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Regions and Economic Resilience

Edited by

Matías Mayor and Raul Ramos

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About the Editors

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Editorial

Regions and Economic Resilience: New Perspectives

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Abstract: The term "resilience" originated in environmental studies and describes the biological capacity to adapt and thrive under adverse environmental conditions. Regional economic resilience is defined as the capacity of a territory's economy to resist and/or recover quickly from external shocks, even improving its situation from the pre-shock status. This editorial introduction provides a summary of the eleven contributions included in the special issue on regions and economic resilience. These eleven articles focus on different channels related to processes of mitigation (resistance-recovery) and adaptive resilience (reorientation-renewal) in a wide variety of geographical settings and scales. They include methodological advances and also relevant results from a policy perspective. The editorial concludes by providing some directions for future research.

Keywords: resilience; regional sustainable development; human capital; labour force; college graduates; regional embeddedness; agglomeration economies; urbanization; innovation; technology absorption; financial development; energy; water pollution; agriculture and forestry

1. Background and Motivation

The interest of scientists and policy makers has moved to analyze the factors that have allowed some regions and cities to resist and/or to recover from the Great Recession. The notion of regional and local economic "resilience" has found currency among those interested in economic geography. The term "resilience" originated in environmental studies and describes the biological capacity to adapt and thrive under adverse environmental conditions. In economics, resilience has been defined as the return to a status of equilibrium [1]. The idea of regional resilience is quite close to the evolutionary perspective within economic geography [2], and the recognition that major shocks may exert a formative influence over how the economic landscape changes over time. In particular, a resilient region is one that retains the capacity to recover quickly from external shocks, even improving its situation from the pre-shock status. The author of [3] identified four dimensions of regional economic resilience to a recessionary shock:

1. Resistance: the degree of sensitivity or depth of reaction of regional economy to a recessionary shock,
2. Recovery: the speed and degree of recovery of regional economy from a recessionary shock,
3. Reorientation: the extent of adaptation of regional economy in response to recessionary shock, and
4. Renewal: the extent to which the regional economy renews its growth path: resumption of pre-recession path or shift to new growth trend.

According to recent literature [4,5], the sort of factors that appear to have been helpful in the past to explain these capacities would include a modern productive infrastructure; a skilled, innovative and entrepreneurial workforce; a supportive financial system; or a diversified economic base, not over-reliant on a single industry. These factors may be endogenous or, given a lack of resources at the local level, may need external support that would justify government intervention, mainly through public funding. Every single element in this list can be studied in each dimension of resilience, making the list of potential empirical analysis too vast. In this special issue, we tried to gather relevant pieces of research related to the two main dimensions of resilience from our point of view, what we have labelled as factors helping to mitigate the effect of shocks and those that allow a quick adaptation to the new context after the shock. Thus, contributions in this special issue are related to processes of mitigation (resistance-recovery): What are the mechanisms by which the region's firms, workers and institutions respond and adjust to shocks? and to adaptive resilience (reorientation-renewal): Why are some regional economies more successful than others are after a shock? Which factors shape regional economic and social success? The next section provides a brief description of these contributions in order to help the reader achieve a better understanding of the joint implications of their results, but also a broader view of the interrelationships between them.

2. A Wide Spectrum of Topics Are Covered in the Special Issue

As mentioned in the previous section, the special issue includes eleven contributions about regional economic resilience where mitigation and/or adaptive resilience are considered using different data sets and different methodologies and statistical/econometric tools.

