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Mine closures and local diversification: Job diversity for coal-mining areas in a post-coal economy

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ABSTRACT

This paper tries to shed light in the research that relates mining activities and regional diversification by studying how a group of local economies heavily specialized in mining diversified its economy after the ending of public subsidies that supported coal extraction. The case of study are the mining municipalities located in the center of Asturias (an autonomous region in Northern Spain), which constituted one the most important coal basins in the country. Although the extraction of coal was one of the main driving forces of the economic activity of the region, the mine pits were located in just a few municipalities across the territory. The economy of this area experienced the most severe effects produced by this policy, which started to be implemented in the early nineties and that gradually led to the cease of coal extraction in 2018. According to recent literature (see Fitjar and Timmermans, 2019), this shift in the public mining policy should have produced a greater diversification in the local economies previously specialized in mining activities, but a proper measurement of this effect can be problematic. Traditional methods, as difference-in-differences, are precluded due to the small number of spatial units directly affected by the treatment. This paper applies the estimation strategy proposed in Abadie and Gardeazabal (2003) of the Synthetic Control Method (SCM) to overcome this problem. The application of the SCM generates a weighted average of the untreated units (non-mining municipalities) that closely matches the treated unit over the pre-treatment period. Outcomes for this synthetic control are then projected into the post-treatment period using the weights identified from the pre-treatment comparison. This projection is used as the counterfactual for the treated unit. This methodology will be exploited together with rich historical data on local employment classified by industry, available for all the municipalities of the region for the period 1978-2018. The level of diversification on each area is quantified by calculating a Herfindahl-Hirschman Index (HHI), being this indicator the variable of interest. Taking the initial years of the 1990 decade as the break-point (when the policies of public support to coal extraction started to end), the application of this technique shows how this sped-up the diversification of the mining area, producing significant differences on the HHI with the counterfactual synthetic unit and indicating that the level of concentration of the economic activity is significantly lower than it would be if the mining activity had prolonged over time.

1. Introduction

A branch of recent literature on economic geography studies the consequences of inter-industry relatedness in one particular region impacts on its economic specialization and producing effects on opposite directions. In the one hand, a variety of positive effects have been identified: local firms may benefit from knowledge spillovers flowing between industries, being this spillovers effect more important if their workforce shares a similar set of skills. Empirical studies showed that regions presenting larger levels of related variety had experienced larger growth rates (Frenken et al., 2007). Boschma and Frenken, (2009) studied how industry relatedness in one region facilitates the emergence of new industries, especially on those economic activities using technologies connected with the regional areas of specialization. These ideas have been the theoretical support for designing regional policies that promote the specialization on economic areas more suitable for the emergence of these cascade of positive effects (McCann and Ortega-Argilés, 2015; Balland et al., 2019).

However, relatedness between industries not only facilitates inter-industry knowledge spillovers but it might also involve interindustry competition in factor markets, especially if the activity of these industries requires a common pool of inputs (e.g., workers with some

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specific skills). Recent literature on resource economics has investigated this aspect from a different approach, by studying the implications for the performance of other industries competing for factors with a powerful resource-intensive industry: the so-called "Dutch Disease" is expected to produce negative effects in the non-resource sectors of these economies (Lashitew et al., 2021). In this branch of the literature there has been previous attempts to identify theoretical channels that help to establish causal connections between the abundance of natural resources and economic diversification (see Frankel, 2012). More recently, Venables (2016) focuses on the specific risks that specialization in resource industries might imply for the economic diversification in developing countries: due to the particularities of this type of activities, it is found that only a small part of the developing countries with abundance of natural resources had been successful in diversifying their economies. In a similar fashion, Alsharif et al. (2017) study systematically the relation between the economic exploitation of natural resources and diversification for a sample of resource rich countries they find strong negative correlation between oil dependency and diversification. This branch of the literature suggests that we should expect that the presence of one dominant natural resource industry has some effects in the degree of economic diversification. If this premise holds, this would imply that similar territories with similar characteristics but differing only in the presence of this natural resource industry are expected to present different patterns in terms of their economic diversification. More specifically, the presence of economic activities that exploit natural resources would produce lower levels of diversification.

This potential pattern has been recently investigated by Fitjar and Timmermans (2019) by connecting it with the idea of regional inter-industry relatedness for the case of the effects generated by one natural resource industry -oil extraction-, which played a dominant role in the regional economy of Stavanger, which was the main oil producer within Norway. These authors conduct their study on a period of rising oil prices to analyze the effects over other industries of the expansion experienced by the oil extraction industry. Their findings suggest that industries related to petroleum grew more than unrelated industries, being the price paid by this comparatively higher growth a rising of their labour costs. And another negative consequence suffered by the rest of economic activities is the loss of human capital, which tends to concentrate in the dominant oil extraction and oil-related industries and that in the long term might lead to a loss of economic diversification in the regional economy.

This paper grounds on the analysis of Fitjar and Timmermans (2019) by analyzing a case of study. On this regard, the paper is mainly empirical and tries to contribute to this branch of the literature by studying the historical trends along the 1978-2018 period for a set of local economies in the region of Asturias, North of Spain. These economies were characterized by the presence of a powerful coal mining industry that was the main economic activity until the early 1990s, mainly supported by public subsidies, to later experience a rapid decline when the public supporting policies dramatically reduced finally leading to the closure of coal pits. On this regard, the analysis presented here differs from the case of study in Fitjar and Timmermans (2019), since in their analysis the local economy was undergoing a process of growth. By constructing counterfactual scenarios, the research conducted in this paper tries to identify and quantify the impact that the presence of a dominant mining industry had on the degree of diversification of local economies. The rest of the paper is structured as follows. Section two presents a brief description of the region that is going to be analyzed, in terms of their recent economic history and its main characteristics. Section three details the empirical strategy used to conduct this analysis, which bases on the use of the Synthetic Control Method estimator proposed in Abadie and Gardeazabal (2003). Section four presents the data to be studied and the results of the analysis, and section five closes the paper with some concluding remarks.

