
Inseguridad alimentaria moderada	16,877,439	17,3	18,096,208	17,5	18,502,794	16,5	19,604,940	16,4	23,784,806	18,9
Inseguridad alimentaria severa	10,790,847	11,1	9,928,215	9,6	9,762,074	8,7	10,205,615	8,5	16,751,464	13,3
Total	97,483,412	100	103,263,388	100	112,336,538	100	119,530,753	100	124,025,545	100

Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

Una explicación sobre las desigualdades encontradas, es que 70% de la población nacional se localiza ya en zonas urbanas y más del 60% en zonas metropolitanas las cuales, además de conservar su rango de municipio, se expanden a través de un proceso de conurbación dinámico hacia otro gran número de municipios (INEGI, 2021). Como la alimentación en las ciudades resulta por lo regular de mayor calidad y diversificación, independientemente de su heterogeneidad en los niveles sociales, esto ayuda al mejoramiento de los promedios generales, pero esconde la situación real de la desigualdad en la medida que la población pobre que cambió de ubicación territorial mantiene en lo general, los mismos niveles de inseguridad.

Por ese rezago estructural en la relación población-municipio en inseguridad alimentaria severa, inferimos que la marginación y los niveles de vulnerabilidad alimentaria están aún muy lejos de superarse y más bien se agudizaran ante fenómenos coyunturales e inesperados como las pandemias.

En igual sentido, estos resultados municipales no varían significativamente con respecto a la escala regional. En el año 2000, es decir al inicio del periodo analizado, se registraron 59 regiones medias con una cobertura adecuada de su seguridad alimentaria, además de que observaron un relativo incremento en número que se mantuvo en los años 2005 y 2010, pero que disminuyó hasta 43 en 2015, consecuencia de las secuelas de la crisis económica y alimentaria de 2008. Para el año 2020, únicamente 37 regiones alcanzaron esta condición.

En dirección contraria, pero complementaria a la explicación anterior, las 64 regiones medias que al inicio del periodo observaron inseguridad alimentaria leve y habían disminuido a 61 en el año 2005, comenzaron a registrar, con 66, un claro repunte en el año 2010, que se disparó hasta 84 en el año 2015 aunque volvió a bajar a 67 en el año 2020. Las ubicadas en inseguridad alimentaria moderada aumentaron en cinco unidades al pasar de 54 en el año 2000 a 59 al final del periodo (véase tabla 3).

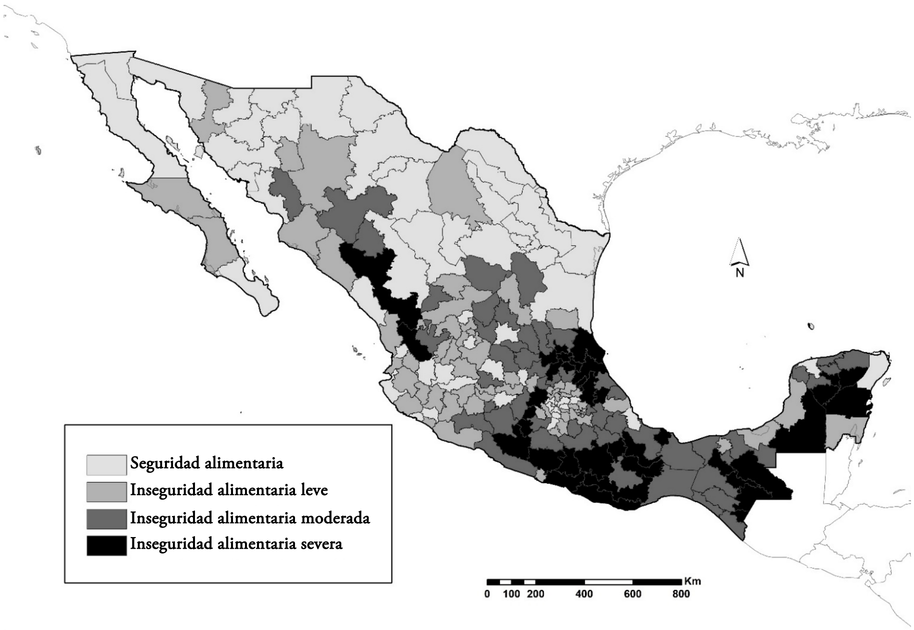
En el caso de las regiones medias ubicadas en el rango de inseguridad alimentaria severa, donde se concentra la población más marginada y en un espacio cercano a los niveles del hambre o en pobreza extrema según otras mediciones, encontramos que su número aumentó notablemente. De las 37 que se registraron en el año 2000, aumentaron a 51 en el año 2020, lo que expresa el deterioro estructural en las condiciones de reproducción de la sociedad que se agudizaron en el contexto de la pandemia COVID19 (Ver mapas 1, 2, 3, 4 y 5).

Otra explicación válida para entender las asimetrías regionales de la seguridad alimentaria en México se desprende de que las dinámicas de movilidad de la población rural, sobre todo hacia Estados Unidos que también se reconcentraron en centros urbanos del país, permitieron que la población en condición de inseguridad alimentaria severa no fuera contabilizada en esas regiones sino en otras. Asimismo, el mejoramiento del envío de remesas que se destinan casi en 80% al consumo, donde la mayor parte se ocupa para comprar alimentos, ayudaron a una mejor estabilidad y nivel de consumo entre familias y comunidades pobres, aunque no revirtió esa tendencia estructural al deterioro constante.

Asimismo, los programas de atención social instaurados desde los años noventa del siglo pasado que buscaban aliviar temporalmente el problema de la accesibilidad a través de transferencias monetarias directas a las personas, tuvieron por igual un efecto importante. Sin embargo, al carecer de un componente para activar la producción interna y el autoconsumo entre la población pobre dentro del modelo económico seguido que supere las condiciones coyunturales y ubique la solución de problemas estructurales, no evitaron que la inseguridad alimentaria se incremente de una región a otra.

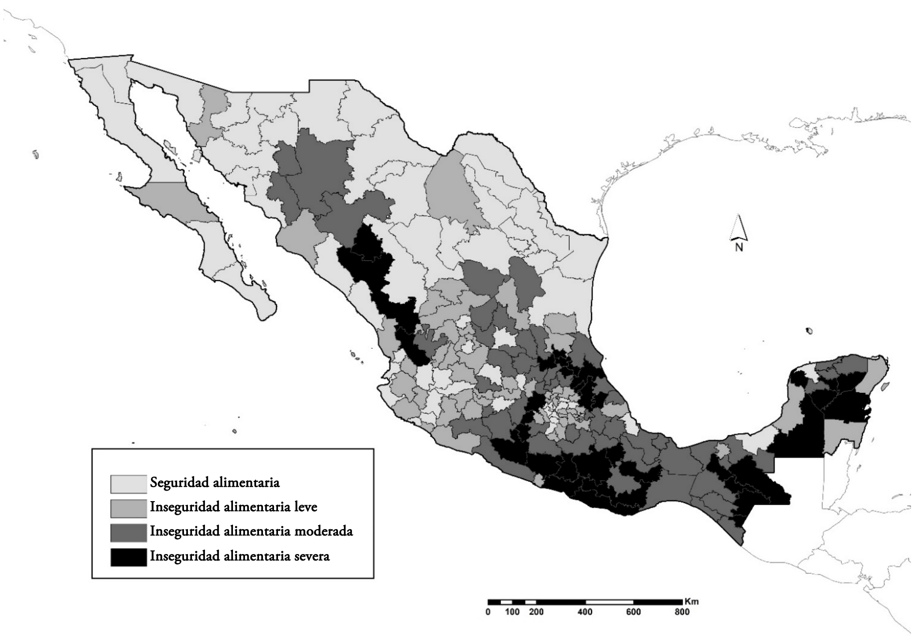
Prueba de ello es que el estado de Oaxaca no registró mejoría en todo el periodo, solo dos de sus regiones medias alcanzaron el nivel de inseguridad alimentaria moderada, mientras que seis de ellas nunca rebasaron el rango de inseguridad alimentaria severa; este es el mismo caso de Chiapas con tres y seis en ambos casos, o Guerrero con tres y cuatro del total. Una situación similar correspondería al Estado de Yucatán con una región en inseguridad alimentaria leve, dos en moderada y seis en severa.

Mapa 1.
México: regiones medias y su situación de seguridad alimentaria, 2000



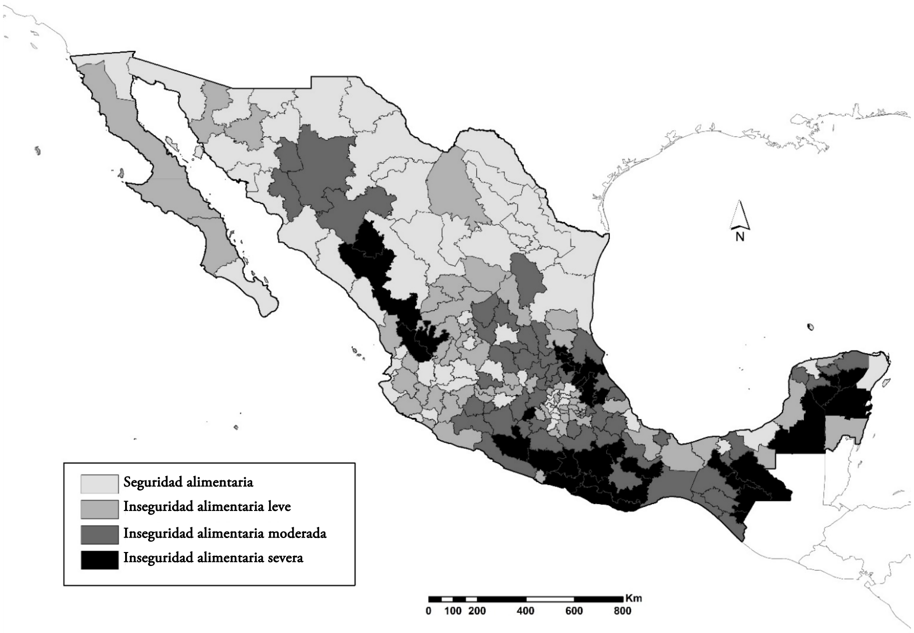
Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

Mapa 2.
México: regiones medias y su situación de seguridad alimentaria, 2005



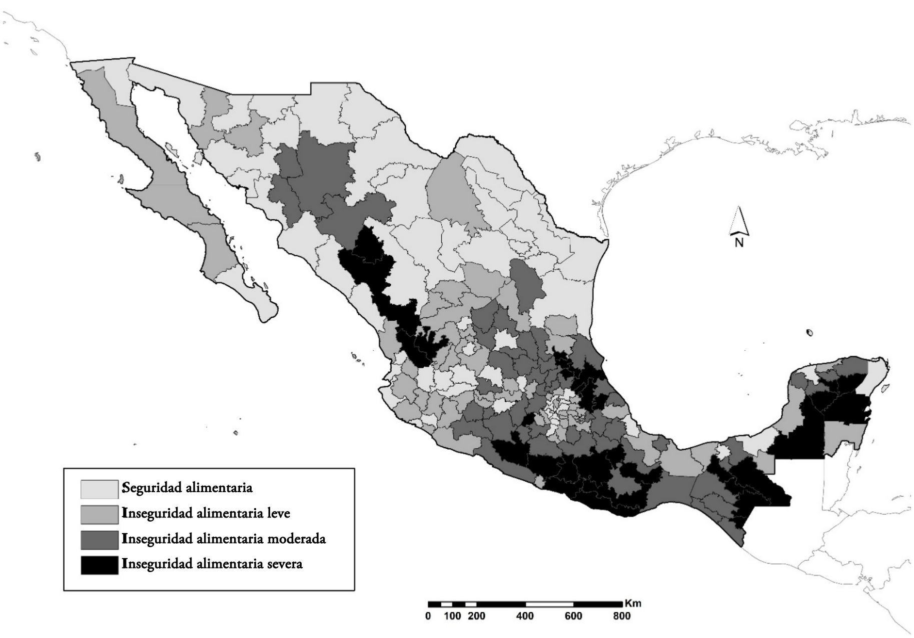
Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

Mapa 3.
México: regiones medias y su situación de seguridad alimentaria, 2010



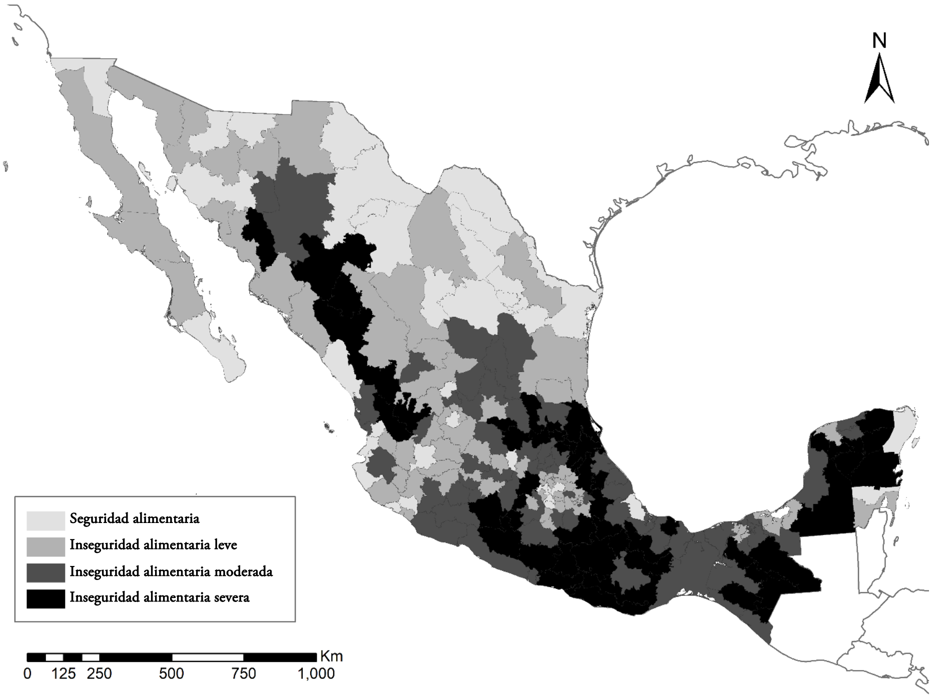
Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

Mapa 4.
México: regiones medias y su situación de seguridad alimentaria, 2015



Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

Mapa 5.
México: regiones medias y su situación de seguridad alimentaria, 2020



Fuente: Elaboración propia con base en Ávila et al. (2016), CONEVAL (2017; 2021), DIF–SEP–INCMNSZ (1994; 1997; 2004), DIF–SEP–SSA–INCMNSZ (2006), INEGI (2000; 2005; 2010a; 2015;2020), Sánchez (2021) y Sistema de Información Agroalimentaria y Pesquera (SADER).

Por su parte, también los estados de Durango y Tabasco presentan una condición semejante al registrar cada uno cuatro regiones en inseguridad alimentaria severa, aunque cabe destacar que en esta primera entidad se ubicó una región en el rango de inseguridad alimentaria leve. Una situación más grave se presenta en Hidalgo, donde seis regiones se ubican en el rango de seguridad alimentaria severa, mientras que en los estratos de moderada y leve se registran dos y una, respectivamente. El estado de Guanajuato, sin alcanzar condiciones óptimas, de sus seis regiones, dos se ubican en inseguridad alimentaria leve, tres en inseguridad alimentaria moderada y una en inseguridad alimentaria severa; un nivel similar se manifiesta en las regiones medias de Tlaxcala.