There is a first group of articles where the process of mitigation is the common denominator. The authors of [6] study the relationship between embeddedness and resilience for the NUTS-2 regions in UK, considering its effect on employment generation. They found that the relationship between embeddedness and resilience is positive up to a certain point, i.e., this is an inverted U-shaped relationship. Consequently, the level of regional embeddedness may constitute one of the most relevant channels for the mitigation process. Article [7] analyzes the effect of agglomeration economies on employment evolution at the local level in Aragon (Spain). In this research, they introduce a different perspective considering the existence of small cities and small businesses, which characterize this Autonomous Community in Spain. The obtained results pointed out that local specialization in industry, construction and services have a negative effect on local employment growth, whereas diversity had a non-significant effect on employment growth. Only a positive effect of diversity in services is found in municipalities with more than 3000 inhabitants. This result shows the performance of the municipalities from 2000 to 2015, so agglomeration economies (specialization and diversification) cannot be identified as a mitigation channel in terms of the employment evolution. The contribution by [8] focuses on a critical issue in the analysis of regional economic resilience: technology and its regional absorption. They highlight that technology is one of the important driving forces for regional resilience and sustainable development, but their results are different from previous approaches. Their empirical results for 30 provinces in China show that, in technology input areas, technology absorption can promote regional economic growth, but in technology output areas, the effect of technological absorption on economic growth cannot be determined. Finally, we include in this group the article by [9] about the effect of the financial and economic regional differences on the capital structure decisions of small and medium-sized enterprises (SMEs). In fact, there is a vast literature about the impact of institutional factors on SMEs but this article offers a regional perspective. The performance of the regional financial sector may mitigate the economic effects of crisis, helping SMEs to access credit markets. The estimation results point out that more developed financial systems favor the use of debt as a financial source, and that bank concentration reduces the use of debt by SMEs.

A second group of articles study mitigation and adaptive resilience processes at the same time. Article [10] analyzes the economic resilience of the regions of seven Eastern European countries (Bulgaria, Hungary, Croatia, Czech Republic, Romania, Slovakia and Slovenia) by, first, constructing resistance and recovery indexes, and, second, looking at their determinants. Their results show the relevance of sectoral specialization and diversity not only as relevant factors in terms of mitigation, but also to drive recovery, although their results should be taken with caution due to the reduced sample size. Focusing on a different geographical scale and a different group of factors, [11] studies the relationship between the female labor force participation and economic development in the EU (28 countries) during the period 1990–2016. They test the hypothesis that this long-term relationship follows a U-shape. The empirical result supports this hypothesis when the 28 European countries are considered. However, when "old" and "new" state members are separately analyzed, the U-shaped relationship is not verified for the EU-15. Their analysis is clearly relevant as a higher participation of women in the labor market can clearly contribute to economic growth and to a more equal and sustainable society. The authors of [12] analyze the decisions of young college graduates to remain or not in lagged regions looking for a suitable job in Korea. In this study, individual characteristics and regional indicators are considered together with non-economic factors such as family or friend ties and affection toward student colleges. The explicit inclusion of these factors constitutes the main contribution of this research. They found that the effect of living cost on the graduates' decisions is greater than that of wages or job security. Also, they highlighted that once a high-school graduate decides to remain at the local university, the probability of remaining there for a long time is higher. A third article where both processes (mitigation and adaptive resilience) are studied is [13]. They present a structural analysis of economic resilience and examine different roles played by major economic sectors in shaping national economic resilience. However, the article does not offer a more classical view based on the identification of strong/weak sectors. The authors emphasize the critical role of the different sectors' relationships and how internal interactions generate resilient outcomes.

The last three articles are more focused in the adaptive resilience channels. The authors of [14] analyze the energy performance of Chinese provinces and their regional evolution in terms of sustainability. In particular, this research shows that investing in low-carbon energy infrastructure has a positive effect on long-term regional economic performance. Therefore, policy makers should be evaluated not only on the direct effect of this measure (the reduction of CO_2 emissions), but also the indirect effect on the regional economy. Article [15] offers an interesting analysis about how territories react, in economic terms, after forest fires. Their main conclusion is that the impact of the forest fires on the agroforestry activity is moderate. Moreover, their estimation of the forest fires' effect on agricultural employment is positive, whereas the effect on forestry employment is slightly negative, as was expected. The impact of the 11th Five-year Plan's environmental policies amendment on Northeast China is analyzed using a difference-in-differences approach by [16]. There are two different strategies operating at the same time. Local authorities are interested in reaching the pollution objectives as a way to be promoted. However, prefecture-level municipal governments are interested in attracting industrial activities (more pollutants). The authors conclude that moving these activities to the border of neighboring regions guaranties the fulfilment of the local authorities' objectives: the maintenance of economic activity and, at the same time, reaching the reduction requirements.