2. Describing the case study: Asturias and the Central Coal Basin

Asturias is a region located in the Northwest of Spain, organized in the form of autonomous community as the rest of Spanish NUTS-2 regions.[1] Although the mining tradition in the region could be dated to ancient times, with gold and silver mines being exploited several centuries ago, the exploitation of coal started in the mid-19th century. Since that time, the Asturian coal pits constituted on of the main suppliers of fossil fuels for the Spanish economy, both as intermediate input for other industries as for the final consumption. During the twentieth century, Asturian coal mining experienced several phases that ranged from severe protectionism during the first years of the dictatorship of Franco -in the 1940s and 1950s-, to the industrial modernization and nationalization of mining industries in the decade 1960s. In the mid-1960s, the private owners of the coal mines requested the nationalization of their companies from the government since they could not cope with the economic losses. As a consequence, the National Institute of Industry (INI) entered into the coal sector by creating in 1967 the public company *Hulleras del Norte Sociedad Anónima* (HUNOSA). Apart from this change in the ownership, from private to public, in the mines, the structural and technological transformation in the Spanish economy caused that by 1970, coal had already been widely replaced by oil as the most extensively used fuel in Spain. Additionally, the entry of Spain in the European Economic Community in the mid-1980s entailed some major changes in the policies designed to support coal mining as a strategic sector. For a more detailed description of the public policies regarding coal in Spain between the mid 1960s to the late 1900s, see Del Rosal (2000). In this context, one milestone that produced a major shift in the Spanish energy policy was the decision 91/3/ECSC of the European Commission.[2] Whit this decision, the public subsidies received by the Spanish mining companies to cover operating losses were effectively put to an end. As a consequence of this change in the policy, the generally unprofitable Asturian coal mines decreased rapidly their activity and their weight in the regional economy dropped.

The consequence of this shift did not distribute uniformly across the regions, but they were largely concentrated in some particular areas of the region. The extraction of coal in Asturias located in the South-center and, to a lesser extent, in the Southwest of the region. The mining municipalities located in the center of the region, an area denominated as the Central Coal Basin (CCB), have traditionally been the main producers of coal within Asturias, while there was a comparatively less important presence of coal mining in the Southwest Basin as well. The core of the territories that constitute the CCB is a group of six municipalities (Langreo, Mieres, Aller, San Martin del Rey Aurelio, Laviana and Morcin). Map 1 shows the geographical location of the CCB area within the region:

The municipalities that form this area presented an idiosyncratic pattern within the general decline or shrinkage of the regional economy during the last decades (Heeringa, 2020). The population located in the CCB area summed up 180,000 inhabitants in the late seventies, accounting for more than 16% of the regional population by that time, while the population on 2018 have reduce to slightly more than 120,000 and they account for less than 12% (Prada Trigo, 2012). In summary, it is possible to distinguish two parallel declining processes that started several decades ago: (i) in the region of Asturias as a whole, as a consequence of several structural transformations on which the progressive mining closures is included, and (ii) a particular shrinking trend of the economies located in the CCB. Fig. 1a and 1b visually represent this process.

[1] Spain is divided into seventeen autonomous communities that correspond with the NUTS-2 level within the hierarchy of Nomenclature of Territorial Units for Statistics (NUTS) of the European Union.

[2] See https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:31991D0003&qid=1635447582692&from=ES.

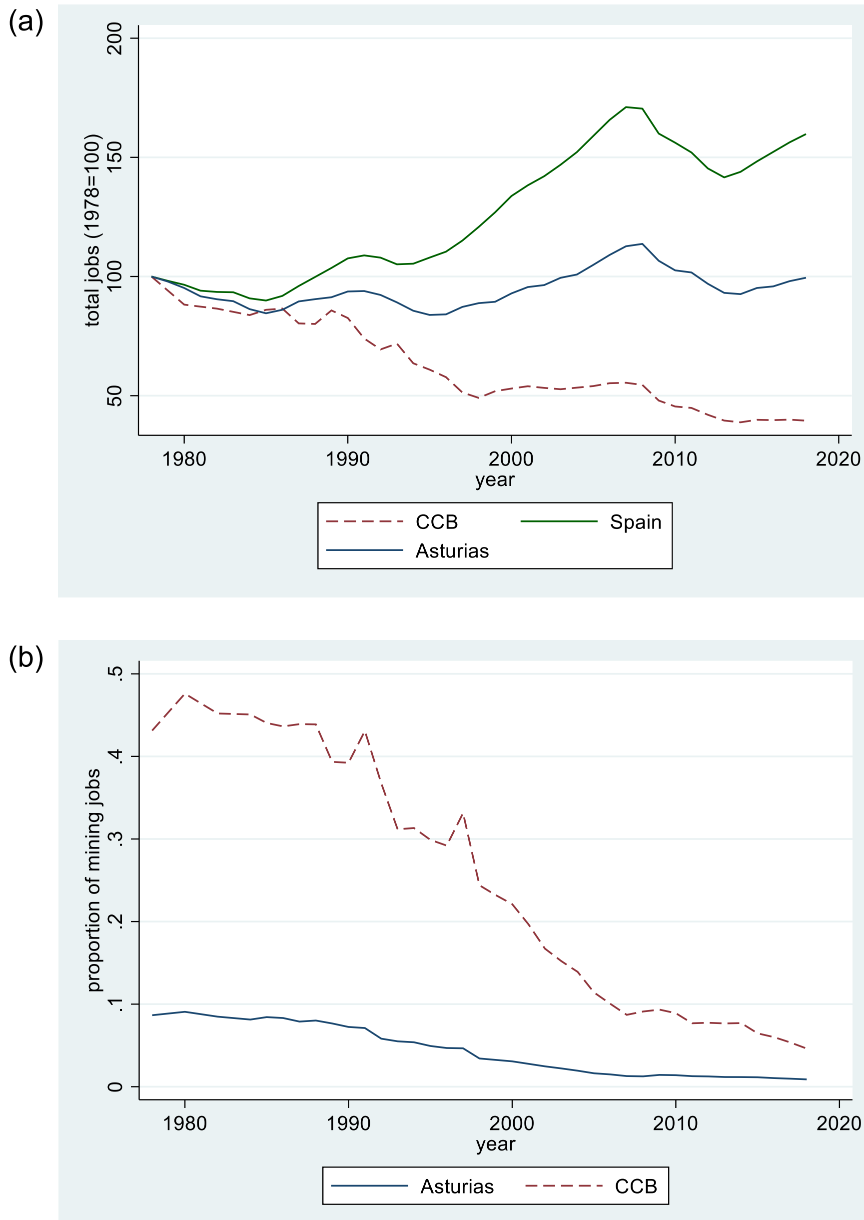


Fig. 1. a: comparative evolution of jobs, 1978-2018 (1978=100), Figure 1b: share of mining jobs over the total, 1978-2018

Fig. 1a plots the temporal evolution from 1978 to 2018 of the number of jobs (taking 1978 as the base year) for the Spanish economy as a whole, the region of Asturias and the CCB. This figure illustrates how in the span of forty years studied, the national economy had experienced a remarkable increase of around 50% in the labour force, while the regional figures where approximately at the same figures as in 1978.[3] The patterns presented in these figures show the progressive decline in both economies, with a steady decrease in the number of jobs, which is partially recovered at the regional level during the positive stages of the business cycle for the Spanish economy -e.g., late 1990s and the 2000s decade previous to the 2008 crisis. However, the economic dynamics in the CCB began to fall during the 1980s decade, to accelerate this decline already in the early 1990s and never recover job figures similar to the initial ones.