Un hecho preocupante es que la connotación del deterioro de las condiciones alimentarias en su vertiente territorial, refleja también cómo esta afecta cada vez más a las capas medias de la población, las cuales pierden su ubicación en el rango de seguridad alimentaria, para transitar en el de inseguridad alimentaria leve o inseguridad alimentaria moderada. Este deterioro inhibe las posibilidades presentes y futuras de alcanzar mejores niveles de desarrollo en un ambiente económico competitivo mundial, dado que disminuye con la calidad de su alimentación.

Una constante en los resultados de estudios precedentes y que se repite en el que aquí presentamos, es que la mayor parte de las regiones medias ubicadas en el rango de seguridad alimentaria se localizan en el Norte del país, algunos del Centro, o bien en Estados que no corresponden a esta categoría como conjuntos, pero integran zonas específicas de alto desarrollo turístico o industrial.

Así, por ejemplo, en Baja California y Baja California Sur, las regiones que mantuvieron esa condición óptima en el año 2000 fueron: Tijuana-Tecate, Ensenada, Loreto Comondú y la Paz; en cambio para el año 2020 solo Tijuana-Tecate y la Paz la conservaron. Una situación parecida observamos para el caso de Sonora ya que en el año 2000 registró con el rango de seguridad alimentaria a regiones como Desierto de Sonora, Hermosillo Centro, Guaymas Empalme, Yaqui Mayo, Frontera Centro, Rio Sonora San Miguel, Frontera Norte y Sierra Alta. Sin embargo, la tendencia fue hacia el deterioro ya que solo se conservaron Hermosillo Centro, Frontera Centro y Frontera Norte.

Es importante destacar, como constante de los cambios de rango de la seguridad alimentaria hacia una peor condición que, en el caso del Estado de México, de las regiones medias que se integran principalmente con los municipios conurbados a la Ciudad de México y que en el año 2000 se ubicaron en el rango más alto como Cuautitlán Izcalli, Tlalnepantla, Tultitlán, Ecatepec, Naucalpan, Nezahualcóyotl y Texcoco, estos tres últimos perdieron ese nivel en el año 2020, si bien las alcaldías que corresponden a la actual Ciudad de México, lo conservaron en todo el periodo.

Resulta también de interés que algunas de las regiones medias ubicadas para el año 2000 en entidades federativas consideradas como las más rezagadas: Región XI Apan (Hidalgo), Metropolitana (Yucatán) y Caribe Norte (Quintana Roo), sólo esta última se mantuvo. Estos cambios han provocado que poco más de un millón de mexicanos perdieran su ubicación en el rango de seguridad alimentaria. Con ello se infiere que transitaron hacia inseguridad alimentaria leve o inseguridad alimentaria moderada y que lleva a un paulatino deterioro en la calidad de la alimentación del país.

Lo anterior refuerza nuevamente la tesis de que los rezago existentes en la inseguridad alimentaria interna, obedecen más bien a un problema estructural del desarrollo económico que mantiene e incluso tiende a profundizar las desigualdades, las cuales pueden deslocalizarse cíclicamente en términos regionales, pero deja intacto el problema en la medida que reproduce la pobreza y no resuelve otros factores de rezago en la producción y estabilidad agroalimentaria a partir de la dependencia también estructural del sector.

Por ello, de las 37 regiones medias encontradas en inseguridad alimentaria severa para el año 2000, éstas disminuyeron a 31 en el año 2015, pero repuntaron a 51 en el año 2020. De estas últimas, Chihuahua (Región III Parral), Nayarit (Sierra Nayarit) y Jalisco (Norte Jalisco) registraron una; Durango registró dos (Quebradas y Sierra Durango); Estado de México tres (Valle de Bravo, Tejupilco y Atlacomulco); San Luis Potosí contabilizó cuatro (Centro Sur San Luis Potosí, Media Este, Huasteca Centro y Huasteca Sur); el resto se localizan en las entidades más pobres del país, mismas que se han mantenido a lo largo del tiempo.

Aunque la unidad de medición en nuestro análisis es la región media, no podemos considerar esos resultados regionales al margen de la población que se localiza en ellas. La proporción porcentual entre regiones medias y número de habitantes para los distintos rangos de seguridad alimentaria puede ser diferente en magnitud, aunque presente la misma dinámica de comportamiento en el tiempo. Una evidencia es que el número absoluto de población en una mejor o peor condición casi no cambia durante el periodo analizado, pero se manifiesta un incremento proporcional con la que se ubica en condiciones peores de manera constante en relación con la población total del país. Reiteramos, el problema de la seguridad alimentaria permanece enraizado como problema estructural del desarrollo en México.

Si se analizan esas regiones de acuerdo con sus niveles de concentración de población, se obtiene que el estado de inseguridad alimentaria en zonas rurales críticas se dispersa hacia grandes concentraciones de población, de tal manera que se infiere una disminución en los niveles de seguridad alimentaria de éstas, aunque no impacten claramente en sus rangos debido a que las personas trasladan inseguridad alimentaria hacia otras localizaciones regionales.

Al ubicar las regiones medias de acuerdo con su tamaño de población, se observa que, en el periodo 2000-2020, el porcentaje de mexicanos que alcanzan el rango de seguridad alimentaria se contrajo 12.5%, al pasar de 50.1% a 37.6%. La misma dinámica se presentó en términos absolutos, ya que el número de personas en esta condición disminuyó en 1.3 millones, con lo que más de la mitad de los mexicanos presenta algún grado de inseguridad alimentaria (véase tabla 4).

De esa manera, los resultados muestran que, por el tamaño de los estratos ubicados en inseguridad alimentaria, estos absorbieron prácticamente a todo el incremento demográfico alcanzado en el lapso. Este fenómeno obedece fundamentalmente al deterioro en las condiciones de vida de las personas, a la baja observada en la producción de alimentos, al éxodo campesino y al detrimento en la situación nutrimental y de salud, además del impacto de la pandemia por COVID-19.

La población ubicada en inseguridad alimentaria leve aumentó 17.1 millones de personas, lo que significó en términos porcentuales un incremento de 21.5 a 30.2%, respecto a la población total. En el caso de la inseguridad alimentaria moderada, la población ubicada en este estrato registró la misma dinámica al aumentar de 16.8 a 23.7 millones de personas, aunque en términos relativos se incrementó marginalmente de 17.3 a 18.9% en el mismo periodo.

Finalmente, la población situada en inseguridad alimentaria severa empeoró su situación. Al inicio del periodo, 10.7 millones de personas padecieron esta condición, lo cual se redujo a 9.7 millones en 2010, sin embargo, repuntaron a 10.2 millones en el año 2015 y alcanzó su máximo en 2020 con 16.7 millones. La proporción aumentó, en este último caso, del 11.1% a 13.3%. Vale señalar que lo que se incrementó realmente fueron las cantidades de los consumos de manera temporal y no de cobertura de la seguridad alimentaria, debido a que la producción regional de alimentos no mejoró y menos con ello la complementariedad de suministros por autoabasto entre la población rural que antes tenía esta posibilidad. De cualquier forma, lo más importante es que visto por el lado del número de regiones o del tamaño de la población, más de la mitad de los mexicanos enfrenta actualmente algún grado de inseguridad alimentaria.

5. Conclusiones

Los resultados en materia alimentaria en el periodo establecido en México que coinciden con el avance de la apertura comercial, han sido la crisis y estancamiento del sector agropecuario y de toda la estructura de la economía interna. El desmantelamiento de la base campesina y crecimiento de la migración rural, la perdida de la autosuficiencia alimentaria y la mayor dependencia de las importaciones de alimentos, el saldo deficitario estructural de las cuentas externas agroalimentarias así como un déficit en la balanza comercial, acompañados de los bajos niveles de crecimiento de la economía nacional, las caídas del salario y del poder adquisitivo, la contracción en el nivel de empleo, el repunte de la pobreza, pero principalmente una permanente vulnerabilidad alimentaria que se manifiesta de manera diferenciada en el territorio nacional, destacan entre los factores relevantes que han llevado a un deterioro de la seguridad alimentaria interna.

En el periodo analizado, encontramos en México una pérdida gradual de la seguridad alimentaria, que se expresa en que un mayor número de municipios y regiones pasen claramente a una situación de inseguridad alimentaria en el tiempo, lo mismo que a un incremento notorio de la población en esa misma condición. Esto también es reflejo del fracaso en el tratamiento de la pobreza, misma que se está incrementando a partir de la pandemia del COVID-19. De esa manera, los niveles nutricionales en los estratos de la población pobre resultan críticos y con posibilidades reales de pasar a una situación de hambruna.

El reto para la seguridad alimentaria en México, visto por el acceso, pero extensivo a la producción agropecuaria, consiste en producir alimentos suficientes a bajo costo, garantizar el abasto y la obtención de los mismos, preservar el medio ambiente mediante esquemas productivos óptimos de aprovechamiento de los recursos, para evitar estallidos sociales regionales, mediante la generación de empleo directo en el campo, garantizando niveles de certeza en la posesión de la tierra, una diseminación regional del crédito agrícola en la producción de básicos y medidas proteccionistas temporales y diferenciadas en los precios que frenen el embate de la apertura comercial sobre esquemas no competitivos como el nuestro.

Para ello, el Estado mexicano debe transformar la política económica mediante el impulso a la autosuficiencia y soberanía en alimentos estratégicos, la diversificación de las exportaciones que reduzcan la dependencia, sobre todo con Estados Unidos, y fortalecer la producción interna de granos básicos; además, incrementar el crédito y mejorar los precios a los pequeños productores, aumentar la inversión en infraestructura agrícola, y diseñar una política agroalimentaria que asuma la seguridad alimentaria como una condición básica para la seguridad nacional.

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Articles

Resource use efficiency level of public organizations. The case of Spanish health systems

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Abstract:

Objectives: This paper seeks to detect, in the Spanish health system, which health services are efficient, and which are not, as well as propose corrective measures that allow inefficient health services to achieve efficiency. Methods: This paper applies the Data Envelopment Analysis (DEA) methodology, which allows obtaining natural and managerial efficiencies, as well as deviations from inefficient units in relation to efficient ones and proposing corrective measures that imply only budgetary (natural) modifications or changes in the policies of resource management (management).

Results: Through the efficiencies, or the lack of them, the health services of the 17 Spanish autonomous communities are classified into four groups: With high, medium-high, medium-low or low natural or managerial efficiency.

Conclusions: The lack of natural efficiency can be corrected with a greater budgetary endowment and the lack of managerial efficiency with a budget cut and changes in resource management policies. This tendency contrary to the adjustments is precisely what gives this work of interest and novelty with respect to others that apply the DEA in different sectors such as those that study the impact on the environment of resource consumption. Another important aspect of this study is the possibility of applying it to other countries with similar political structures.

Keywords: Data envelopment analysis; natural efficiency; managerial efficiency; cluster analysis; Spanish Health System.
JEL Classification: C4; C5; C6.

Nivel de eficiencia del uso de recursos por las organizaciones públicas. Caso: Sistemas Sanitarios Españoles

Resumen:

Objetivos: Con este trabajo se persigue detectar, en el sistema sanitario español, que servicios sanitarios son eficientes y cuáles no, así como proponer medidas correctoras que permitan a los servicios sanitarios ineficientes alcanzar la eficiencia.

Metodología: Este trabajo aplica la metodología del análisis envolvente de datos (DEA), que permite obtener las eficiencias natural y gerencial, así como las desviaciones de las unidades ineficientes con relación a las eficientes, y proponer medidas correctoras que impliquen únicamente modificaciones presupuestarias (natural) o cambios en las políticas de gestión de recursos (gerencial).

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Resultados: A través de las eficiencias, o la falta de ellas, los servicios sanitarios de las 17 comunidades autónomas españolas se clasifican en cuatro grupos: Con eficiencia natural o gerencial alta, media-alta, media-baja o baja.
Conclusiones: La falta de eficiencia natural puede corregirse con una mayor dotación presupuestaria, la falta de eficiencia gerencial con un recorte presupuestario y cambios en las políticas de gestión de recursos. Esta tendencia contraria de los ajustes es precisamente la que dota este trabajo del interés y novedad con respectos a otros que aplican el DEA en sectores diferentes como aquellos que estudian el impacto en el medioambiente de los consumos de recursos. Otro aspecto importante de este estudio es la posibilidad de aplicarlo a otros países con estructuras políticas similares.

Palabras clave: Análisis envolvente de datos; eficiencia natural; eficiencia gerencial; análisis clúster; Sistema Nacional de Salud.

Clasificación JEL: C4; C5; C6.

1. Introduction

Throughout history, public participation in the various economic sectors has been a bone of contention argued over by the supporters of public ownership and the free market. Despite of this, public participation in some specific economic sectors such as health has become a fundamental premise in developed States, and this sparks further debate on the suitability of the public sector's breadth of intervention or investment.

In the case of public administrations, once public resources have been allocated, the estimated amount of revenue places a limit on public expenditure with no further expenditure having to be incurred for income to be raised.

This limitation has dual implications. First, the expenses that are to be met need to be prioritized, with the available resources allocated according to the needs determined to be the most important. Second, the decision to use more or fewer resources on a specific expense implies limiting to a greater or lesser extent the resources that can be devoted to other expenses. All this makes effective and efficient management of public resources essential.

The Spanish health system is considered to be the most efficient in Europe and the third most efficient in the world after Hong Kong and Singapore (Bloomberg Report 2018). The Bloomberg Report measures the efficiency of health systems by life expectancy, per capita spending on health and the percentage of GDP spent on health.

According to the Euro Health Consumer Index report1, Spanish health is in nineteenth place with 698 points, behind Serbia and Slovakia. The report highlights the fact that the Spanish health system is "very regionally decentralized".

The Spanish health system is decentralized. It is implemented by the country's autonomous regions—the seventeen autonomous communities (CAs), all of which operate their own independently-managed health services, which can, therefore, be compared and improved.

The purpose of this study is to detect the Spanish health services that are efficient and those that are not. Measures are then proposed that can be implemented by any health services that are inefficient for them to be able to achieve a level of efficiency and, consequently, help improve the Spanish health system overall.

2. Methodology

According to González et al. (2010), an efficiency study can be approached in two ways, with either the use of management measures based on ratio analysis, which can generate contradictory results depending on the indicators (Goddard et al., 2003) used or, alternatively, on the use of global efficiency indexes.

The latter include Data Envelopment Analysis (DEA), which is a management approach to evaluate operations in organizations in both the public and private sectors (Lowell et al. 2003). The popularity of this method can be seen in Emrouznejad et al. (2008). The history of DEA is described by Glover et al. (2009) based on the contributions of Cooper et al. (2001), while Ijiri et al. (2010) describe the philosophical background of accounting and the economy around which DEA came to pivot. Numerous studies of environmental issues have been published in recent years. (Cooper et al., 2001; Zhou et al., 2008; Sueyoshi et al., 2011; Sueyoshi et al., 2012; Sueyoshi et al., 2013; Sueyoshi et al., 2014).

Many publications have applied the DEA model with a range of variations since it first emerged out of the work by Farrell (1957). These have included approaches from the angle of both the inputs and the outputs depending on the controlled variable (Campos-Lucena et al., 2013) and included a distinction between good and bad outputs according to the efficiency achieved by raising or reducing their numbers. (Sueyoshi et al., 2011; Campos-Lucena et al., 2013; Campos-Lucena et al., 2018; Expósito et al., 2020)

It is important to differentiate between the natural and managerial character of the input variables. Unlike what occurs with other types of organizations, the natural variation in allocated resources in a health system means that any increase in the allocated budget must inherently lead to an improvement in outcomes. In contrast, managerial variation implies that the obtained results are compelled to improve when fewer resources are allocated, and different managerial policies applied.