3. More Focused Interdisciplinary Research Is Required

The wide spectrum of topics and analyses among the contributions in this special issue extend the current framework to analyze regional economic resilience from the intersection of several disciplines involving geographers, economists, demographers, but also environmental scientists. The complex links between demographic, economic, social and environmental characteristics of territories are not yet fully understood. Further cooperation between these different fields is needed in order to provide a better identification of the factors that can help to improve regional conditions and citizen's quality of life. Combining different quantitative and qualitative methods as suggested by [17] would also be a positive direction for future research. Lastly, from the analyses in this special issue, it seems clear that the case for policy intervention is clearly justified under some circumstances. However, the way in which policies interact along several dimensions provides the perfect framework to consider the possibility of adopting comprehensive policy packages instead of isolated interventions.

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Article

The Role of Embeddedness on Regional Economic Resilience: Evidence from the UK

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Abstract: This paper examines the role of local industrial embeddedness on economic resilience in UK Nomenclature of Territorial Units for Statistics (NUTS2) regions. The 2008 financial crisis had a profound effect on the socioeconomic conditions of different places. UK regions had significantly divergent experiences based on their capacity to avoid or overcome the shock. Research has shed light on some potential drivers behind this differential resilience performance such as skills, but others, such as the degree of a production system's local embeddedness, are largely underexplored. This paper aims at filling this gap. We hypothesise that the combination of positive external economies of complexity and negative lock-in effects lead to an inverted U-shaped relationship between embeddedness and resilience. We use a novel dataset and method for approximating embeddedness and fixed-effects panel regressions for the period 2000–2010 to control for regional heterogeneity. The results support our hypothesis and suggest that embeddedness has a positive effect on resilience up to a point, after which more embeddedness leads to negative resilience effects. The results call for greater attention on the relationships among local industries, particularly with regards to the recent development of local industrial strategies.

Keywords: economic resilience; input–output; embeddedness

1. Introduction

The 2008 crisis and, in particular, its uneven impact at the subnational level, have brought economic resilience to the centre stage of regional economic research [1–3]. Since then, most global economies have exited the great recession of the 21st century, but the notion of resilience as the capacity to avoid or overcome a negative shock remains more crucial than ever. It is not by chance that even using a narrow understanding of economic resilience still directly relates to nine of the 17 United Nations Sustainable Development Goals, such as goals number 3 *Good Health and Wellbeing* and number 8 *Decent Work and Economic Growth* (Appendix A Table A1). Similarly, the recently developed local industrial strategies in the UK explicitly mention resilience and inclusivity as important considerations of future growth efforts [4].

The importance of resilience has led to several studies examining the determining factors that contribute or hinder the ability of a place (or an individual) to mitigate the negative impact of a crisis. As a result, several resilience-promoting factors have been identified, ranging from human capital to physical geography [1,5].

Within this literature, nuanced characteristics of local industrial structures have been largely underexplored. In fact, only recently have researchers started to examine issues such as the effects of industrial relatedness and technological coherence [6] on resilience. These studies propose links between some qualitative characteristics of local industrial structures and resilience performance. However, partly due to data constraints, it is still unknown how the input–output (I–O) relationships between industries in a locality (and thus the embeddedness of a local economic system) affect resilience performance. This has been particularly relevant at the UK subnational level since the re-emergence of the importance of place-based policies.

Our paper addresses this gap by conceptualising and operationalising the relationship between embeddedness and resilience. In particular, we hypothesise that embeddedness has an inverted U-shaped relationship with resilience, taking advantage of activity complex economies [7] and knowledge externalities. However, we expect this relationship to be positive up to an inflexion point, after which lock-in effects [8,9] impact negatively on the capacity of an area to avoid or overcome a recession.

To test our theorisation, we employ panel data econometric methods. We use employment growth to identify crisis years and approximate resilience and a novel dataset modelling intra-regional sectoral I–O relationships to estimate the level of embeddedness at NUTS2 regions in the UK during 2000–2010. We allow a recession year to vary from one region to the other and use fixed-effects regressions to account for the unobserved heterogeneity between regions. Our findings support an inverted U-shaped relationship between embeddedness and resilience during recession years. The policy implications suggest that localities need to focus on understanding the embeddedness of their industrial structures in greater detail and identify the thresholds that allow them to have a positive rather than a negative effect on resilience. This is particularly relevant to local industrial strategies currently emerging in the UK.

The paper is structured as follows. Section 2 considers the background and our conceptualisation of the relevant notions. This is followed by a description of our data and operationalisation. Section 4 presents our findings, which are discussed in Section 5 together with potential limitations and steps for further research. Section 6 concludes the paper.