[3] The homogenous long-run series of labour figures for Spain has been obtained from the RegData database, produced by the Foundation for the Applied Economics Research FEDEA (https://fedea.net/what-is-fedea/).

Fig. 1b shows the share that jobs in coal extraction represented together in Asturias and on the CCB, revealing the progressive fall of the share of jobs directly involved in mining activities, which represented around 10% of the total jobs in the region in 1978 but more than 40% in the municipalities located in the CCB. This percentage gradually falls throughout the 1980s decade but, again, dropped since the end of the public supporting policies in the early 1990s.

In terms of economic specialization, a comparison between the CCB area with other areas in the region also provides a broader picture of the wide transformation in the span of forty year studied. Table 1 shows the percentages of jobs in agriculture, mining, manufactures and the rest of sectors in the CCB and the rest of Asturias. These shares show that the agricultural sector still had a remarkable importance in the Asturian economy in the 1980s and 1990s, with percentages larger than 10%, while in the CCB was much smaller than in the rest of the region. Moreover, these figures indicate that the CCB economy was largely dominated by the extraction of coal, being the jobs directly related to this activity largest than any other activity until 1990, to gradually

Table 1
percentages of jobs in different activities in the CCB and the rest of the region, several years.

	1980 Rest of Asturias	CCB	1990 Rest of Asturias	CCB	2000 Rest of Asturias	CCB	2010 Rest of Asturias	CCB	2018 Rest of Asturias	CCB
% of jobs in agriculture	22.47%	6.52%	16.57%	4.78%	12.00%	3.45%	5.96%	2.55%	5.18%	1.73%
% of jobs in mining	6.25%	47.60%	4.92%	43.08%	2.20%	22.12%	1.10%	8.90%	0.76%	4.62%
% of jobs in manufactures	26.57%	15.10%	19.65%	10.39%	17.41%	15.03%	17.23%	20.88%	15.10%	18.06%
% of jobs in rest of activities	44.71%	30.78%	58.86%	41.75%	68.39%	59.40%	75.71%	67.66%	78.95%	75.59%

Note: percentages are calculated as number of jobs in one particular industry over the total number of jobs. Means are weighted by population figures on each selected year

decline later. In summary, there were significant differences in terms of economic specialization of the CCB is compared with the rest of the region, but these differences where gradually disappearing to end up in somewhat similar economic structures in 2018.

This prominent presence of the mining industry in the CCB until the early 1990s was obviously heavily conditioning the specialization of the economic activity, and the literature would predict lower levels of diversification. One possibility to estimate to what extent the presence of the coal mining industry was impacting on the diversification level in the Asturian CCB would be to compare some indicator of diversification there with the corresponding values in some reference area. But the result provided by this difference might be misleading since the characteristics, besides the presence of the coal mining industry, of the areas being compared can be different and the identification of this impact would be not possible due to confounding factors. Next section presents the details of the empirical strategy followed to identify this impact by constructing a counterfactual.

3. Methodology: the synthetic control approach

The Synthetic Control Methodology (SCM) is a data-driven approach to small-sample comparative case-studies for estimating treatment effects. The basic idea behind synthetic controls is that a combination of units often provides a better comparison for the unit exposed to the intervention than any single unit alone. Similar to a difference-in-differences design, SCM exploits the differences in treated and untreated units across the event of interest. However, in contrast to a difference-in-differences design, SCM does not give all untreated units the same weight in the comparison. Instead, it generates a weighted average of the untreated units that closely matches the treated unit over the pre-treatment period. Outcomes for this synthetic control are then projected into the post-treatment period using the weights identified from the pre-treatment comparison. This projection is used as the counterfactual for the treated unit.

The methodology was initially developed in Abadie and Gardeazabal (2003), where the authors applied this design to estimate the cost inflicted by the presence of terrorism in the Basque Country. Their hypothesis was that the appearance on the early 1970s of the terrorist activities of ETA -the shock, in terms of the SCM approach- should have impacted on the trend followed by the Basque GDP -the treated unit-, but measuring the size of this impact is problematic by applying traditional difference in differences (DID) because of two reasons:

i It was an idiosyncratic shock, in the sense that other Spanish regions were not significantly affected or not affected at all by the activity of this terrorist group.
ii The trends of regional GDPs before the 1970s were very heterogenous across the Spanish regions.

The alternative estimation technique proposed in Abadie and Gardeazabal (2003) and later applied to estimate the effect of a tobacco control program implemented in California in the mid-1990s, or to the economic effect of the German reunification (see, respectively, Abadie et al., 2010a, 2010b) consists on modifying the traditional regression equations used in panel data estimation or in DID. The intuition behind this SCM estimator is relatively simple: the estimator tries to construct a counterfactual evolution of the variable of interest in the area under study in a hypothetical situation on which the policy never took place. For example, in Abadie et al., (2010a) the authors depict the hypothetical tobacco consumption in California if a bill designed to limit tobacco consumption which was effectively implemented on 1994 had never been put into action. The difference between the observed and the counterfactual (projected by the SCM in the absence of the 1994 bill) tobacco consumption provided an estimate of the effect of this program.