With respect to the outputs, a distinction must be made between those that are considered to be good and improve the organization's efficiency, and those that are bad and improve efficiency when they are eliminated.

The model proposed (Sueyoshi et al., 2012) can be used to calculate the slope of the marginal productivity curve. This determines the variability of the Return to Scale (RTS) for good outputs and the Damage to Scale (DTS) for bad outputs.

The model seeks a radial focus and to solve it SCSC (Strong Complementary Slackness Condition) (Sueyoshi et al., 2012) has been applied, requiring the corresponding two problems to be obtained.

In our DEA models (Sueyoshi et al., 2012), Natural and Managerial, each j-th DMU $j = 1, \dots n$, uses inputs $X_j = (x_{1j}, \dots, x_{mj})^T$ and generates desirable (good) outputs, represented by $G_j = (g_{1j}, \dots, g_{sj})^T$, and undesirable (bad) outputs, represented by $B_j = (b_{1j}, \dots, b_{hj})^T$. Furthermore, $\mathrm{d}_i^x, i = 1, \dots m$, $\mathrm{d}_r^g, r = 1, \dots, s$, and $\mathrm{d}_f^b, f = 1, \dots, h$ represent slack variables related to inputs, and desirable and undesirable outputs, respectively. $\lambda = (\lambda_1, \dots, \lambda_n)^T$ are unknown structural or intensity variables, which are used for connecting the input and output vectors via a convex combination. R is the range resolute throughout the upper and lower bounds of inputs, desirable outputs and undesirable outputs, and is expressed by following expressions:

$$R_i^x = (m + s + h)^{-1}\left(\max\{x_{ij}|j=1, \dots, n\} - \min\{x_{ij}|j=1, \dots, n\}\right)^{-1}$$

$$R_r^g = (m + s + h)^{-1}\left(\max\{g_{rj}|j=1, \dots, n\} - \min\{g_{rj}|j=1, \dots, n\}\right)^{-1}$$

$$R_f^b = (m + s + h)^{-1}\left(\max\{b_{fj}|j=1, \dots, n\} - \min\{b_{fj}|j=1, \dots, n\}\right)^{-1}$$

Following the DEA study, a cluster analysis is performed in order to create groups according to natural efficiency and managerial efficiency, which will be explained in the results. The cluster analysis has been carried out using the IBM SPSS Statistics 26 software.

A. Natural-health model

Our health model is based on the Sueyoshi et al. (2012) study but with substantial differences. The natural model proposed by Sueyoshi implies that a reduction in inputs results in a natural adjustment of bad Outputs. However, the natural-health model proposed in this study implies that an increase in the Inputs results in a natural increase in the good Outputs that must rise in number and a reduction in the bad Outputs that have to decrease, and that this leads to an improvement in the obtained results.

Analytically:

$$Max \quad \sum_{i=1}^{m} R_i^x\, d_i^x + \sum_{r=1}^{s} R_r^g\, d_r^g + \sum_{f=1}^{h} R_f^b\, d_f^b \qquad (1)$$

Subject to

$$\sum_{j=1}^{n} x_{ij}\,\lambda_j - d_i^x = x_{ik} \quad (i = 1, \dots, m),$$

$$\sum_{j=1}^{n} g_{rj}\,\lambda_j - d_r^g = g_{rk} \quad (r = 1, \dots, s),$$

$$\sum_{j=1}^{n} b_{fj}\,\lambda_j + d_f^b = b_{fk} \quad (f = 1, \dots, h),$$

$$\sum_{j=1}^{n} \lambda_j = 1,\ \lambda_j \geq 0 \quad (j = 1, \dots, n),$$

$$d_i^x \geq 0 \ (i = 1, \dots, m), d_r^g \geq 0 \ (r = 1, \dots, s), \text{ and } d_f^b \geq 0 \ (f = 1, \dots, h).$$

Model (1) considers only deviations $-d_i^x$, $(i = 1, \dots, m)$ to attain the natural disposability.

Its solution provides the necessary efficiency scores, measured by:

$$\theta^* = 1 - \left(\sum_{i=1}^{m} R_i^x\, d_i^{x^*} + \sum_{r=1}^{s} R_r^g\, d_r^{g^*} + \sum_{f=1}^{h} R_f^b\, d_f^{b^*}\right)$$

The equation within the parenthesis, obtained from the optimality of Model (1), indicates the level of inefficiency under natural disposability.

b. Managerial-health model

The managerial-health model (Sueyoshi et al., 2012) implies that the increase in efficiency is linked to changes in the management policies that enable the number of resources consumed to be increased while the number of bad Outputs generated is reduced.

In the case of the managerial-health model proposed in this study, the reduction in inputs or resource used must result in no reduction in desirable Outputs by virtue of good management and the fact that the non-desirable outputs must be reduced for efficiency to be improved.

Analytically:

$$Max \quad \sum_{i=1}^{m} R_i^x\, d_i^x + \sum_{r=1}^{s} R_r^g\, d_r^g + \sum_{f=1}^{h} R_f^b\, d_f^b \qquad (2)$$

Subject to

$$\sum_{j=1}^{n} x_{ij}\,\lambda_j + d_i^x = x_{ik} \quad (i = 1, \dots, m),$$

$$\sum_{j=1}^{n} g_{rj}\,\lambda_j - d_r^g = g_{rk} \quad (r = 1, \dots, s),$$

$$\sum_{j=1}^{n} b_{fj}\,\lambda_j + d_f^b = b_{fk} \quad (f = 1, \dots, h),$$

$$\sum_{j=1}^{n} \lambda_j = 1,\ \lambda_j \geq 0 \quad (j = 1, \dots, n),$$

$$d_i^x \geq 0 \ (i = 1, \dots, m), d_r^g \geq 0 \ (r = 1, \dots, s), \text{ and } d_f^b \geq 0 \ (f = 1, \dots, h).$$

Model (2) considers only deviations $+d_i^x$, $(i = 1, \dots, m)$ to attain the natural disposability.

Its solution provides the necessary efficiency scores, measured by:

$$\theta^* = 1 - \left(\sum_{i=1}^{m} R_i^x\, d_i^{x^*} + \sum_{r=1}^{s} R_r^g\, d_r^{g^*} + \sum_{f=1}^{h} R_f^b\, d_f^{b^*}\right)$$

The equation within the parenthesis, obtained from the optimality of Model (2), indicates the level of inefficiency under managerial disposability.

The variables used have been taken from the Spanish National Health System Key Indicators Database (Bases de Datos de Indicadores Clave del Sistema Nacional de Salud: INCLASNS [2019]). The study has been carried out using 2016 data. The Inputs used are territorialized public health expenditure per protected citizen (Input 1); territorialized public health devoted to training, per citizen (Input 2), and territorialized public health expenditure devoted to outsourcing per protected citizen (Input 3). These three variables cover almost the entire expenditure of the autonomous communities' health services on health. Numerous studies can be found that use similar variables. (Hadad et al., 2013)

These Input variables have been selected on the basis of the major ongoing debate around the appropriateness or inappropriateness of outsourcing or privatizing services, (Moschuris et al., 2006; Hodge et al., 2007; Girth et al., 2012; Alonso et al., 2015; Choi et al., 2016) and the need to invest in training and research (Hartley, 2005; Glasgow et al., 2012; McKee et al., 2012; Begley et al., 2015; El-Noush et al., 2015; Thune et al., 2016).

The following Outputs have been selected: the degree of civic satisfaction with the way that the public health system works (Output 1–Good) and the general mortality rate adjusted for age, per 100,000 inhab. (Output 2–Bad), to represent user perception of the quality of the health services. The latter is also recognized to be an indicator of the quality of health services (Wiley et al., 2016) by the World Health Organization. Earlier works therefore also exist that use these outputs as adequate measures of efficiency (Donghua et al., 2008; Adang et al., 2007; Clement et al., 2008).

3. Results

According to the models based on studies (Sueyoshi et al., 2012) were applied to the variables explained. The corresponding data are given in Table 1.

Table 1.
Original data used in this study.

Autonomous Community		Input 1	Input 2	Input 3	Output-G	Output-B
1	Andalusia (AN)	1160,65	22,632675	47,238455	6,39	491,77
2	Aragon (AR)	1577,52	21,454272	61,838784	7,25	426,75
3	Asturias, Principality of (AS)	1595,83	27,288693	97,824379	6,97	472,75
4	Balearic Islands (IB)	1379,63	19,728709	144,171335	6,86	438,08
5	Canary Islands (CN)	1432,9	22,49653	138,41814	5,99	468,68
6	Cantabria (CB)	1487,19	36,882312	53,687559	7,05	441,14
7	Castile and Leon (CL)	1523,55	27,271545	59,266095	6,91	408,12
8	Castile - La Mancha (CM)	1382,27	21,148731	69,528181	6,34	429,91
9	Catalonia (CT)	1423,64	13,239852	356,052364	6,35	422,34
10	Valencia, Community of (VC)	1411,18	25,260122	59,128442	6,41	456,49
11	Extremadura (EX)	1592,59	23,411073	70,07396	6,51	473,74
12	Galicia (GA)	1464,29	25,039359	86,685968	6,35	455,89
13	Madrid, Community of (MD)	1237,23	32,044257	132,507333	6,73	374,69
14	Murcia, Region of (MC)	1552,63	29,344707	103,094632	6,91	457,82
15	Navarre, Community of (NC)	1587,02	21,742174	115,693758	7,29	409,73
16	Basque Country (PV)	1652,63	27,598921	111,883051	6,86	421,24
17	La Rioja (RI)	1406,59	23,068076	110,135997	7,23	407,73

Source: Prepared by authors.

The results obtained from applying the model (Sueyoshi et al., 2012) can be examined in detail in annexes I and II, note that the programming of the DEA models is done using linear programming in Mathematica 12.3. The first column of both tables indicates natural or managerial efficiency, respectively, taking a value between 0 and 1 being 1 efficiency. Columns I1, I2, I3 deviations indicate the increase in the budget required to achieve efficiency (value 1 in the first column), in each of the inputs studied. Columns O1, O2 deviations indicate the increase or decrease in the degree of satisfaction and the mortality rate, respectively, when achieving efficiency.

Linked to the variation in resources invested in the various health systems, the effect that this variation has on the results has to be taken into account. For this, the Return to Scale (RTS) should be observed that indicate the effect that any variation in the Inputs has on the Output-G (good Outputs). This rate could be increasing, constant, or decreasing, which implies that any variation in the Inputs causes a variation in the Output-G that is proportionally greater, proportionally the same, or proportionally smaller, respectively.

The Damage to Scale (DTS) that link the variation in Inputs to the variability of the Output-B (bad Outputs) also need to be considered. As with the RTS, any variation in the Inputs causes variations in the Output-B that are proportionally greater, the same or smaller.

Annex I (column RTS and DTS) show the increases that these health services require to their health care budgets. These increases would impact on their Outputs and ensure that their production functions are in line with the set of health services that are part of the efficiency border that the remaining health services should target.

Sueyoshi et al. (2012) address environmental issues. In such a context, any increase in Inputs inherently worsens the results, i.e., there is an increase in bad Outputs and a decrease in good Outputs. This study's context is different. Increasing the Inputs intrinsically raises the good Outputs and reduces the bad Outputs.

The efficiencies calculated with this model should, therefore, be interpreted the other way round, which means that environmental studies dealt with in natural efficiency health system studies should be interpreted as managerial efficiency and vice versa.

Based on the above data and following the grouping taken from the combination of rescaled difference clusters of natural efficiency, health services can be classified into the following groups:

Table 2.
Classification of health services by cluster analysis

Autonomous Community		Natural cluster	Managerial cluster
1	Andalusia (AN)	G4	G1
2	Aragon (AR)	G1	G1
3	Asturias, Principality of (AS)	G1	G2
4	Balearic Islands (IB)	G2	G1
5	Canary Islands (CN)	G4	G4
6	Cantabria (CB)	G1	G1
7	Castile and Leon (CL)	G1	G1
8	Castile - La Mancha (CM)	G3	G1
9	Catalonia (CT)	G1	G1
10	Valencia, Community of (VC)	G3	G2
11	Extremadura (EX)	G3	G3
12	Galicia (GA)	G3	G3
13	Madrid, Community of (MD)	G1	G1

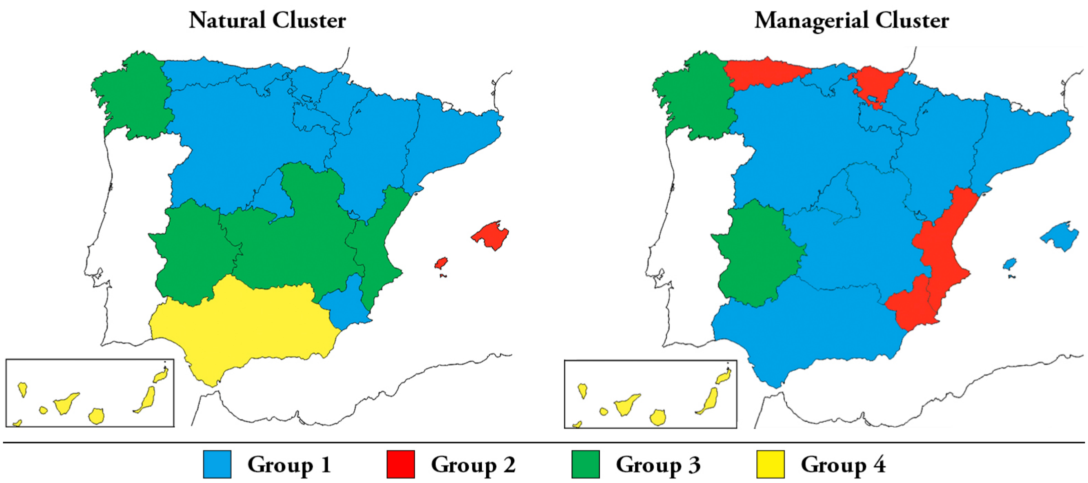
TABLE 2. CONT.
Classification of health services by cluster analysis

14	Murcia, Region of (MC)	G1	G2
15	Navarre, Community of (NC)	G1	G1
16	Basque Country (PV)	G1	G2
17	La Rioja (RI)	G1	G1

Source: Prepared by authors.

As can be observed, applying the two models, natural and managerial, classifies health services into four groups, which will be analyzed in the following.

GRAPHIC 1.
Classification of health services by cluster analysis



Source: Prepared by authors.

GROUP 1: HEALTH SERVICES WITH HIGH NATURAL EFFICIENCY

This group is formed of the health services with either natural efficiency or with minimum health inefficiency as, in the worst case, the service's inefficiency does not reach 1.405382% (Murcia case, see Annex I). These are the health services of the Cantabria, Catalonia, Madrid, Navarre, Basque Country, La Rioja, Castile-Leon, Aragon, Asturias and Murcia CAs.

The first five of these health services are naturally efficient, which implies that they have sufficient resources that are being well-managed.

Also, the Murcia CA health service does not require any increase to its budget and its budget does not need to be redistributed (the value in "I1 deviations", "I2 deviations" and "I3 deviations" are 0). However, its available resources should be better exploited for the results to give a 1.405341% (annex I, column "01 deviations") boost to civic satisfaction and lower the mortality rate by 6.68588% (annex I, column "02 deviations").

The remaining health services are also approaching efficiency, but all require a minimum increase to their budgets, which should have a natural knock-on effect that improves their efficiency. This improvement would result in an increase in Output-G and a decrease in Output-B.

Group 2: Health services with mid-to-high natural efficiency

This group is composed of the Balearic Islands health service alone. The inefficiency of this health service does not reach 0.05. However, it is beginning to deviate from the efficiency of the previous group's health services.