The technical details of the SCM estimator base on the inference techniques applied to panel-data. Suppose that we observe $N+1$ units along time periods $1,\ 2,\ \ldots,\ T$. Unit i is exposed to the intervention during periods $T_0+1,\ \ldots,\ T$ and the remaining N units are not. We take these untreated N units as a set of controls or *donor pool* in terms of the SCM. The SCM estimator consists on defining a response variable Y_{it} for region i on time period t and a non-observed counterfactual Y_{it}^N, which contains the value of the respone variable in region i on time period t region i was not affected by the shock of interest. Y_{it} is defined as:

$$Y_{it} = \alpha_{it} D_{it} + Y_{it}^N \tag{1}$$

Equation (1) defines Y_{it} as the sum of a time-varying treatment effect D_{it}, quantified by means of a binary indicator as:

$$D_{jt} = \begin{cases} & \text{if } j=i \text{ and } t \geq T_0 \\ & \text{otherwise} \end{cases}$$

plus the no-treatment counterfactual Y_{it}^N. Our target is to estimate α_{it} for $t \geq T_0$, which will provide us with information of the impact of the shcok in the unit i. Note that α_{it} is defined as:

$$\alpha_{it} = Y_{it} - Y_{it}^N, \text{ if } t \geq T_0$$

As a consequence, the problem consists on estimating the non-observed counterfactual Y_{it}^N, since Y_{it} is observable. This non-observed countefactual is modelled in Abadie and Gardeazabal (2003) and Abadie et al. (2010a) as:

$$Y_{it}^N = \delta_t + \boldsymbol{\theta}_i \boldsymbol{X}_i + \boldsymbol{\mu}_i \boldsymbol{\lambda}_t + \varepsilon_{it} \tag{2}$$

Where δ_t is an unknown common constant factor across units, $\boldsymbol{\lambda}_t$ is a $(F \times\ 1)$ vector of unobserved common factor, $\boldsymbol{\mu}_i$ is a $(1\ \times F)$ vector of unknown factor loadings and ε_{it} is a zero-mean residual. In equation (2), $\boldsymbol{X}_i$ stands for a vector of $(k \times\ 1)$ observable covariates impacting on Y_{it}^N through the $(1\ \times k)$ vector of non-observable parameters $\boldsymbol{\theta}_t$.[4]

Defining the $(k \times N)$ matrix $\boldsymbol{X}_j^0$ as the matrix that contains the same covariates as in $\boldsymbol{X}_i$ for the $j = 1, \ldots, N$ non-treated units, the SCM estimator tries to find weights $\boldsymbol{\omega}' = (\omega_1, \omega_2, \ldots, \omega_N)'$, where each weight $\omega_{j \neq i} \geq 0$ and $\sum_{j \neq i}^N \omega_j = 1$, that minimizes the norm $\| \boldsymbol{X}_i - \boldsymbol{X}_j^0 \boldsymbol{\omega} \|$ subject

[4] Note that (2) approximates to a traditional panel-data fixed effect equation if $\boldsymbol{\mu}_i \boldsymbol{\lambda}_t = \gamma_i$.

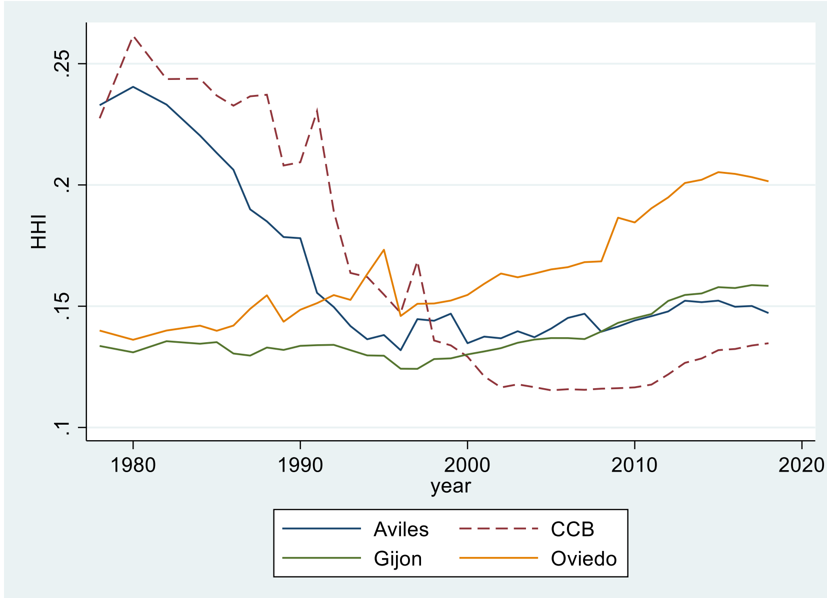


Fig. 2. Hirschman-Herfindahl Index, labour shares, 1978-2018

to these weight constraints. Once this distance is minimized and the optimal weights $\boldsymbol{\omega}^*$ are found, the estimate of the effect of the treatment in the treated unit i in the post-intervention time period $t \geq T_0$ is:

$$\widehat{\alpha}_{it} = Y_{it} - \widehat{Y}_{it}^N = Y_{it} - \sum_{j \neq i}^{N} \omega_j^* Y_{jt}$$

A weighted Euclidean distance is commonly employed to measure the discrepancy between X_i and $X_j^0 \boldsymbol{\omega}$ and the estimation problem consists of minimizing:

$$\| X_i - X_j^0 \boldsymbol{\omega} \| = \left[\left(X_i - X_j^0 \boldsymbol{\omega} \right)' V \left(X_i - X_j^0 \boldsymbol{\omega} \right) \right]^{(1/2)} \quad (3)$$

Where V is a matrix with $v_k \geq 0$ elements in the main diagonal and zeros otherwise that control the relative importance of obtaining a good match between each value in X_i and the corresponding value in $X_j^0 \boldsymbol{\omega}^*$. An optimal choice of V assigns weights to linear combinations of the variables in X_i and X_j^0 to minimize the mean square error of the synthetic control estimator. Implementations of SCM generally choose V such that the resulting synthetic counterfactual unit i approximates the trajectory of the response variable of the affected region in the pre-intervention periods. More specifically, V is set such that the mean square error between Y_{it} and $\widehat{Y}_{it}^N$ is minimized when $t < T_0$ (see Abadie and Gardeazabal, 2003, Appendix B, for details).

4. Estimating the impact of the coal mining industry in the diversification of the Asturian CCB

The SCM estimator described in previous section will be implemented here to estimate the effects on the diversification of the Asturian CCB economy as a consequence of the closure of coal mines that initiated in the early 1990s. Note that the setting is appropriate to apply the SCM estimator because:

i This process of mine closure can be taken as an idiosyncratic policy, which only affected to a few municipalities were coal mines plants were located. Most of the 78 Asturian municipalities were not directly affected by this process.

ii The trends of the local economies in Asturias presented high variability before the intervention period, where some territories were growing and diversifying comparatively much faster than others.