This health service requires a budget increase of around 190€/inhab. (Annex I, columns "I1 deviations" + "I2 deviations"), mostly for health expenditure directly managed by the public service and only a small part allocated to training. If the current management of public resources remains the same, this budget increase would result in a small 0.3186 (annex I, column "01 deviations") improvement in the degree of civic satisfaction and a general 26.8559 (annex I, column "02 deviations") reduction in the age-adjusted mortality rate per 100,000 inhab.

It must be borne in mind that RTS is decreasing, which implies that Output-G variability is less than proportional with respect to the increase in Inputs. This means that, in order to achieve efficiency, a more-than-proportional increase in inputs is required to achieve the desired improvement in the output that requires the increase. DTS is constant, which means that the impact on the improvement in the Output-B is proportional to the budget effort made and, consequently, also on the advantage achieved from this variable.

Group 3: Health services with mid-to-low natural efficiency

This group is formed of health services with a natural efficiency between 0.878165074 (Galicia case, annex I) and 0.905349683 (Castile-La Mancha case, annex I). These are the health services of Castile-La Mancha, Extremadura, Valencia, and Galicia. All these health services have constant RTS and DTS rates. This implies that the increase in resources allotted to their health systems managed both directly by the public service and set aside for training and external contracts with private companies results in a proportional improvement in the results in the form of both an increase in user satisfaction and a reduction in the mortality rate.

These increases in resources and their recommended distribution, which can be observed in detail in annex I, cause a natural improvement in both civic satisfaction with the various health systems and to the age-adjusted mortality rate per 100,000 inhab., and positions the health services of these CAs on the border marked by the production functions that operate efficiently naturally.

Group 4: Health services with low natural efficiency

The health services that form this group are those of Andalusia and the Canary Islands. These health services have an efficiency level of between 0.845352402 and 0.861361693 (see annex I) and require an increase in their budget effort. In the case of Andalusia, an increase of €420.50 (annex I, column "I1 deviations") per protected citizen is required to health expenditure directly managed by the health service and €64.81 (annex I, column "I3 deviations") to health expenditure for external contracts. The increase to the budget required to achieve efficiency in this Autonomous Community is significant (almost €500 per inhabitant).

Depending on the model applied, this increase to the budget will result in a 13.8636% (annex I, column "01 deviations") rise in civic satisfaction with the health system and a 16.3069% (annex I, column "02 deviations") reduction in the mortality rate.

The following table shows in graphic form the variation required in Inputs and Outputs (should any variation be necessary) for health efficiency to be achieved naturally.

None of the adjustments referred to in the previous paragraphs require any changes to their management at all but they do need the resources that they have been allocated to be better exploited with the use of the same procedures.

TABLE 3.
Summary of results of natural-health model application

Autonomous Community		I1 Deviations	I2 Deviations	I3 Deviations	O1 Deviations	O2 Deviations
1	Andalusia (AN)	↑	↔	↑	↑	↓
2	Aragon (AR)	↑	↑	↑	↑	↓
3	Asturias, Principality of (AS)	↔	↔	↑	↑	↓
4	Balearic Islands (IB)	↑	↑	↔	↑	↓
5	Canary Islands (CN)	↔	↑	↔	↑	↓
6	Cantabria (CB)	↔	↔	↔	↔	↔
7	Castile and Leon (CL)	↔	↔	↑	↑	↓
8	Castile - La Mancha (CM)	↔	↑	↑	↑	↓
9	Catalonia (CT)	↔	↔	↔	↔	↔
10	Valencia, Community of (VC)	↑	↔	↑	↑	↓
11	Extremadura (EX)	↔	↔	↑	↑	↓
12	Galicia (GA)	↑	↔	↑	↑	↓
13	Madrid, Community of (MD)	↔	↔	↔	↔	↔
14	Murcia, Region of (MC)	↔	↔	↔	↑	↓
15	Navarre, Community of (NC)	↔	↔	↔	↔	↔
16	Basque Country (PV)	↔	↔	↔	↔	↔
17	La Rioja (RI)	↑	↔	↑	↑	↓

Source: Prepared by authors.

It must be borne in mind that the philosophy that governs the management of public budgets is totally different from the basis for their management in the private sector. In the public sector, administrations have resources that do not depend on expenditure, although these do limit them, i.e., the maximum that budgeted public expenditure can reach is the total amount of budgeted public revenue. This implies that an increase in the budget for any given expenditure causes a reduction in the budget for some other expenditure, which means that although resource management is fundamental in any organization, this is even more the case in the public sector.

For this reason, apart from seeking efficiency in this type of public organizations by way of a higher resource budget, it is desirable for their management to be improved through changes to management policies that lead to a simultaneous savings in resources and better results. This is the reason why this study groups health services together according to the criteria taken from the combination of rescaled difference clusters of managerial efficiency. This enables the health services to be classified into four groups, although this entails different implications:

Group 1: Health services with high managerial efficiency

This first group is the most populated. The health services that comprise this group are the Andalusia, Aragon, Balearic Islands, Cantabria, Castile-Leon, Castile-La Mancha, Catalonia, Madrid, Navarre and La Rioja CAs. These are all health services run with managerial efficiency, which means that the production functions of said health services define the efficiency border that the remaining DMUs must target to achieve efficiency. They all manage their resources efficiently, so no changes are required to their budget management procedures.

In the case of Andalusia, note that it is inefficient by taking into account the natural efficiency, while it is efficient if we take into account the managerial efficiency. This leads to an additional question being posed with regard to the congestion of resources. The law of diminishing marginal returns states that when a given level of resources is reached, excess resources lead to negative returns, i.e., any increase in Inputs can inherently cause a worsening of Outputs due to the management of the former being hampered. This is an issue that will be addressed in a forthcoming study.

Group 2: Health Services mid-to-high managerial efficiency

The second group is composed of health services that, despite not achieving managerial efficiency, have an inefficiency between 0.04277 (Basque country case, annex II) and 0.05246 (Valencia case, annex II). The group includes the health services of Asturias, Valencia, Murcia and the Basque Country. In most cases, for managerial efficiency to be achieved they need to use fewer resources while nonetheless improving the obtained results.

The biggest budget cutback should be made by the Basque Country health service, which needs to make an almost €270 (annex II, columns "I1 deviations" + "I2 deviations") per person cut in its investment in health services. Most of this should be to direct management by the health service with a small reduction to the training of residents. In Asturias and Murcia, only a minimal cutback is required and in Valencia, there is no need for any cutback at all. Nevertheless, in cases where new, reduced budgets are necessary, the health services need to change their resource management policies to achieve better results, raise the level of civic satisfaction and reduce the mortality rate in their respective CAs.

In the specific case of the Basque Country, as the population of this CA was 1,049,555 inhabitants in 2016 (according to the INCLASS database [2019] from which all the other data have been taken), the savings made with a cutback of this type would be approx. €284 million, which could be allocated to some other public services.

Group 3: Health services with mid-to-low managerial efficiency

This group is formed of health services with managerial efficiency between 0.890822407 (Extremadura case, annex II) and 0.894502012 (Galicia case, annex II). In this case, they are the health services of the Galicia and Extremadura CAs. The reduction in the budget is minimal in both cases. In Extremadura, this could represent a saving of almost €27 million (537,391 inhabitants dispersed throughout the territory).

The challenge that this health services face is to improve their management processes, i.e., they have to achieve better results that improve the level of civic satisfaction between 0.7107 (Extremadura case, annex II, column "01 deviations") and 0.7299 (Galicia case, annex II, column "01 deviations") and reduce the mortality rate per 100,000 inhabitants by 48-52 persons, i.e., with the same resources but changing the way that they work.

Group 4: Health services with low managerial efficiency

Lastly, the health system with the poorest managerial efficiency is that of the Canary Islands CA. In this case, no cutback in the budget is required but the obtained results need to be improved with the resources that they have.

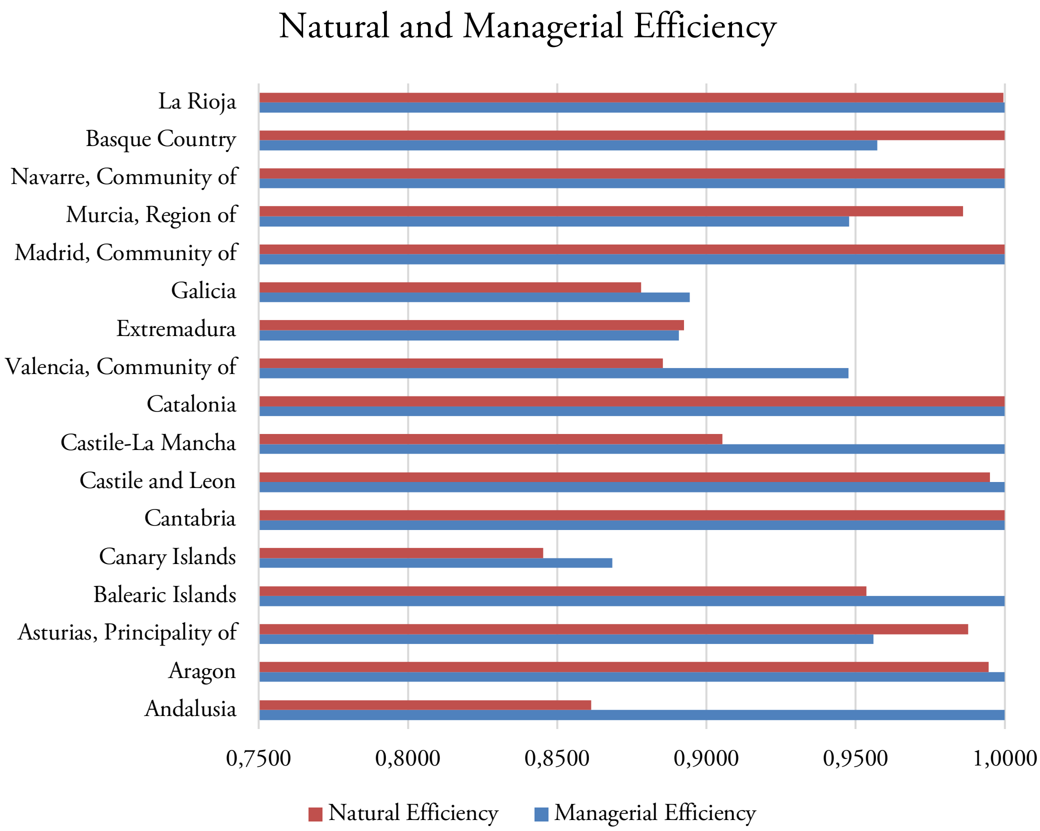
The following table gives a graphic representation of the variations required in inputs and outputs, where these are necessary, to achieve managerial efficiency in health.

TABLE 4.
Summary of results of application of the managerial-health model

Autonomous Community		I1 Deviations	I2 Deviations	I3 Deviations	O1 Deviations	O2 Deviations
1	Andalusia (AN)	↔	↔	↔	↔	↔
2	Aragon (AR)	↔	↔	↔	↔	↔
3	Asturias, Principality of (AS)	↓	↓	↔	↑	↓
4	Balearic Islands (IB)	↔	↔	↔	↔	↔
5	Canary Islands (CN)	↔	↔	↔	↑	↓
6	Cantabria (CB)	↔	↔	↔	↔	↔
7	Castile and Leon (CL)	↔	↔	↔	↔	↔
8	Castile - La Mancha (CM)	↔	↔	↔	↔	↔
9	Catalonia (CT)	↔	↔	↔	↔	↔
10	Valencia, Community of (VC)	↔	↔	↔	↑	↓
11	Extremadura (EX)	↓	↓	↔	↑	↓
12	Galicia (GA)	↔	↔	↔	↑	↓
13	Madrid, Community of (MD)	↔	↔	↔	↔	↔
14	Murcia, Region of (MC)	↔	↓	↔	↑	↓
15	Navarre, Community of (NC)	↔	↔	↔	↔	↔
16	Basque Country (PV)	↓	↓	↔	↑	↓
17	La Rioja (RI)	↔	↔	↔	↔	↔

Source: Prepared by authors.

GRAPHIC 2.
Summary of results of application of natural vs managerial-health model by autonomous community



Source: Prepared by authors.

4. DISCUSSION

Good management of public resources is of vital importance for the proper running of the welfare State. The budget limitations to which the administrations are subjected imply that there is a need to prioritize the investment or expenditure of the resources that they have available. For this reason, this study analyzes the efficiency of the health systems dependent on the CAs in Spain and proposes corrective measures for the inefficient units to achieve efficiency.

The study is based on the application of the DEA model and natural and management efficiency of the health services dependent on the seventeen CAs into which Spain has its territorial organization decentralized. This study extends previous research that has demonstrated the adequacy of the DEA method and allowed researchers to propose corrective measures to achieve overall efficiency in inefficient health systems (Campos et al., 2016) as well as to look for efficiencies can be attained through natural and/or managerial adjustments by increasing the variables that are considered desirable (Campos et al., 2018) arriving at conclusions according to the search for the natural and managerial efficiency.

In the case of natural efficiency, any shortfall can be corrected by making available a higher budget that should be properly managed. This is a fundamental difference from the application made by other studies that apply DEA.

In the case of managerial efficiency, savings to the budget is the main priority. In the specific sector under study, a saving in any given expenditure means an opportunity to increase some other. Managerial efficiency implies that even when fewer resources are available, a change in the way that things are done means that better results can be obtained.

In short, all the health services that are not managerially efficient have to change the way that they operate. They must change their resource management policies in order to achieve better results with the same or a lower budget.

Specifically, as the data demonstrate that the lack of efficiency is to a great extent the result of mortality rates that must be reduced, the resources that are freed up could be allocated to putting preventive medicine policies into effect, which improves public health; restructuring the team of professionals, tasked with putting a greater effort into the early detection of illness; lower patient waiting times, which can be resolved with improvements to the management of operating rooms; and specialized centers with different schedules, which can bring a halt to delays in the detection of illnesses. More resources could be allotted to research, to improving technology, to talks given by experts on important and especially called-for subjects, to the redistribution of resident staff in line with agreed criteria, to the application of incentivizing policies that motivate residents and to improving labor conditions that enable the greater productivity of residents, etc.

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Annexes

Annex I

Table 5.
Natural efficiency levels, INPUT 1, 2 and 3 deviations, and OUTPUT 1 and 2 deviations with respect to natural efficiency

	Autonomous Community	Natural efficiency	I1 Deviations		I2 Deviations		I3 Deviations		O1 Deviations		O2 Deviations		RTS	DTS
1	Andalusia (AN)	0,861361693	420,4982758	36,229550%	0	0%	64,8082700	137,1938%	0,88588386	13,86359%	-80,192550	-16,3069%	Decreasing	Constant
2	Aragon (AR)	0,994482096	9,5	0,602211%	0,287902	1,341933%	53,854974	87,08931%	0,04	0,551724%	-17,02	-3,98828%	Decreasing	Constant
3	Asturias, Principality of (AS)	0,987764874	0	0%	0	0%	3,93839704	4,025987%	0,08527317	1,223431%	-51,791980	-10,9554%	Constant	Constant
4	Balearic Islands (IB)	0,953551629	188,0328128	13,629220%	1,006113803	5,099745%	0	0%	0,3186292	4,64474%	-26,85597	-6,1303%	Decreasing	Constant
5	Canary Islands (CN)	0,845352402	0	0%	2,907746884	1,925313%	0	0%	1,0085683	16,8375%	-72,48006	-15,464%	Constant	Constant
6	Cantabria (CB)	1	0	0%	0	0%	0	0%	0	0%	0	0%	Decreasing	Increasing
7	Castile and Leon (CL)	0,9949286	0	0%	0	0%	58,4698650	98,65651%	0,03504075	0,50710%	-2,0695852	-0,50710%	Constant	Constant
8	Castile - La Mancha (CM)	0,905349683	0	0%	6,623779757	31,319987%	56,0074234	80,55355%	0,62220332	9,81393%	-40,6907064	-9,46493%	Constant	Constant
9	Catalonia (CT)	1	0	0%	0	0%	0	0%	0	0%	0	0%	Decreasing	Increasing
10	Valencia, Community of (VC)	0,885474936	88,60177742	6,278560%	0	0%	55,5643219	93,97224%	0,73410104	11,45243%	-52,279217	-11,4524%	Constant	Constant
11	Extremadura (EX)	0,892483464	0	0%	0	0%	41,9931506	59,92689%	0,69992980	10,75161%	-60,649526	-12,8022%	Constant	Constant
12	Galicia (GA)	0,878165074	19,92984754	1,361059%	0	0%	32,4734391	37,46101%	0,77364992	12,18346%	-55,543191	-12,1834%	Constant	Constant
13	Madrid, Community of (MD)	1	0	0%	0	0%	0	0%	0	0%	0	0%	Decreasing	Increasing
14	Murcia, Region of (MC)	0,98594618	0	0%	0	0%	0	0%	0,09710904	1,405341%	-30,609328	-6,68588%	Constant	Constant
15	Navarre, Community of (NC)	1	0	0%	0	0%	0	0%	0	0%	0	0%	Decreasing	Increasing
16	Basque Country (PV)	1	0	0%	0	0%	0	0%	0	0%	0	0%	Constant	Increasing
17	La Rioja (RI)	0,999447234	146,8260066	1,438457%	0	0%	5,33210028	4,841378%	0,00399193	0,055214%	-0,225122	-0,05521%	Decreasing	Constant

Source: Prepared by authors.

Annex II

TABLE 6.
Managerial efficiency levels, INPUT 1, 2 and 3 deviations, and OUTPUT 1 and 2 deviations with respect to managerial efficiency

Autonomous Community		Managerial Efficiency	I1 Deviations		I2 Deviations		I3 Deviations		O1 Deviations		O2 Deviations	
1	Andalusia (AN)	1	0	0%	0	0%	0	0%	0	0%	0	0%
2	Aragon (AR)	1	0	0%	0	0%	0	0%	0	0%	0	0%
3	Asturias, Principality of (AS)	0,955991995	-11,9621526	-0,749588%	-5,64204648	-20,6754%	0	0%	0,306727778	4,400685%	-57,3726696	-12,135943%
4	Balearic Islands (IB)	1	0	0%	0	0%	0	0%	0	0%	0	0%
5	Canary Islands (CN)	0,868406527	0	0%	0	0%	0	0%	1,121981323	18,730907%	-61,6749883	-13,159296%
6	Cantabria (CB)	1	0	0%	0	0%	0	0%	0	0%	0	0%
7	Castile and Leon (CL)	1	0	0%	0	0%	0	0%	0	0%	0	0%
8	Castile - La Mancha (CM)	1	0	0%	0	0%	0	0%	0	0%	0	0%
9	Catalonia (CT)	1	0	0%	0	0%	0	0%	0	0%	0	0%
10	Valencia, Community of (VC)	0,947534501	0	0%	0	0%	0	0%	0,336303846	5,24655%	-23,9499754	-5,24655%
11	Extremadura (EX)	0,890822407	-48,9951140	-3,076442%	-1,23428842	-5,272242%	0	0%	0,710744151	10,917729%	-51,7216488	-10,917729%
12	Galicia (GA)	0,894502012	0	0%	0	0%	0	0%	0,729906526	11,494591%	-48,0954356	-10,54979%
13	Madrid, Community of (MD)	1	0	0%	0	0%	0	0%	0	0%	0	0%
14	Murcia, Region of (MC)	0,947809905	0	0%	-7,42688383	-25,30910%	0	0%	0,360626751	5,218911%	-44,7816151	-9,781489%
15	Navarre, Community of (NC)	1	0	0%	0	0%	0	0%	0	0%	0	0%
16	Basque Country (PV)	0,957228529	-266,176902	-16,10626%	-3,19547227	-11,57825%	0	0%	0,293403015	4,277012%	-18,0164848	-4,277012%
17	La Rioja (RI)	1	0	0%	0	0%	0	0%	0	0%	0	0%

Source: Prepared by authors.

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Articles

Interregional analysis using a bi-regional input-output matrix for Argentina

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Abstract:

This paper presents a regional case study using a Bi-Regional Input-Output (BRIO) matrix of Buenos Aires City (BAC) and the Rest of Argentina (ROA), constructed from the Argentinian Input-Output matrix. A hybrid approach was applied to obtain the BRIO matrix, which combines pure non-survey methods with matrix-balancing methods like RAS or Cross-Entropy. Once the BRIO matrix was obtained, our study has focused on analyzing the BAC regional structure and the interconnections between regions. We have also estimated the regional and national carbon footprint for the BAC and Argentina, respectively. Results show that service and industry sectors play an important role in the economy of BAC and some of them have strong interregional spillover effects over the rest of the country. In addition, the results also show that sectors on BAC with the highest regional multipliers are also the ones with highest emissions.

Keywords: Interregional input-output model; carbon footprint; bi-regional input-output tables; location quotients; cross entropy.

JEL Classification: C67; D57; R15; R58.

Análisis interregional utilizando una matriz Insumo-Producto bi-regional de Argentina

Resumen:

Este artículo presenta un caso de estudio regional utilizando una matriz Bi-Regional Input-Output (BRIO) de la Ciudad de Buenos Aires (BAC) y el Resto de Argentina (ROA), construida a partir de la matriz Input-Output de Argentina. Se ha utilizado una metodología híbrida para obtener la matriz BRIO, la cual combina métodos indirectos puros y métodos de calibración de matrices como RAS y Entropía Cruzada. Una vez obtenida la matriz BRIO, nuestro estudio se ha centrado en analizar la estructura regional de la BAC y las interconexiones entre regiones. También hemos realizado la estimación de la huella de carbono nacional y regional para Argentina y en la BAC, respectivamente. Los resultados muestran que los sectores de servicios e industria juegan un papel importante en la economía de la BAC y algunos de ellos tienen fuertes efectos indirectos interregionales sobre el resto del país. Además, los resultados también muestran que los sectores de la BAC con los multiplicadores regionales más altos también son los que tienen las emisiones más altas.

Palabras clave: Modelo insumo-producto interregional; huella de carbono; matrices insumo-producto bi-regionales; coeficientes de localización; entropía cruzada.

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Clasificación JEL: C67; D57; R15; R58.

1. Introduction

Interregional Input-Output (IRIO) models are a valuable tool to study a particular region of interest considering the interconnections with the rest of the country. Due to the dramatics socio-economic and political differences between the Buenos Aires City (BAC) and the Rest of Argentina (ROA), implementing an interregional approach becomes essential. In this sense, a Bi-Regional Input-Output (BRIO) matrix is necessary to carry out such analysis (Boero et. Al, 2018 and Round, 1983). As there are no available regional matrices in Argentina, regionalization process has been performed to regionalize Argentina's national Input-Output (IO) matrix into a Bi-Regional one.

Leaving the Regional IO matrices problem aside, our efforts were placed on BAC which is adhered to the 2030 Agenda for Sustainable Development Goals (SDG's). This assumed commitment generates the need for policy makers to have a methodology to quantify the effects of their decisions. This work intends to contribute in that way presenting a case study mainly related to the 8th and 13th SDGs, in which the Buenos Aires City takes on the commitment to boost the local economic developments through incentives to strategic economic sectors and to be a carbon neutral by 2050, respectively.

The economic structure of the BAC differs completely from the national average and considering the interconnections with the ROA is relevant for its study. The BAC is the richest region of the country with the core businesses concentrated on it. It has an approximated area of 203 square kilometers and approximately three million inhabitants that represent 7% of the Argentina population. The political division between BAC and ROA are not implying economical division and companies are integrated between regions with significant "imports" and "exports" between them. National headquarters of the most important companies of the country are centered in this region, especially in the service sectors. Finally, the structure of the BAC job market is inherently interconnected with the ROA because BAC has many commuters from Greater Buenos Aires (GBA), that is the name to call the suburbs of BAC.

Considering the mentioned, the interregional approach using a Bi-Regional IO matrix is essential to perform regional studies on the BAC.

Our main objective is to present a case study of the BAC where the regional structure, the interconnections between regions and carbon footprint are analyzed using a BRIO matrix of Argentina made up by the BAC and the ROA regions. However, as the regional structure was not available, we first had to obtain the BRIO matrix. To go through this first step, we have used a hybrid non-survey approach which combines two of the most frequently used techniques in the field of Input-Output matrices (Mastronardi and Romero, 2012). They are the Location Quotients (LQs), (Flegg et al., 1995; Flegg and Webber, 1997, 2000) and, additionally, the well-known matrix balancing methods like RAS and Cross Entropy.

Considering Lamonica (2020), we built, in a practical case and with other point of view, a regional estimation inside a country when is not common to have a lot of information about intermediate purchases and sales between regions, final regional consumption, exports, national taxes, etc.

In absence of primary data, researcher would probably construct the most important regional internal intermediate consumption with secondary data, with an important focus on specific sector that she will analyze before in a sectoral economic analysis. Considering the specific case of Buenos Aires City, we used specific estimations for intermediate purchases and sales developed in a specific academic project to study its economic structure[1].

This article could be the first stone to continue contributing to the analysis of the impacts of public policies that are defined within the framework of the SDGs, such as the initiative to create green jobs. Interregional analysis of other economic problems could be also extensions of this work, such as

[1] Modelos regionales: Desarrollo de un modelo de equilibrio general para CABA – UADE PID IE-10D1, Universidad Argentina de la Empresa, 2010-2012

applications for tourism in the Province of Salta in Haslop et. al (2020) or for green energy in the Misiones province in Perrota et. al (2020).

Finally, we have decided to make the regionalization methodology explicit in this paper. With this, it is intended to help colleagues from different disciplines in economics to be able to estimate the BRIO matrix in a relatively simple way.

The paper is organized as follows. Section 2 presents a brief introduction of the non-survey methods based on Location Quotients which are important to understand the regionalization methodology and constitute the first step of our regionalization process. Section 3 presents an initial Regionalized National Input-Output matrix which includes intra-regional and inter-regional sub-matrices. Section 4 introduces two calibration methods (RAS and Cross Entropy) which could by applied over the initial matrix obtained in the previous section. The end of this section shows only the results obtained by applying the Cross-Entropy method. Section 5 present the case study using the BRIO matrix obtained in the previous sections. Finally, Section 6 provides final remarks and potential extensions.

2. Intra-regional input-output: The use of location quotients

2.1. Overview

As we have mentioned before, we first need to build a BRIO matrix to perform the regional study. In this sense, the regionalization process consists of separating Argentina into two regions, the BAC and the ROA. Therefore, the national input-output table is broken down into four regional tables, which represent: [A] intra-regional commerce (within each region) and [B] inter-regional commerce between regions (exports and imports from/to another region). The construction procedure of [A] will be detailed in this section while the construction procedure of [B] will be detailed in section 3.

Table 1 shows a scheme for "n" sectors of the economy in each region to describe the tables.

Table 1.
An example of Regional Input-Output Table for N sectors

		BAC activity sectors	ROA activity sectors
		S_1 … S_n	S_1 … S_n
BAC activity sectors	S_1 … S_n	BAC Input-Output [A]	BAC Exports- ROA Imports [B]
ROA activity sectors	S_1 … S_n	ROA Exports- BAC Imports [B]	ROA Input-Output [A]

Source: Own elaboration.

Having computed matrices A and B, it is necessary to combine them to find an initial bi-regional table. After that, matrix balancing methods adjust that initial bi-regional table to find the final bi-regional matrix that can be used to perform regional analysis.

Non-survey or indirect methods, including Location Quotients (LQs) methods, are used to estimate a regional (r) IO matrix from a national (n) IO one by adjusting national coefficients to reflect regional production structures. In order to estimate a IO matrix of a single region, it can be applied the regional technical coefficients ($a_{ij}^{r} = \alpha_{ij}^{r} a_{ij}^{n}$) and the regional input coefficients ($a_{ij}^{rr} = \beta_{ij}^{r} a_{ij}^{r}$). The first one does not distinguish the local or imported origin of inputs (i) to produce a unit of output (j), but the second does identify local input requirements per unit of output.

The assumptions behind the regional input coefficients estimation are:

- Identical technologies between the nation and the region ($a_{ij}^{r} = a_{ij}^{n}$), which implies $a_{ij}^{rr} = \beta_{ij}^{rr} a_{ij}^{n}$; then $\alpha_{ij}^{r} = 1$
- Regional demand preferences for regional production, and
- Positive regional exports after regional demand satisfaction.

In this work, both [A] matrices (BAC and ROA), were constructed by means of indirect methods based on (LQs) which are the most frequently used to estimate a single-region IO matrix. Some of them are Simple LQ (SLQ), Cross Industry LQ (CILQ), Flegg's LQ (FLQ) and Augmented FLQ (AFLQ) (Flegg et al., 1995; Flegg and Webber, 1997, 2000). Several empirical studies on different countries' regions, such as Argentina (Flegg et al., 2015), Finland (Flegg and Tohmo, 2013), Germany (Kowalewski, 2015), Greece (Psaltopoulos and Balamou, 2005; Lampiris et al., 2018), Ireland (Morrissey and O'Donoghue, 2013; Morrissey, 2016), Northern Australia (Stoeckl, 2012), Scotland (Johns and Leat, 1987), South Korea (Zhao and Choi, 2015; Flegg and Tohmo, 2016) and the United States (New York State Department of Labor, 2017), have used this methodology.

LQ methodology, has assumed that the regional input coefficient (a_{ij}^{rr}) differ from the national coefficients (a_{ij}^{n}) only by a share, which has explained the regional trade (lq_{ij}) (Jensen *et. al*, 1979). Thus, lq_{ij} measures the proportion of regional requirements of input i that can be satisfied by firms located within the region and, for this reason, $lq_{ij} \in [0,1]$ by definition (Flegg and Tohmo, 2013).

The regional input coefficient has been defined as follows:

$$\begin{cases} a_{ij}^{rr} = lq_{ij}.a_{ij}^{n} & if \quad lq_{ij} < 1 \\ a_{ij}^{rr} = a_{ij}^{n} & if \quad lq_{ij} > 1 \end{cases} \tag{1}$$

that, in general terms, if $lq_{ij} < 1$ then $\beta_{ij}^{r} = lq_{ij}$ and $\alpha_{ij}^{r} = 1$. On the other hand, when q_{ij} is greater than 1, then $\beta_{ij} = 1$.

The constraint to one implies that if the regional sector is self-sufficient or a net exporter ($lq_{ij} < 1$) the regional input coefficient is exactly the national technical coefficient. Instead, if the regional sector is a net importer ($lq_{ij} > 1$) the regional input coefficient will be a share of the national coefficient.

In this work we have built the intra-regional matrices using the Augmented Flegg Location Quotient (AFLQ) (Flegg and Webber, 2000), which is a theoretical improvement of the Flegg Location Quotient (FLQ) (Flegg et al., 1995; Flegg and Webber, 1997).

We first introduce the FLQ and then, from there, arrive at the AFLQ by introducing an adjustment.