The metric considered here to assess the effect of mine closures will be the Hirschman-Herfindahl Index (HHI) calculated on the shares of jobs, defined as $HHI = \sum_{i=1}^{N} s_i^2$and where s_i represents the share of jobs in industry i over the total number of jobs (see Mack et al., 2007 for an application of this indicator when analyzing regional diversification). This indicator ranges from $1/N$ -perfect diversification with uniform equal shares- to one -no diversification at all, being all the labour taken by one single industry-. In this context the SCM can be applied to quantify the potential shift in the HHI experienced in the CCB economy that can be attributed to the treatment -i.e., the mine closure process- taking as intervention period $T_0 = 1991$. This year is taken as the intervention period because it was the first year on which the decision 91/3/ECSC of the European Commission that put to an end the public subsidies to cover operating losses to mining companies was put to an end.[5]

4.1. Data

The datasets taken to apply the SCM estimator comes from the historical database with local and sectoral detail produced by the official Asturian Regional Statistics Agency SADEI. This institution produced data on labour figures and gross value added at municipal scale for the 78 municipalities of the region of Asturias. Labour data is produced distinguishing 12 different industries: namely agriculture, mining, food manufactures, other manufactures, metals, energy, construction, commerce, transport, hospitality activities, services to companies and other

[5] Note that setting 1991 as the year of the intervention does not mean that the policies under studied were applied only on that year and nothing happened afterwards. On the contrary, it was on this year on which they started to be implemented but they were continued and augmented throughout subsequent periods, as for example, the case of the decision 2010/787/EU, which accelerated the closure of non-competitive coal mines.

services, which allows for studying the degree of economic diversification at the municipal scale. The database also contains estimates of gross value added at municipal scale, but without an industry breakdown.[6] This database allows for having a series of economic indicators from 1978 until 2018 that allows to track the local economic diversity by calculating municipal HHIs. Fig. 2 shows the temporal evolution of the HHI for the CCB area in comparative terms to other municipalities in the region: Oviedo, which is the capital city of the region, and Gijon and

Aviles, which are respectively the most populated and the third most populated cities in the region. Considered together, these four areas represented more than 80% of the population and the labour of the region at the beginning of the period under study.

This figure shows the heterogeneity commented before and how the impact of the treatment cannot be clearly identified by simply trying to find a shift in the HHI before and after the intervention period. While the economic concentration, measured as the HHI, was comparatively higher in the CCB than in the other cities at the late 1970s and during the decade of the 1980s, this indicator dropped in the CCB -similarly to what happened in Aviles- during the 1990s while remained constant in Gijon and started to grow in Oviedo. At the end of the period of study (2018), the CCB presented lower levels of its HHI than Gijon or Aviles and a much smaller value than in Oviedo.

This visualization suggests that the process of mine closure impacted positively on the diversification of the CCB economy, but this simple comparison is problematic for identifying this particular effect, since there are other factors that were affecting to the degree of diversification in the other cities that can be producing these temporal patterns. A proper identification of the effect of the coal mine closures in the CCB would require comparing the temporal evolution of the HHI in the CCB with the hypothetical HHI that would be observed there if the mining policies that provided public support to coal extraction had continued along time.

In order to identify this effect, the SCM estimator will be applied taking the CCB area as the treated unit and the rest of municipalities as the pool of potential donor to construct the synthetic CCB.[7] A group of five very small municipalities with population smaller than 200 people were excluded from this pool. Additionally, another group of three municipalities with some coal mining activity (Cangas de Narcea, Degaña and Teverga) but not located in the CCB were excluded as well, to have a donor pool with municipalities not potentially affected by the treatment, which results in a pool of 69 donors. The covariates considered in the analysis are the size of the local economies, both in terms of the gross value added as in terms of the total number of jobs on each municipality, and the number of jobs not in the coal mining industry, all measured in logs. Additionally, the values of the HHI in 1982, 1988 and 1991 have been included as covariates in matrix $\boldsymbol{X}$, similarly to the procedure applied in Abadie et al. (2010a). Table 2 summarizes these indicators for the treated CCB and the mean of the remaining non-treated municipalities.

4.2. Results of a SCM estimator

Table 2 indicates that just taking a (population weighted) mean of the non-treated municipalities does not seem to produce and adequate counterfactual to compare with the case of CCB: the mean of the non-treated units presented higher levels of economic diversification in the

Table 2
Covariates in the treated unit (CCB) and the donor pool, 1978-1991.

Covariates in matrix X	CCB	Non treated municipalities
Gross Value Added (logs)	13.4265	14.8388
Total Jobs (logs)	10.7638	11.3299
Jobs in non-mining industries (logs)	10.1919	11.2986
Hirschman-Herfindahl Index (1982)	0.2437	0.1194
Hirschman-Herfindahl Index (1988)	0.2372	0.1188
Hirschman-Herfindahl Index (1991)	0.2304	0.1120

Note: the mean values for the control units exclude municipalities with some mining activity out of the Central Coal Basin of the region. Figures reported here are weighted means taking municipal populations in 2018 as weights.

pre-treatment period, and the average size of their economies in terms of total jobs, non-mining jobs and gross value added was remarkably higher.

In order to overcome this problem, the SCM estimator constructs a counterfactual basing on the set of weights $\boldsymbol{\omega}^*$ that minimizes equation (3). The application of this SCM estimator taking as pre-intervention periods the span of years from 1978 to 1991, produces a vector of optimal coefficients $\boldsymbol{\omega}^*$ that gives the largest weight to the city of Gijón (78.5%), followed by the municipalities of Tineo (12.7%) and Las Regueras (8.2%), being the weights assigned to the rest of the municipalities equal to zero. This assignment of weights constructs a “synthetic CCB” that resembles its endowment of productive inputs and sectoral diversification in the pre-intervention years. Table 3 summarizes this:

Table 3 shows how the SCM produces a synthetic unit with much more similar characteristics during the pre-intervention years than simply the mean of the non-treated municipalities. As a consequence, and provided that the covariates selected here truly explain variation in HHI, the trend of this synthetic CCB should match the actual HHI trend between 1978 and 1992. The differences in the HHI between the real and the synthetic unit in the post-intervention years is the estimate of the impact of the coal mines closure over the diversification of the CCB economy.