The FLQ can be computed as follow:

$$\begin{cases} FLQ_{ij} = \lambda^{*}.CILQ_{ij} & for \quad i \neq j \\ FLQ_{ij} = \lambda^{*}.SLQ_{i} & for \quad i = j \end{cases} \tag{2}$$

where the λ is the parameter estimated by the equation (3), with which the FLQ consider the region's size in relation compared to country size.

$$\lambda^{*} = [\log_2\left(1 + \frac{x^r}{x^n}\right)]^{\delta}, \quad with \quad 0 < \delta < 1 \tag{3}$$

In this sense, it can be seen that if $\delta = 0$, then the FLQ equals:

- The $SLQ_i = \frac{x_i^r/x^r}{x_i^n/x^n}$ when $i = j$, where the x_i^r and x^r correspond to the region r gross output of the sector i and total regional gross output, respectively, while x_i^n and x^n have the same meaning but at national level.

- The SLQ has been viewed as a measure of the ability of regional industry i to supply the demand placed in that region. So, if the industry i is less specialized in the region than in the nation ($SLQ_i < 1$), it's seen as less capable of satisfying regional demand with it production. Conversely, if the industry i is more specialized ($SLQ_i > 1$), then it is assumed that the national technical coefficient of industry i is appropriate to represent the region's structure, and that the regional surplus produced by i will be export to the rest of the country;
- The $CILQ_{ij} = \frac{SLQ_i}{SLQ_j}$ when $i \neq j$ and it measures the relative importance of the supplying industry i with respect to the demanding industry j, in the same region. It is important to notice that if the regional production of the supplying industry i (in terms of its national production) is greater than the regional production of the purchasing industry j (in terms of its national production), the $CILQ_{ij}$ is greater than one and the input requirements of j sector could be satisfied within the region. On the other hand, if $CILQ_{ij}$ is lower than one, the inputs needed by the purchasing industry might not be produced by the supplying sector and, consequently, they would need to import the inputs from another region.

However, if $\delta > 0$ then the FLQ accounts the size of the region by means of the value of λ, for instance, the greater the region the lower the need for imports.

The value of δ is intensely discussed in the literature [we could mention Lampiris et. al (2019), Lamonica et.al (2018), Flegg and Webber (1997), Flegg and Tohmo (2013) and Kowalewski (2015), among others] but, in this case, for simplicity, we have used the definition derived from Flegg and Tohmo, 2014:

$$\delta = \frac{\log[(x^r/x^n)/\log_2\{1+(x^r/x^n)\}]}{\log[\log_2(1+(x^r/x^n))]} \tag{4}$$

Flegg and Webber (1997) have acknowledged that a standard and a reference value of δ could be 0.3, with smaller (greater) value than that for smaller (bigger) regions (Miller and Blair, 2009).

The AFLQ have theoretically improved the FLQ by allowing the regional technical coefficients of a particular industry to be greater than the national one. This version of LQ includes the regional specialization effect of each industry (Miller and Blair, 2009), by means of a correction of the equation (2) if and only if the industry is self-sufficient in that region ($SLQ_i > 1$). If that occurs, $AFLQ > FLQ$ and, consequently, the regional import are lower. As with the FLQ, the constraint AFLQij ≤ 1 is imposed.

$$AFLQ_{ij} = \lambda^* . CILQ_{ij}. [\log_2(1 + SLQ_i)] = FLQ_{ij}. [\log_2(1 + SLQ_i) \tag{5}$$

Either FLQ and AFLQ significate an improvement of previous LQs. Lampiris et al. (2019) highlights that FLQ and AFLQ, are preferable quotients and provide satisfactory results, even for small regions.

Although the AFLQ has some theoretical merits relative to the FLQ, its empirical performance is typically very similar (Flegg and Tohmo, 2019). For instance, in the Monte Carlo study by Bonfiglio and Chelli (2008), the AFLQ gave only slightly more accurate results than the FLQ. This outcome was confirmed by Flegg et. al. (2016) and Kowalewski (2015). In this work we have used the AFLQ.

It is worth mentioning the contribution of Pereira et al. (2020) which generalizes Flegg`s methodology by using a bidimensional approach, the 2D-LQ. This methodology yields better results than FLQ or AFLQ since it takes advantage of the available information and overcomes the fact that Flegg`s methodology makes the adjustment of purchasing sectors proportionally to the productive specialization.

Table 2 shows the production value of 14 sectors[2] in each region and the corresponding SLQ, using national data.

TABLE 2.
Production values (PV) and Simple Location Quotient for BAC and ROA

Nº	Sectors	PV of Argentina	PV of BAC	SLQ	PV of ROA	SLQ
1	Agriculture, forestry and hunting	64,594	1,282	**0,09**	63,312	**1,27**
2	Fishing	2,792	75	**0,12**	2,716	**1,27**
3	Mining and quarrying	47,229	4,586	**0,42**	42,643	**1,17**
4	Industry	403,266	62,122	**0,67**	341,145	**1,10**
5	Water, Electricity and gas	23,048	4,412	**0,83**	18,636	**1,05**
6	Construction	96,792	13,99	**0,63**	82,802	**1,11**
7	Commerce	93,114	24,346	**1,13**	68,768	**0,96**
8	Hotels and restaurants	31,432	12,821	**1,77**	18,611	**0,77**
9	Transport and communication	102,246	34,321	**1,45**	67,925	**0,86**
10	Financial intermediation	40,411	21,863	**2,34**	18,548	**0,60**
11	Real estate, renting and business	77,833	45,272	**2,52**	32,561	**0,54**
12	Public administration	50,727	11,554	**0,99**	39,172	**1,00**
13	Education, health and social services	78,117	17,635	**0,98**	60,482	**1,01**
14	Other services	50,489	14,051	**1,21**	36,438	**0,94**
	Total	**1,162,089**	**268,329**		**893,759**	

Source: Own elaboration based on INDEC, Ministerio de Hacienda GCBA and Chisari et. al (2010).

It must be remarked that non-survey methods use only production figures. In our case, we also have information on intermediate consumption and value added. Hence, we have a more precise notion about the existent technology at the sectorial level. These are included as additional constraints that our estimation of the RIO tables must enforce. In the next sections we will show calibration techniques to deal with these constraints

Once the $AFLQ_{ij}$ is computed over the national matrix (see Annex), we can estimate the regional input coefficients a_{ij}^{rr} and build the intra-regional technical coefficient matrix for each region. Then, these coefficients could be used to estimate the intra-regional transaction matrix corresponding to each region by multiplying them by the regional production value. Table 3 shows BAC´s intra-regional technical coefficient matrix[3].

[2] Given that the available gross output disaggregation of BAC was only 14 sectors and we took this as our primary regional data, we had to use a small disaggregation.

[3] The ROA´s intra-regional I-O matrix can be constructed by following the same procedure.

TABLE 3.
BAC´s Intra-regional technical coefficient matrix

	Sectores	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Agriculture, forestry and hunting	0,0058	0,0016	0,0000	0,0109	0,0000	0,0000	0,0000	0,0001	0,0000	0,0000	0,0000	0,0000	0,0000	0,0001
2	Fishing	0,0000	0,0021	0,0000	0,0002	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
3	Mining and quarrying	0,0001	0,0000	0,0141	0,0208	0,0545	0,0818	0,0000	0,0000	0,0002	0,0000	0,0000	0,0001	0,0000	0,0000
4	Industry	0,1769	0,1813	0,0693	0,1469	0,0331	0,2101	0,0172	0,1599	0,0510	0,0102	0,0138	0,0304	0,0364	0,0599
5	Water, Electricity and gas	0,0027	0,0012	0,0158	0,0075	0,1458	0,0024	0,0065	0,0101	0,0033	0,0027	0,0041	0,0131	0,0034	0,0101
6	Construction	0,0109	0,0000	0,0363	0,0011	0,0004	0,0000	0,0000	0,0186	0,0014	0,0000	0,0211	0,0079	0,0045	0,0034
7	Commerce	0,0174	0,0291	0,0022	0,0208	0,0011	0,0391	0,0117	0,0121	0,0106	0,0012	0,0007	0,0035	0,0029	0,0091
8	Hotels and restaurants	0,0020	0,0159	0,0000	0,0070	0,0001	0,0000	0,0008	0,0006	0,0053	0,0176	0,0071	0,0582	0,0273	0,0102
9	Transport and communication	0,0209	0,0681	0,0143	0,0793	0,0387	0,0968	0,0576	0,0126	0,1319	0,0680	0,0153	0,0394	0,0126	0,1208
10	Financial intermediation	0,0217	0,0173	0,0124	0,0107	0,0171	0,0604	0,0952	0,0088	0,0480	0,1297	0,0215	0,0854	0,0032	0,0436
11	Real estate, renting and business	0,0013	0,0374	0,0202	0,0191	0,0260	0,0566	0,0796	0,0233	0,0530	0,0666	0,0130	0,0360	0,0090	0,0923
12	Public administration	0,0013	0,0050	0,0019	0,0024	0,0085	0,0002	0,0009	0,0000	0,0082	0,0020	0,0005	0,0010	0,0009	0,0026
13	Education, health and social services	0,0005	0,0006	0,0298	0,0028	0,0233	0,0000	0,0004	0,0030	0,0014	0,0022	0,0126	0,0191	0,0964	0,0129
14	Other services	0,0009	0,0001	0,0317	0,0049	0,0138	0,0001	0,0005	0,0012	0,0140	0,0052	0,0022	0,0086	0,0077	0,0125

Source: Own elaboration.

3. Construction of the inter-regional input-output table

As we mentioned, a BRIO national matrix includes both intra-regional and inter-regional sub-matrices (see Table 1). While in the previous section, we have estimated the intra-regional sub-matrices, both for BAC and ROA, in this section we discuss how to estimate the inter-regional sub-matrices.

It is known that the SLQ_i indicates whether the region is a net-exporter ($SLQ_i > 1$) or net-importer ($SLQ_i < 1$). In this way, BAC region is considered as net-exporter of service sectors and the ROA the importer of those services (see Table 2).

From these assumptions it follows that the sum of transactions by sector, must reproduce the transactional value of national sector in terms of the intermediate consumption and intermediate sales. In other words, the sum of regional *ij*'s transactions for a particular sector must reproduce the *ij* national transaction for that sector. This constraint implies enforcing the national technical coefficients and it can be summarized by following the equation:

$$t_{ij}^{n} = \sum_p \sum_s t_{ij}^{ps} \text{ , } \forall ij \tag{6}$$

Where t_{ij}^{ps} is the regional *ij* transaction from the purchasing region "p" and the supplying region "s", and t_{ij}^{n} is the national *ij* transaction.

Considering the mentioned, we have estimated the inter-regional matrices under the following assumptions:

a. A regional sector is exporter if and only if its SLQ_i is greater than one. Therefore, the sectors that do not comply with this rule have a 0 in the export matrix.

b. Given the equation (6) and that one sector can be net-exporter or net-importer but not both, it follows that ${t_{ij}}^{BAC,ROA} = 0$ or ${t_{ij}}^{ROA,BAC} = 0$ and the initial export transaction value for ${t_{ij}}^{BAC,ROA}$ (if ${t_{ij}}^{ROA,BAC} = 0$) or vice versa is:

$${t_{ij}}^{BAC,ROA} = t_{ij}^{n} - t_{ij}^{BAC,BAC} - t_{ij}^{ROA,ROA} \tag{7}$$

Once we have obtained the inter-regional matrices for BAC and ROA, the BRIO matrix was built by joining the inter-regional and intra-regional matrices (obtained in the previous section) as in Table 1

4. Calibration methods

4.1. Preliminary comments about the initial table

Pure indirect methods like LQs theory only needs production data to perform a regionalization. However, if there were additional regional information (i.e. intermediate consumption of one region), this methods would not take advantage of that extra information. In this sense, calibration methods could be a helpful tool by allowing us to improve our estimation with some extra information. The objective of these methods is to fit the internal values of the analyzed matrix such that their sum (by rows or columns) equals the values of the Intermediate Consumption and Sales vectors with information from external sources.

In the case of Argentina, we have taken advantage of the availability of Intermediate Consumption information of BAC which has been introduced through a control vector. This control vector of Intermediate Consumption [IC*] probably differ from the Intermediate Consumption vector [IC] obtained by our BRIO matrix estimated. This vector was built such that $IC_i^{BAC} + IC_i^{ROA} = IC_i^{ARG}$, where IC_i^{BAC} and IC_i^{ARG} come from external sources and IC_i^{ROA} was estimates as the difference between these vectores. Additionaly, it is important to mention that information about regional intermediate sales (IS) was not available. In this case, we have used the estimated intermediate as the control vector.

To adjust the differences between the information and our estimation, Cross Entropy (CE) was applied, but RAS could be a reasonable alternative. In this way, the use of borders ensures the resolution of the problem above.

Table 4 presents the initial matrix with the control vectors. This table have been used as the basis for the application of the calibration methods described in the following subsections. To clarify the understanding of the table, note that the row sum of each sector [IC] differs from the intermediate consumption control vector [IC*], but only in its internal structure since the total sum of IC and IC * is identical.

It is important to mention that this complementary method presented on our contribution in a hybrid technique requires information that it could not be available as a primary source. In our case, if the additional information were not available, we would not be able to use calibration methods to improve our first estimate with pure LQs.

TABLE 4.
Initial Regionalized National Input-Output Table for Argentina in 2006 (transactions)

		BAC Activity Sectors													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
BAC Activity Sectors	**1**	7,5	0,1	0,0	676,9	0,0	0,4	0,0	0,8	0,1	0,0	0,0	0,2	0,1	1,7
	2	0,0	0,2	0,0	15,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	3	0,2	0,0	64,6	1.293,3	240,6	1.144,4	0,0	0,0	5,5	0,0	0,1	0,6	0,3	0,2
	4	226,8	13,6	318,0	9.124,6	146,0	2.938,6	418,9	2.050,0	1.750,1	222,1	623,9	350,8	642,5	841,0
	5	3,4	0,1	72,4	468,1	643,2	32,9	158,8	128,9	112,1	58,7	187,7	151,2	60,5	141,2
	6	14,0	0,0	166,6	67,6	1,6	0,0	0,1	238,3	47,8	0,0	954,1	90,9	79,5	48,4
	7	22,3	2,2	9,9	1.293,2	5,1	547,1	284,6	154,7	364,0	26,7	30,3	39,9	51,5	128,2
	8	2,6	1,2	0,0	433,1	0,5	0,0	20,5	7,1	181,6	384,6	323,0	671,9	480,7	143,3
	9	26,8	5,1	65,8	4.924,3	170,9	1.354,2	1.401,9	161,9	4.526,6	1.485,8	692,7	454,9	221,9	1.697,7
	10	27,8	1,3	57,0	663,9	75,4	845,7	2.318,5	113,4	1.648,6	2.834,6	974,1	986,4	56,7	612,8
	11	1,7	2,8	92,6	1.184,8	114,7	791,4	1.939,1	299,3	1.818,0	1.457,0	590,3	416,0	159,0	1.296,4
	12	1,7	0,4	8,8	146,3	37,4	3,0	21,5	0,0	281,9	42,8	22,0	11,3	15,6	36,2
	13	0,7	0,0	136,5	172,8	102,7	0,0	10,8	39,1	48,0	48,7	568,5	220,6	1.699,3	181,6
	14	1,1	0,0	145,3	302,3	60,8	1,4	12,8	15,0	481,7	113,4	100,0	99,5	135,8	175,0
ROC Activity Sectors	**1**	105,3	0,1	0,2	6.142,9	0,0	3,7	0,0	14,3	1,0	0,0	0,1	2,1	1,2	24,8
	2	0,0	1,6	0,0	97,1	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0
	3	0,0	0,0	134,8	1.370,0	375,2	1.066,8	0,0	0,0	13,5	0,0	0,4	1,3	0,6	0,5
	4	547,5	23,0	71,7	8.628,4	89,5	816,7	425,9	2.749,4	2.072,3	359,5	1.060,6	322,5	579,7	887,5
	5	15,5	0,3	45,4	152,5	363,8	10,2	98,9	113,9	84,9	65,0	220,1	101,2	39,9	92,4
	6	26,4	0,0	20,6	25,9	1,2	0,0	0,1	356,3	63,5	0,0	1.791,5	95,0	81,6	57,7
	7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	10	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	11	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	12	10,8	1,8	9,0	73,7	17,2	1,7	10,1	0,0	134,5	33,0	18,2	6,8	9,2	14,8
	13	4,3	0,2	135,8	84,8	47,3	0,0	5,1	23,4	23,5	38,3	478,9	132,2	1.018,7	74,9
	14	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	IC	1.046,4	53,9	1.554,9	37.341,6	2.492,9	9.558,3	7.127,7	6.465,8	13.659,1	7.170,1	8.636,4	4.155,1	5.334,2	6.456,3
	IC*	475,0	30,6	1.051,6	35.667,4	2.473,3	6.510,0	8.272,1	5.611,9	15.862,4	7.149,0	13.499,4	3.720,3	6.708,7	7.355,4