The set of weights $\boldsymbol{\omega}^*$ obtained by the SCM estimator produce a Root Mean Squared Prediction Error (RMSPE), defined as the root of the mean squared differences between the real and the synthetic HHI between 1978 and 1991, as low as 0.0088. For the post-intervention years -i.e., 1992 to 2018- the synthetic CCB presents a HHI consistently larger than the real CCB, being the mean difference of 0.0813. Fig. 3 below summarizes this:

The graphs displayed on Fig. 3 show how the SMC (dashed line) approximates the trend of the actual HHI in the CCB (solid line) between 1978 and 1991, to show a gap between them from 1992 onwards: the actual HHI is steadily below the counterfactual HHI in the CCB economy if the treatment had not been implemented. This gap can be taken as the shift experienced by the CCB economy in terms of diversification as a consequence of the starting of the mine closure process implemented

Table 3
Covariates in the treated unit, the donor pool and the synthetic unit;1978-1991.

Covariates in matrix X	CCB	Non treated municipalities	Synthetic CCB
Gross Value Added (logs)	13.4265	14.8388	12.9824
Total Jobs (logs)	10.7638	11.3299	10.5367
Jobs in non-mining industries (logs)	10.1919	11.2986	10.5082
Hirschman-Herfindahl Index (1982)	0.2437	0.1194	0.2427
Hirschman-Herfindahl Index (1988)	0.2372	0.1188	0.2343
Hirschman-Herfindahl Index (1991)	0.2304	0.1120	0.2136

Note: the mean values for the control units exclude municipalities with some mining activity out of the Central Coal Basin of the region. Figures reported here are weighted means taking municipal populations as weights.

[6] All data are public and the figures for recent period are available at www.sadei.es, but the agency provided the author with data starting from 1978 upon request. The author highly appreciates this help to get access to the historical data. While data on labour is produced on a yearly basis, figures on gross value added are only produced bi-annually (for the even years) and they were interpolated for the odd years.

[7] The implementation of this estimator has been done in Stata software by using the *synth* and *synth_runner* commands.

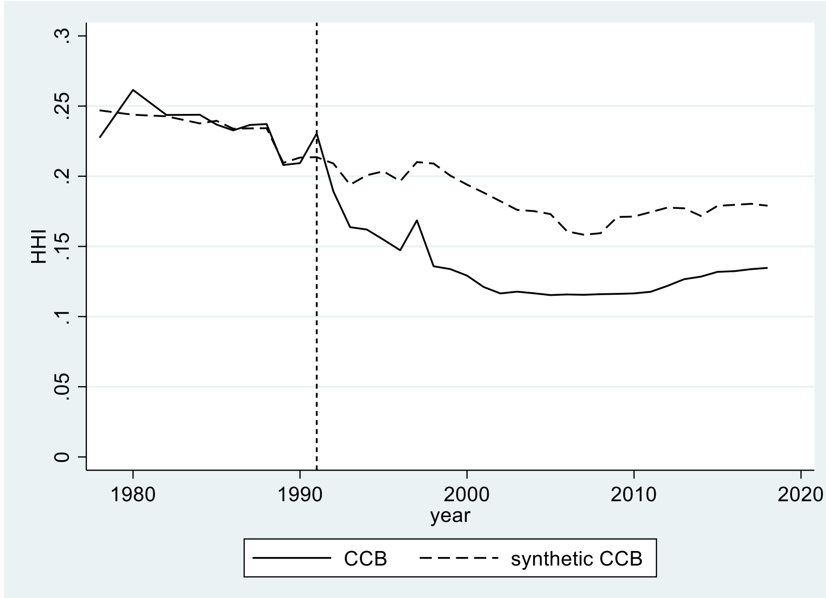


Fig. 3. HHI in the real and synthetic CCB, 1978-2018

from 1991 onwards. To provide a reference of the significance of these results, note that adding the estimated mean effect (0.0813) to the actual values of the HHI in the CCB economy observed in 2018, would produce similar figures to the degree of economic diversification in the city of Oviedo.[8]

4.3. Robustness

One open question in the analysis presented here is to what extent the estimated effects are statically significant and robust to the specification of a different treated unit. Following the procedure suggested in Galiani and Quistorff (2017), a placebo estimation is conducted, running multiple synthetic control estimations in space considering alternative treated units and different time periods (placebo estimates). This procedure allows to extend the analysis presented before in two different ways. One, it allows for doing some diagnosis and statistical inference in the form of p-values, by comparing the estimated main effect with the distribution of placebo effects. Table 3 summarizes the outcomes of such an analysis and provides more detail about the estimated effect of mining closure on the diversification, reporting the estimated difference in the HHI between the actual and the synthetic CCB for each year during the post-treatment period. Table 4 includes a column reporting for each post-treatment year the p-value for testing the hypothesis that this estimated effect is zero

The second possibility that the strategy proposed in Galiani and Quistorff (2017) allows is the comparison of the mean effect along the post-treatment years as a consequence of simulated different choices for the treated unit. Fig. 4 visually represents these alternative effects calculated for the full pool of donors if they have been chosen as treated instead of the CCB.

The results obtained by applying both analyses suggest that the identification of a positive impact of the mining closure on a more diversified economy in the CCB area is robust. The estimates reported in Table 4 indicate a significantly different from zero effect for each year over the post-treatment period, presenting standardize p-values below 5% every year from 1992 to 2018. The graphs of the effects represented in Fig. 4, moreover, reinforce the conclusions obtained for the CCB: the effects plotted there for almost all the set of the alternative donors are above the line that represents the estimated effect for the CCB. Only a few exceptions are encountered -the solid lines below the dahs line represent the estimated effect for the CCB during the post-treatment period-, but they correspond to municipalities that yield a RMSPE in the pre-treatment period much larger -more than three times- than the obtained for the case of the CCB. As explained in Abadie et al. (2010a), placebo runs with poor fit during the pre-treatment do not provide information to measure the relative rarity of estimating a significant effect

Table 4
Estimates of the treatment and standardized p-values; 1991-2018.