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Table 4. cont.
Initial Regionalized National Input-Output Table for Argentina in 2006 (transactions)

		ROC Activity Sectors													
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
BAC Activity Sectors	**1**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	7	186,7	13,3	13,6	933,1	2,6	434,7	104,6	58,7	104,4	14,5	17,9	21,8	27,8	46,7
	8	43,3	14,4	0,0	722,1	0,6	0,0	14,8	2,9	61,6	0,0	6,4	649,7	471,0	88,2
	9	334,9	46,5	143,0	5.913,1	150,4	1.773,3	648,8	12,0	1.765,4	299,4	165,6	305,3	151,1	635,5
	10	665,2	22,7	249,5	1.677,8	144,2	2.312,2	2.765,6	46,0	1.167,3	1.070,8	0,0	1.491,2	86,8	649,7
	11	44,6	53,8	445,4	3.305,0	243,0	2.387,1	2.593,2	149,1	1.491,9	188,8	209,9	698,1	270,1	1.550,4
	12	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	13	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
	14	10,4	0,0	226,5	251,0	36,0	1,3	5,2	4,4	100,7	50,9	49,4	52,3	70,6	58,0
ROC Activity Sectors	**1**	5.571,6	7,5	2,0	37.451,2	0,0	24,8	0,0	21,9	2,0	0,0	0,1	7,7	4,3	68,6
	2	0,1	63,4	0,0	616,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,0	0,1	0,0
	3	8,4	0,0	1.853,9	14.625,6	2.601,1	13.087,3	0,0	0,0	37,5	0,0	0,4	6,5	3,3	1,7
	4	10.651,6	469,6	2.884,8	97.490,6	994,4	21.006,0	2.386,3	6.966,9	7.565,0	493,4	1.211,5	2.282,7	4.191,5	4.482,7
	5	154,6	3,0	627,7	2.553,5	4.253,6	184,5	728,0	352,4	389,8	104,9	293,3	772,6	309,9	605,8
	6	664,6	0,0	1.528,5	513,5	12,0	0,0	0,5	863,1	220,1	0,0	1.974,7	630,1	552,6	275,2
	7	913,6	65,7	78,3	6.168,7	18,8	2.803,4	753,1	309,7	927,1	35,0	34,6	136,4	176,3	382,9
	8	86,1	28,9	0,0	1.656,3	1,4	0,0	43,2	7,4	297,8	326,3	236,9	1.628,5	1.177,7	283,4
	9	988,4	138,5	468,8	21.128,6	571,5	6.241,9	3.311,0	252,4	7.193,1	1.514,5	617,3	1.236,9	609,9	3.767,2
	10	709,3	24,3	280,6	1.968,2	174,1	2.693,0	3.783,3	118,6	2.095,5	1.334,1	700,6	1.853,2	107,6	939,4
	11	39,6	47,9	415,3	3.201,3	241,6	2.297,2	2.884,0	285,3	2.106,2	1.047,3	214,7	712,3	275,2	1.811,5
	12	71,3	11,7	73,1	729,6	158,7	16,2	80,4	0,0	824,3	64,3	28,9	47,0	64,2	129,6
	13	29,0	1,5	1.133,7	864,3	440,3	0,0	41,0	90,6	141,5	73,7	753,4	915,5	7.275,6	658,8
	14	44,7	0,1	1.125,0	1.409,2	221,0	7,1	36,6	28,2	1.152,6	139,4	107,4	312,3	426,9	395,8
	IC	21.218,2	1.012,9	11.549,6	203.178,5	10.265,3	55.270,0	20.179,5	9.570,0	27.643,8	6.757,4	6.623,0	13.760,1	16.252,3	16.831,0
	IC*	21.789,5	1.036,3	12.053,0	204.852,7	10.284,9	58.318,4	19.035,1	10.423,8	25.440,5	6.778,5	1.759,9	14.194,9	14.877,7	15.931,8

Source: Own elaboration.

4.2. The RAS method

Biproportional Adjustment, usually called RAS method (Stone, 1962 and Bacharach, 1970) is a well-known technique widely used by analysts to adjust and/or update IO tables. Although the literature covers this topic in detail, we can say that basically the technique takes an initial matrix and a set of row and column vectors as a benchmark to enforce. After several iterations, the method offers a new table with transactions that has a similar structure to the initial matrix, but it enforces the constraints (at rows and columns level)[4].

4.3. Regional Cross-Entropy: additional constraints for the regional problem

The principle of minimum Cross-Entropy (CE) is an inference statistic application based on information theory that consists of estimating an unknown probability density of q when there exists a prior estimate of the density p and new information in the form of constraints on expected values (Shore, John E. et. al, 1981).

The procedure implies to minimize a cross-entropy measure of distance (Kullback-Leibler, 1951) between the initial and the new probabilities. This principle implies that we should choose the posterior q with the least cross-entropy, between all densities that satisfy the constraints.

It could be considered that this method as more flexible than RAS because it allows updating the tables starting from inconsistent data. Moreover, it allows including additional constraints like non-linear constraints of information on each transaction or a set of them (not necessarily total row or column).

In our case, once the BRIO matrix was estimated, the problem has become to find a new set of coefficients (new BRIO matrix) close to the already existing ones (initial BRIO matrix), minimizing the cross-entropy distance but enforcing the constraints.

Thus, let a_{ij}^{*} and a_{ij} denote the original coefficient and the new coefficient, respectively. Then,

$$\min \sum_i \sum_j a_{ij} \ln \frac{a_{ij}}{a_{ij}^{*}} \tag{8}$$

such that,

$$\sum_i a_{ij} = 1; \qquad \sum_j a_{ij} x_j = y_i \tag{9}$$

with $0 \leq a_{ij} \leq 1$, where x and y are vectors of known data (in our case, production and IC data). The solution is obtained by solving a Lagrangian that includes equations (8) and (9). The results combine information about the new coefficients matrix and the initial one:

$$a_{ij} = \frac{a_{ij}\, exp\left(\varphi_i y_j^{*}\right)}{\sum_{ij} a_{ij}^{*}\left(\varphi_i y_{ij}^{*}\right)} \tag{10}$$

Where φ_i are the Lagrange multipliers associated with the row-columns sum and the denominator is the normalization factor. This methodology is used to update the social accounting matrices.[5]

Furthermore, this paper introduces additional transaction and transversality constraints in the minimizing program. The first one has been introduced by means of equation (6). On the other hand, the transversality constraint (which consider the assumptions in the previous Section 3), has been introduced as follow,

$$\prod_{p \neq s} t_{ij}^{p,s}\ 0. \tag{11}$$

where p and s are the purchasing and supplying region and ij are the specific sectors.

---

[4] It has been shown by Bacharach (1971) that RAS converges under some necessary and sufficient conditions.

[5] A methodological approach has been shown by Chisari *et. al* (2010) and Romero (2009). In addition, it could also be seen in Arndt, Robinson and Tarp (2002) to view application focuses on computable general equilibrium models.

It is important to mention that the transaction constraint cannot be applied for the entire matrix because the BAC intra-regional table have been fixed, being the loss of degrees of freedom the main problem. Instead, the equation (11) was enforced for each interregional transaction.

Enforcing these constraints implies less distance between transaction values of our estimated national IO matrix (constructed from the BRIO matrix) and the values of the original one.

One of the advantages of cross entropy is that we have some degrees of freedom in some values from the total column/row. Lamonica (2020) presents an hybrid method combining constrained matrix-balancing methods for the case of the world input-output table. He found that Cross Entropy method boosted by de FLQ has better estimators. Our paper is in line with this method, but, unlike Lamonica (2020), we applied it to adjust a Bi-Regional table.

4.4. Cross-entropy method applied over the initial BRIO matrix.

CE method has been run in GAMS (General Algebraic Modeling System) with different quantities and combination of restrictions at the sectoral level to find the best fit between the original national IO matrix and the estimated one.

Firstly, the program was run without these constraints. Secondly, the first principal purchasing transaction for each sector at national level was fixed. Finally, the second purchasing transaction was computed. This procedure was followed until all possible restrictions were applied without neglecting the objective of maximum approximation in the aggregation.

The final BRIO transaction matrix is shown in the following Table 5.

TABLE 5.
Final BRIO Transaction Matrix for Argentina (2006)

		BAC Activity Sectors													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
BAC Activity Sectors	1	3,4	0,1	0,0	681,0		0,3		0,7	0,1		0,0	0,1	0,1	1,9
	2	0,0	0,1		15,1				0,0					0,0	
	3	0,1	0,0	45,0	1.627,6	244,4	823,7			7,6		0,3	0,6	0,5	0,3
	4	103,1	7,7	218,1	9.300,5	146,0	2.017,0	505,7	1.810,7	2.137,2	230,3	1.005,1	323,0	879,8	982,5
	5	1,6	0,1	48,8	390,7	634,5	21,6	177,9	109,7	124,1	56,9	282,9	134,0	78,3	158,1
	6	6,3		109,1	37,3	1,6		0,1	187,4	42,1		1.109,7	74,6	91,4	49,3
	7	10,1	1,2	6,7	1.219,8	5,0	368,9	335,9	134,2	432,5	27,2	50,2	36,3	69,2	147,6
	8	1,2	0,7		382,3	0,5		23,5	6,1	207,5	380,1	507,0	603,0	633,7	162,4
	9	12,2	2,9	44,7	4.493,4	169,6	906,2	1.626,1	139,2	5.237,8	1.483,8	1.255,1	410,4	294,7	1.937,2
	10	12,6	0,7	38,7	593,3	74,6	563,7	2.672,3	97,0	1.888,9	2.824,4	1.542,7	887,6	74,8	696,7
	11	0,8	1,6	62,9	1.086,0	113,9	530,2	2.253,2	257,9	2.106,2	1.454,7	908,7	376,0	211,7	1.480,8
	12	0,8	0,2	5,9	114,9	36,7	2,0	23,5		302,9	40,6	31,8	9,9	19,9	39,9
	13	0,3	0,0	88,4	77,3	97,2		9,7	29,4	39,0	38,7	643,7	175,5	1.851,5	178,6
	14	0,5	0,0	98,7	267,8	60,3	0,9	14,8	12,9	553,8	113,5	161,1	89,8	180,3	199,7
ROC Activity Sectors	1	47,8	0,1	0,1	5.705,0		2,5		12,3	1,1		0,1	1,9	1,5	28,4
	2		0,9		90,2				0,1					0,0	
	3			91,7	1.265,9	372,8	716,2			15,8		0,7	1,2	0,9	0,5
	4	248,5	13,1	48,9	8.003,1	88,9	548,8	495,5	2.381,7	2.402,3	360,5	1.595,2	291,8	772,8	1.015,0
	5	7,0	0,2	30,9	142,3	361,8	6,8	115,8	99,2	100,1	65,5	359,9	91,6	53,3	106,0
	6	12,0		14,0	24,5	1,2		0,1	312,9	75,2		3.080,0	86,2	109,4	66,3
	7														
	8														
	9														
	10														
	11														
	12	4,9	1,0	6,1	69,1	17,1	1,1	11,9		159,3	33,3	29,8	6,1	12,3	17,0
	13	2,0	0,1	92,9	80,2	47,2		6,2	20,5	28,9	39,6	935,3	120,9	1.372,6	87,3
	14														
	IC	475,0	30,6	1.051,6	35.667,4	2.473,3	6.510,0	8.272,1	5.611,9	15.862,4	7.149,0	13.499,4	3.720,3	6.708,7	7.355,4
	IC*	475,0	30,6	1.051,6	35.667,4	2.473,3	6.510,0	8.272,1	5.611,9	15.862,4	7.149,0	13.499,4	3.720,3	6.708,7	7.355,4

TABLE 5. CONT.
Final BRIO Transaction Matrix for Argentina (2006)

		ROC Activity Sectors													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
BAC Activity Sectors	1														
	2														
	3														
	4														
	5														
	6														
	7	191,7	13,5	14,2	1.027,9	2,6	468,4	101,4	63,9	99,2	14,7	4,7	22,7	25,6	44,7
	8	41,7	14,6		552,5	0,6		13,2	3,1	54,2		1,6	648,1	406,6	81,0
	9	335,1	47,0	145,6	5.430,5	149,4	1.827,7	599,0	13,0	1.592,4	298,0	46,2	310,0	133,9	593,9
	10	649,5	23,0	249,8	1.373,3	142,2	2.328,9	2.507,9	49,1	1.032,5	1.063,7		1.500,5	75,1	601,5
	11	45,1	54,4	456,6	3.111,5	242,1	2.475,9	2.406,1	160,9	1.348,8	187,9	52,1	713,0	241,5	1.452,9
	12														
	13														
	14	10,4	0,0	230,5	195,9	35,7	1,4	4,8	4,8	89,6	50,8	12,7	53,1	62,6	54,2
ROC Activity Sectors	1	5.633,2	7,7	2,0	37.885,1		26,5		23,7	1,9		0,0	7,9	3,8	64,7
	2	0,1	64,4		622,6				0,2					0,1	
	3	8,5	0,0	1.916,6	14.393,6	2.599,7	13.758,6			34,7		0,1	6,7	2,9	1,6
	4	11.074,3	485,5	3.007,6	97.939,9	994,9	22.195,5	2.221,4	7.573,9	6.847,9	492,8	295,6	2.341,1	3.761,0	4.213,7
	5	157,8	3,1	647,6	2.655,5	4.264,4	198,5	689,0	386,3	364,5	105,2	76,0	794,2	279,8	575,3
	6	686,0	0,0	1.592,6	567,1	12,0		0,5	957,4	208,3		530,5	652,2	504,3	261,9
	7	920,8	66,8	80,9	6.147,2	18,8	2.948,0	715,0	335,5	863,7	35,1	9,0	140,4	159,6	362,6
	8	89,3	29,4		1.870,9	1,4		41,6	8,0	283,1	328,8	61,9	1.698,9	1.089,2	271,5
	9	1.012,5	140,2	484,8	22.042,1	571,6	6.635,6	3.136,5	273,5	6.654,9	1.517,9	174,3	1.274,3	552,7	3.569,2
	10	740,0	24,7	293,8	2.302,9	175,1	2.958,3	3.687,1	129,2	1.990,1	1.351,3	183,6	1.942,8	99,3	903,7
	11	41,2	48,5	433,7	3.493,6	242,6	2.469,7	2.756,9	310,3	1.961,1	1.050,6	54,0	740,0	252,6	1.724,6
	12	73,1	11,9	75,7	777,4	158,8	17,6	76,5		778,5	64,6	7,5	48,4	58,2	122,9
	13	32,0	1,6	1.230,8	964,4	449,9		42,1	100,3	143,5	75,6	221,8	972,0	6.769,5	649,5
	14	47,3	0,1	1.190,2	1.498,7	223,2	8,0	36,1	30,8	1.091,5	141,4	28,4	328,5	399,5	382,4
	IC	21.789,5	1.036,3	12.053,0	204.852,7	10.284,9	58.318,4	19.035,1	10.423,8	25.440,5	6.778,5	1.759,9	14.194,9	14.877,7	15.931,8
	IC*	21.789,5	1.036,3	12.053,0	204.852,7	10.284,9	58.318,4	19.035,1	10.423,8	25.440,5	6.778,5	1.759,9	14.194,9	14.877,7	15.931,8

Source: Own elaboration.

5. Case study of Buenos Aires City – multipliers, Rasmussen indicators and footprint analysis

Once the BRIO matrix is obtained, we are able to undertake any kinds of regional studies using an interregional approach, which allows us to take into account the interconnections between the regions.

Considering the objective of the 8th SDG we compute the intraregional and interregional multipliers to analyze sectoral structure of BAC and understand its interregional spillover effects. In addition, we follow the Rasmussen (1956)'s methodology to identify the relevance of each sector in the regional economy network. On the other hand, taking into account the objective of the 13th SDG we compute the BAC regional carbon footprint to determine the sectoral emissions responsibilities.

We present the methodology insights in section 5.1 and then we briefly interpret the results in section 5.2.

5.1. Methodology insights

To analyze the interdependencies between sectors of each region, considering the interregional spillover effects, we follow Rasmussen's methodology. This methodology consists of computing two indices at sector level: the Power of Dispersion index (PD) and the Sensitivity of Dispersion index (SD), which allow us to identify the relevance of each sector for the regional economic network.

To compute these indices, we first have to calculate the Leontief (L) matrix associated with the estimated BRIO matrix. It should be noted that, since it is an IRIO model, we have:

$$L = (I - A)^{-1} = \begin{bmatrix} L^{BAC,BAC} & L^{BAC,ROA} \\ L^{ROA,BAC} & L^{ROA,ROA} \end{bmatrix} = \left(\begin{bmatrix} I & \theta \\ \theta & I \end{bmatrix} - \begin{bmatrix} A^{BAC,BAC} & A^{BAC,ROA} \\ A^{ROA,BAC} & A^{ROA,ROA} \end{bmatrix} \right)^{-1} \tag{12}$$

where,

- $A^{BAC,BAC}$ and $A^{ROA,ROA}$ matrices are the intraregional technical coefficient matrix estimated before,
- $A^{BAC,ROA}$ and $A^{BAC,ROA}$ matrices are the interregional technical coefficient matrix estimated before, and
- I and θ are the identity matrix and null matrix, respectively.

The PD indicator is defined as the relative extent to which an increase in final demand for the products of industry j is dispersed throughout the total system of sectors:

$$PD_j = \frac{\frac{1}{n}\sum_i l_{ij}}{\frac{1}{n^2}\sum_i \sum_j l_{ij}} \tag{13}$$

where l_{ij} are the elements of the Leontief matrix. If the $PD_j > 1$, the intermediate input requirements increase generated by one unit increase in final demand of sector j, will be greater for such sector than for the economy's average. Thus, such sector has a robust backward drag. Conversely, if $PD_j < 1$, the j sector will have a low carry-forward and insignificant effects on the economy.

On the other hand, the SD indicator describes the extent to which the industry system draws on the given i industry, generating forward linkages:

$$SD_i = \frac{\frac{1}{n}\sum_j l_{ij}}{\frac{1}{n^2}\sum_i \sum_j l_{ij}} \tag{14}$$

If the $SD_i > 1$, the increase in the production of sector i will be greater than in the productive system's average; and if $SD_i < 1$, the system average increase will be higher than in sector i, denoting slight effects on the productive system. This index represents a measure of forward linkages.

Considering both indices for each sector, Rasmussen proposes a four-way classification according to the results of both indicators:

- Key sectors when $PD_j > 1$ and $SD_i > 1$, indicating that such sector have an above-average drag with strong forward and backward linkages.

- Strategic sectors when only $SD_i > 1$, indicating that such sector have little effect on the rest of the sectors but highly affected by them.
- Pushing sectors when only $PD_j > 1$, indicating that such sector have significantly affect the rest of the sectors.
- Independent sectors when $PD_j < 1$ and $SD_i < 1$, indicating that such sector have little drag both backward and forwards.

We use this four-way classification to interpret the role of each sector for the two regions. Results are presented in Table 6.

In addition, following Miller and Blair (2009), to analyze the sectoral structure and understand the interregional spillover with IRIO model, we compute various types of multipliers using the Leontief submatrices in (12):

- Intraregional multipliers: are obtained as the column sum of the BAC intraregional Leontief matrix ($L^{BAC,BAC}$) elements. It represents the total value of output from all sectors in the region BAC used to satisfy a dollar's worth of final demand for sector j in the same region. Sectors in BAC with a high intraregional multiplier induce the development of other sectors of the region on the demand side.
- Interregional multipliers: are obtained as the column sum of the ROA,BAC interregional Leontief matrix ($L^{ROA,BAC}$) elements. It represents the total value of output from all sectors in the region ROA used to satisfy a dollar's worth of final demand for sector j in the BAC. Sectors in BAC with a high interregional multiplier induce the development of other sectors on the other region on the demand side.
- Regional multipliers: are obtained as the column sum of $L^{BAC,BAC}$ and $L^{ROA,BAC}$ elements.

TABLE 6.
Rasmussen classification criteria, multipliers and production value (PV) of BAC

Nº	Sector	Classification	Multipliers			PV of BAC (%)
			Intraregional	Interregional	Regional	
1	Agriculture, forestry and hunting	Pushing	1,20	0,54	1,75	0,5%
2	Fishing	Pushing	1,32	0,49	1,81	0,0%
3	Mining and quarrying	Independent	1,25	0,16	1,41	1,7%
4	Industry	Key	1,50	0,58	2,08	23,2%
5	Water, Electricity and gas	Pushing	1,54	0,47	2,01	1,6%
6	Construction	Pushing	1,55	0,29	1,83	5,2%
7	Commerce	Independent	1,45	0,13	1,58	9,1%
8	Hotels and restaurants	Pushing	1,35	0,55	1,89	4,8%
9	Transport and communication	Key	1,57	0,28	1,85	12,8%
10	Financial intermediation	Strategic	1,44	0,12	1,55	8,1%
11	Real estate, renting and business	Strategic	1,26	0,31	1,57	16,9%
12	Public administration	Independent	1,39	0,19	1,58	4,3%
13	Education, health and social services	Pushing	1,36	0,31	1,68	6,6%
14	Other services	Pushing	1,63	0,32	1,96	5,2%

Source: Own elaboration.

It is worth noting that intraregional Leontief matrices ($L^{BAC,BAC}$ and $L^{ROA,ROA}$) represent the intraregional effects, both intra- and interindustry, of an exogenous change in the final demand of the region. On the other hand, interregional Leontief matrices ($L^{ROA,BAC}$and $L^{BAC,ROA}$) represent the interregional spillover effects and its elements accounts a measure of the impacts, both direct and indirect, in one region caused by changes in the final demand in another region.

The result of the mentioned multipliers is also presented in Table 6and interpreted further.

Finally, a footprint analysis allows us to complete the sectoral analysis with an environmental dimension. By computing the footprint analysis, we can identify and quantify the generation of carbon emissions (CO2) associated with each sector of each region, given a fixed productive structure and a precise moment in time.

Technically, to compute the CO2 multipliers for each sector of the BAC and ROA, we post-multiply the Leontief inverse matrix - L in (12) - that contains intraregional and interregional, both direct and indirect relationships between sectors, with the CO2 emissions vector from Chisari et al. (2020b).

Then, we compute the CO2 footprints for both regions by multiplying the multiplier vector and the final demand. The aggregate national sectoral results and BAC's share of the carbon footprint are presented in Table 7.

TABLE 7.
National and BAC Carbon footprint in MtCO2eq, percentages and BAC's share

Nº	Sector	Original Emissions	National FP (MtCO2eq)	National FP (%)	BAC FP MtCO2eq	BAC FP (%)	BAC's share (%)
1	Agriculture, forestry and hunting	139,24	36,96	10,1%	1,50	2,0%	4%
2	Fishing	0,34	0,71	0,2%	0,02	0,0%	3%
3	Mining and quarrying	17,74	5,31	1,5%	1,01	1,3%	19%
4	Industry	58,81	158,10	43,4%	32,26	42,3%	20%
5	Water, Electricity and gas	70,98	34,08	9,4%	9,22	12,1%	27%
6	Construction	5,38	38,90	10,7%	4,16	5,5%	11%
7	Commerce	2,91	13,41	3,7%	4,05	5,3%	30%
8	Hotels and restaurants	0,09	8,85	2,4%	2,94	3,8%	33%
9	Transport and communication	50,22	17,97	4,9%	3,75	4,9%	21%
10	Financial intermediation	0,00	0,24	0,1%	0,01	0,0%	4%
11	Real estate, renting and business	4,35	6,75	1,9%	5,24	6,9%	78%
12	Public administration	1,36	11,73	3,2%	2,53	3,3%	22%
13	Education, health and social services	0,00	7,57	2,1%	2,49	3,3%	33%
14	Other services	13,02	23,88	6,6%	7,08	9,3%	30%
	Total	**364,44**	**364,44**	**100%**	**76,27**	**100%**	**21%**

Source: Own elaboration.

5.2. Analysis of results

As was mentioned above, Rasmussen classification enable us to analyze, given the interregional connections, the role of each sector of the BAC and identify key sectors that depend on inter-industrial supply and demand or even their independency from the other sectors of the region. In addition, the intraregional and interregional multipliers, allow us to understand the behavior of the economy's internal structure and its interregional spillover effects.

The Key sectors identified in the economy of BAC (also with strong regional multipliers) are Industry and, Transport and Communication Services representing 36% of the BAC's PV. The Financial Intermediation services and Real estate, renting and business appear to be Strategics sectors for the inter-industrial interactions, concentrating 25% of the regional PV (see Table 6). The Pushing sectors of the BAC concentrates 24% of the regional production value and are mainly represented by service sectors (Construction, Hotels and Restaurants and, Education, Health and Social Services). Independent sectors in the BAC are Commerce and Public Administration which accumulate the remaining 13.4% of the BAC's PV.

Regarding the multipliers, Table 6 shows that Industry and various service sector (mainly Water, electricity and gas, Construction and Transport and communication) have the highest intraregional multipliers of BAC. On the other hand, the primary sector, Industry and only one service sector (Hotel and Restaurants) have the highest interregional multipliers. This result shows the economic structure differences and interconnections between regions

Concerning carbon footprint, Industry and Service sectors (mainly Water, Electricity and gas, Real Estate and Construction) are the responsible for the BAC carbon emissions.

For instance, we can say that the Industry and Water, Electricity and Gas sectors in the BAC are Key and Pushing sectors, respectively, and they have the highest regional multiplier for this regional economy. However, they are carbon-intensive activities. According to Argentina's climate change commitments, these sectors (very important in the BAC) should switch to the use of low-carbon technology.

6. Conclusions

In the light of the assumed commitment by the Buenos Aires City in the 2030 Agenda for Sustainable Development Goals (SDG's), policy makers require a methodology to quantify the effects of their decisions. This paper contributes to these requirements by presenting an interregional Input-Output analysis of two-region economy, the Buenos Aires City, and the Rest of Argentina.

Since the lack of regional matrices in Argentina, to carry out the interregional analysis we had to build a Bi-Regional Input-Output matrix using a hybrid approach that combines the non-survey methods based on Location Quotients and the well-known matrix balancing methods. Considering the contribution of Lamonica et. al (2020) we prefer to boost the preliminary estimation with the cross-entropy method over the RAS method. The former is also capable of replicate more accurately the national input-output table and takes advantage of the information the researcher has.

Once the BRIO matrix was obtained, we analyze sectoral structure of BAC, its interregional connections and we identify the relevance of each sector in the regional economy network. In addition, we estimate the carbon footprint of Argentina and the share of the Buenos Aires city to analyze the responsibilities of the regional sectors.

As expected, results show that service and industry sectors play an important role in the economy of BAC and some of them have strong interregional spillover effects over the rest of the country. In addition, the results also show that sectors on BAC with the highest regional multipliers are also the ones with highest emissions.

It is important to mention that this analysis could be extended for more sectors and to analyze regional matters in other regions. It also could be extended to the analysis of the impacts of environmental policies, such as the initiative to create local green jobs, the deployment of distributed generation or energy efficiency measures.

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ANNEX

Technical coefficients of national Input-Output table for Argentina in 2006

	Sectores	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Agriculture, forestry and hunting	0,0880	0,0028	0,0000	0,1098	0,0000	0,0003	0,0000	0,0012	0,0000	0,0000	0,0000	0,0002	0,0001	0,0019
2	Fishing	0,0000	0,0233	0,0000	0,0018	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
3	Mining and quarrying	0,0001	0,0000	0,0435	0,0429	0,1396	0,1581	0,0000	0,0000	0,0006	0,0000	0,0000	0,0002	0,0001	0,0000
4	Industry	0,1769	0,1813	0,0693	0,2858	0,0534	0,2558	0,0347	0,3743	0,1114	0,0266	0,0372	0,0583	0,0693	0,1230
5	Water, Electricity and gas	0,0027	0,0012	0,0158	0,0079	0,2282	0,0024	0,0106	0,0189	0,0057	0,0057	0,0090	0,0202	0,0053	0,0166
6	Construction	0,0109	0,0000	0,0363	0,0015	0,0006	0,0000	0,0000	0,0464	0,0032	0,0000	0,0606	0,0161	0,0091	0,0076
7	Commerce	0,0174	0,0291	0,0022	0,0208	0,0011	0,0391	0,0123	0,0166	0,0136	0,0019	0,0011	0,0039	0,0033	0,0110
8	Hotels and restaurants	0,0020	0,0159	0,0000	0,0070	0,0001	0,0000	0,0008	0,0006	0,0053	0,0176	0,0073	0,0582	0,0273	0,0102
9	Transport and communication	0,0209	0,0681	0,0143	0,0793	0,0387	0,0968	0,0576	0,0136	0,1319	0,0817	0,0190	0,0394	0,0126	0,1208
10	Financial intermediation	0,0217	0,0173	0,0124	0,0107	0,0171	0,0604	0,0952	0,0088	0,0480	0,1297	0,0215	0,0854	0,0032	0,0436
11	Real estate, renting and business	0,0013	0,0374	0,0202	0,0191	0,0260	0,0566	0,0796	0,0233	0,0530	0,0666	0,0130	0,0360	0,0090	0,0923
12	Public administration	0,0013	0,0050	0,0019	0,0024	0,0093	0,0002	0,0012	0,0000	0,0121	0,0035	0,0009	0,0013	0,0011	0,0036
13	Education, health and social services	0,0005	0,0006	0,0298	0,0028	0,0256	0,0000	0,0006	0,0049	0,0021	0,0040	0,0231	0,0250	0,1279	0,0181
14	Other services	0,0009	0,0001	0,0317	0,0049	0,0138	0,0001	0,0006	0,0015	0,0170	0,0075	0,0033	0,0091	0,0081	0,0125

Source: Own elaboration based on Instituto Nacional de Estadísticas y Censos (INDEC).

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