	Point estimate	Std. p-values
1992	-0.0363	0.0469
1993	-0.0512	0.0000
1994	-0.0611	0.0156
1995	-0.0706	0.0000
1996	-0.0633	0.0000
1997	-0.0524	0.0313
1998	-0.0850	0.0000
1999	-0.0866	0.0000
2000	-0.0891	0.0000
2001	-0.0883	0.0000
2002	-0.0841	0.0000
2003	-0.0873	0.0000
2004	-0.0877	0.0000
2005	-0.0890	0.0000
2006	-0.0792	0.0000
2007	-0.0731	0.0000
2008	-0.0710	0.0313
2009	-0.0942	0.0313
2010	-0.0910	0.0156
2011	-0.0947	0.0313
2012	-0.0905	0.0156
2013	-0.0873	0.0313
2014	-0.0811	0.0313
2015	-0.0863	0.0000
2016	-0.0935	0.0313
2017	-0.0902	0.0313
2018	-0.0858	0.0313

[8] As correctly pointed out by one reviewer, the reader should note that the analysis conducted here focuses mainly on the measurable direct effects generated as a consequence of the mine closures. However, this closure did not only generate direct employment effects but also indirect and induced effects. Although the non-direct effects could be relevant, they are out of the scope of this paper.

Fig. 4. Placebo SCM estimations for the donors

for a unit that was well fitted prior to the treatment -e.g., the CCB area-. Once these poor-fit cases are not considered, the effect estimated for the CCB is clearly more sizable than for any other municipality.

4.4. Impact on the size of local economies

One interesting question, which can be linked to the previous analysis, is to what extent the process that increased the diversification of the economies of the CCB area contributed to expand or reduce the economic activity in this group of municipalities. A greater diversification could be the consequence of growth of other activities: given the lower competition to employ factors, other industries could be attracted to the area and offset the impact derived from the coal mine closures. Alternatively, shutting down the activity of coal mining might have been not replaced by the emergence of other sectors, but they keep constant on their pre-treatment levels.[9] A larger industry diversification would be observed in either case, but the effects on the post-coal economy of the CCB area would be radically different: the first case could foster economic prosperity on the area, while the second scenario would result in a net loss for these local economies.

A preliminary visualization of the data presented in Fig. 1a helps to identify a negative trend in the dynamics of the CCB economies after 1991, but a more precise quantification of this effect is in order. To investigate which one of these two paths the CCB economies followed, the SCM estimator has been applied as well to the evolution of gross value added at municipal level. The data has been obtained as well from the Asturian Regional Statistics Agency SADEI, but there are some differences with respect to the labour database exploited in previous sections. First, information on gross value added is only produced at aggregated level, which prevents conducting the analysis with any sectoral detail. Second, the time span of the available series of municipal gross value added is slightly shorter than for the case of employment, ranging from 1980 to 2016. Despite these limitations, it is possible to apply the SCM estimator to approximate the effect on the economic trend -proxied by the evolution of municipal gross value added- of the CCB area of the policies that led to coal mine closures.

In this case, the total number of jobs (in logs); the shares of labour employed in agriculture, energy, manufacturing, construction, and services; and the (logs of) gross value added in 1980 and 1990 were taken as regressors. Applying the SCM estimator with these regressors, leads to the specification of a vector of coefficients $\boldsymbol{\omega}^*$ that selects the city of Gijón (72%) and Avilés (24.2%) to account for more than 96% of the trend of the (log of) gross value added of the CCB from 1978 to 1991, being the weights assigned to the rest of the municipalities very close to zero. In the same fashion as the analysis conducted with the HHI for studying diversification, Table 5 shows a summary of the set of regressors for the actual and the synthetic CCB.

The SCM estimator generates a Root Mean Squared Prediction Error (RMSPE) between the gross value added in the actual and the synthetic CCB in the pre-treatment period of approximately 6.7%, being the gap between the gross value added of synthetic CCB 44% larger than the actual CCB for the mean of the post-intervention years. This gap approximates the effect of mine closures on the size of the CCB economies and provides evidence for arguing that the diversification of these municipalities was the consequence of removing the major economic activity of this area, but that the comparatively larger shares of other industries was not enough to compensate the loss produced by the mine closures. Additionally, and similarly to the exercise conducted in the previous subsection, a placebo estimation is conducted by running multiple SCM estimations considering alternative treated units. Fig. 5a

Table 5
Covariates in the treated unit and the synthetic unit;1980-1991.

Covariates in matrix *X*	CCB	Synthetic CCB
Total Jobs (logs)	10.8878	10.9362
% of jobs in agriculture	7.37%	5.83%
% of jobs in manufacture	11.10%	34.31%
% of jobs in construction	5.63%	9.23%
% of jobs in services	29.03%	39.75%
% of jobs in energy	1.00%	1.31%
Gross Value Added (logs, 1990)	13.8382	13.9518
Gross Value Added (logs, 1980)	12.9909	12.9547

Note: the mean values for the control units exclude municipalities with some mining activity out of the Central Coal Basin of the region. Figures reported here are weighted means taking municipal populations as weights.

[9] Note that in such a case, their relative shares are increased and the HHI concentration index would be smaller.

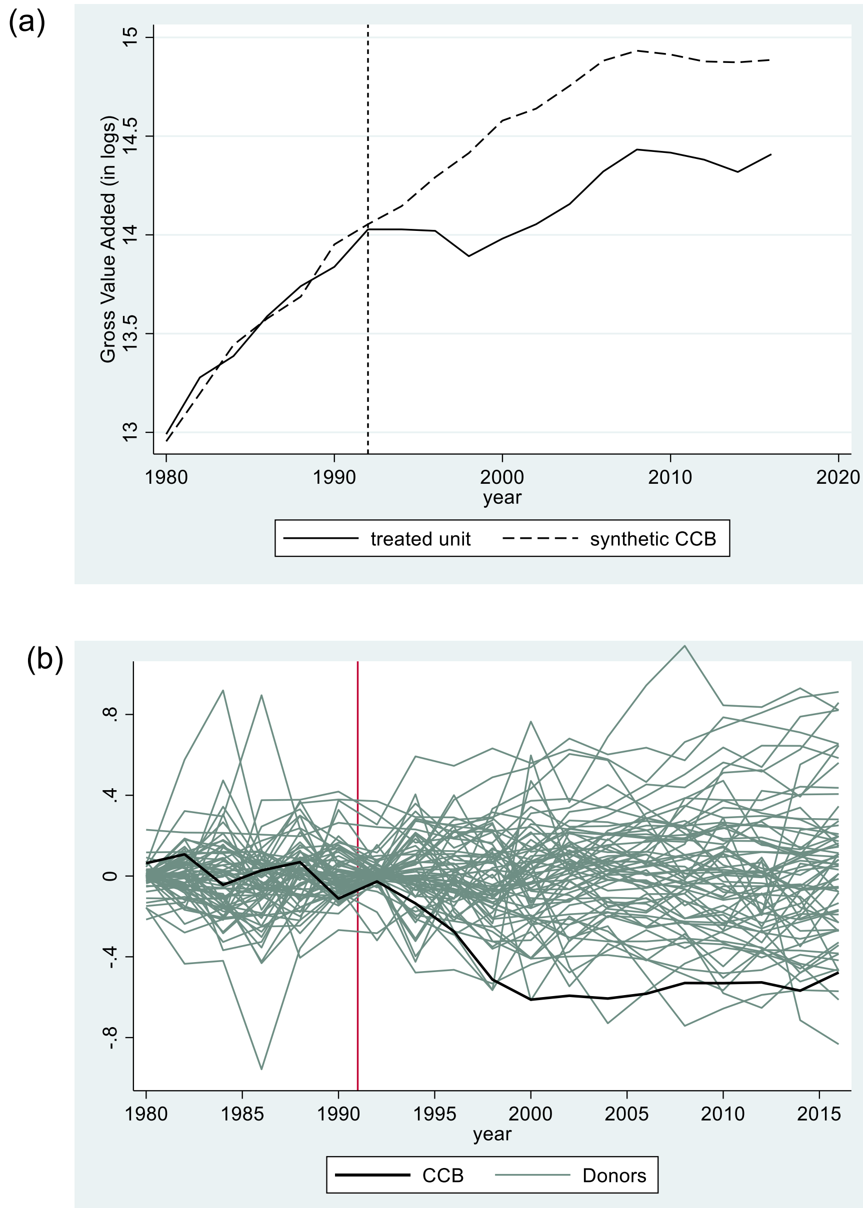


Fig. 5. a: gross value added (in logs) in the real and synthetic CCB, 1980-2016, Figure 5b: Placebo SCM estimations for the donors

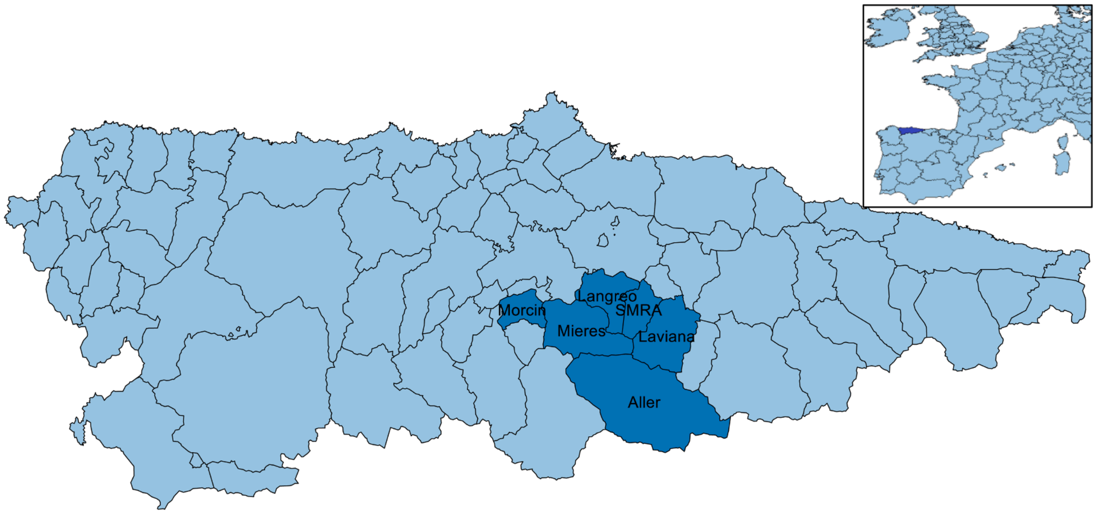
and 5b show these results:

Fig 5a identifies a remarkable gap between the (log of) gross value added of the synthetic (dashed line) and actual (solid line) CCB from 1992 onwards, while these lines roughly overlap previously to the intervention period. The graphs displayed in Fig. 5b suggest that the estimated effect on the gross value added can be attributed with some confidence to the treatment studied and it is not a pure random effect. In summary, the analysis conducted in this subsection helps to understand that the increase in the diversification in the CCB economy was mainly the result of a shrinkage of the aggregate economic activity, and not the consequence of the developing of alternative industries that replaced the predominant role played by the coal mining until the early 1990s.

5. Concluding remarks

The research conducted in this paper tries to contribute to the literature on economic geography that studies the relation between natural resources and economic diversification. The approach followed here is mainly empirical and bases on previous literature that found potential negative aspects of interindustry relatedness. The policies that put to an end the public subsidies to the mining activities in Spain in the early 1990s can be taken as a quasi-experiment that allows for the identification of these potential effects. The application of the Synthetic Control Method strategy proposed in Abadie and Gardeazabal (2003) for the case of the Asturian Coal Central Basin provides empirical evidence that the presence of a dominant coal mining industry was impacting the economic diversification of the studied area. This evidence seems robust to alternative specifications of treatment periods and the choice of alternative treated units. While there is abundant literature on the positive effects of regional relatedness, the research presented in this paper shows empirically that a particular type of relatedness that emerges whit the presence of a resource industry, might produce negative consequences in terms of lower diversification in the long-run.

The findings presented here are relate somehow to the results found in recent literature, as in Fitjar and Timmermans (2019), but with the difference that the case studied corresponds to an economy that experienced a process of deep economic decline: in a situation on which a dominant natural resource industry is booming, Fitjar and Timmermans



Map 1. Asturias within Europe (right corner) and location of the CCB municipalities within Asturias

(2019) found that diversification decreases mainly due to the attraction of workforce from other industries. The opposite scenario is studied here, on which a previously powerful mining industry declines, and diversification rises. However, the channel by which this greater diversification occurs is not purely by relocating workers across alternative industries, but as the consequence of -almost completely- shutting down one industry while no other economic activities emerge to replace it. On this regard, this paper contributes to the discussion on the relationship between a greater diversification and economic welfare, since the former can be produced not because jobs in other industries become more attractive for workers, which is the main channel identified in Fitjar and Timmermans (2019), but as a result of a reduction in the size of the economy.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.exis.2022.101086.

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