2. Background and Conceptualisation

2.1. Economic Resilience and Its Drivers

Resilience has multiple meanings in different fields. As we understand the notion, it originated in environmental and ecological studies with the writings of Holling [10] then was used in hazard and disaster studies (see paper by Noy and Yonson [11] for a useful review) before finding its way into regional economics and economic geography [12–14]. In the latter fields, the notion moved along a spectrum of understandings, differentiated on the perspective of single vs. multiple equilibria vs. resilience as a dynamic approach of continuous adaptation (Table 1).

Table 1. Understandings of resilience.

Perspective	Meaning	Measurement
Resilience of ecosystems (Engineering resilience)	Movement back to equilibrium (Single equilibrium approach)	Speed or amount of force counterbalanced
Ecology (Ecological resilience)	Movement to new equilibrium point or stability domain (multiple equilibria with adaptation perspectives)	Amount of force sustained until change of structural characteristics
Resilience as a dynamic process	Adaptation to continuously changing environments	Capacity to adapt and create new development paths

Source: Kitsos (2018) [15].

Initial approaches have used the notion of engineering resilience, where a crisis throws a place off their pre-determined path and a locality is resilient if it quickly bounces back [16]. Refuting this deterministic approach, multiple equilibria perspectives argued that an area might move from one equilibrium to another higher or lower one with the potential for permanent hysteretic effects [17–19].

This means a shift in the deterministic trend of engineering resilience approaches. The most recent understanding of the term disputes the static view of equilibrium-based approaches and treats resilience as a dynamic process. This adds an evolutionary perspective to the notion, which is seen as adaptation of socio-economic systems to continuously changing environments [3,20,21].

The pluralism of definitions has been accompanied by a variety of operationalisations that included both composite indicators as well as single proxies [15,22]. The multifaceted nature of economic resilience has prompted attempts to create composite indicators in order to reflect the notion [23–25]. These indicators have several advantages such that they allow the consideration of more than one aspect of the notion, they assist the comparison of different places with a single measure, and they can represent difficult concepts in a simple, widely understood metric. At the same time, though, their use is not yet universally accepted due to the influence of the creator on matters such as the aggregation and the weighting of the different dimensions [26].

Consequently, it is not surprising that the majority of empirical studies use single measures of economic output and/or labour market performance [1,2,27]. Measures such as gross value added (GVA) and labour market indicators offer the advantage of timely and regular publication, consistency in their production, and understanding by a wide range of stakeholders. In particular, labour market performance could reflect wider socioeconomic conditions, since the lack of employment could lead to significant knock-on effects on wellbeing and the economy, such as scarring effects, family breakdowns, and criminality, as well as reduced demand conditions in a local economy [28–30].

Using these indicators, several studies have identified factors that help or hinder local economic resilience. The range expands from skills [1,27] to economic structure characteristics [31] and from territorial capital [32] to agency, institutions, and geography [5,20,33,34].

Human capital emerges as a significant determinant of economic resilience. Predominantly proxied by the share of population with a certain qualification level (e.g., degree and above level qualifications), human capital (or the lack of it) has a positive (negative) influence on the resilience performance of localities and individuals in different countries [1,27,35,36]. This result is among the most consistent in resilience studies both in terms of the time periods considered and the areas under consideration [15].

Factors that are more inconclusive revolve around entrepreneurship and the industrial structure of localities. Through its positive effects on growth and employment [37,38], entrepreneurship would be expected to have a positive effect on the mitigation of a crisis impact. However, quantitative examinations to date suggest that the relationship between entrepreneurship and resilience is more complex and could be influenced by factors such as the local prevalence of foreign businesses [39]. Both Kitsos and Bishop [1] and Rocchetta and Mina [6] failed to identify a positive effect of new firm formation on the resilience performance of localities in the UK. Bishop [40] suggests that qualitative characteristics of local knowledge such as size, (un)relatedness, and diversity mediate the extent to which entrepreneurship can influence adaptation and resilience. Similarly, Kacher et al. [41] found evidence that higher, pre-crisis entrepreneurial dynamism was detrimental during the recession period of the 2008 crisis, whilst it bolstered growth in local areas during the recovery period.

The effects of the industrial structure on resilience are similarly perplexing. The mix of industries in an area is often a prime suspect with regards to the origin and the propagation of crises in different areas. Economic downturns usually have differential impacts on industries with varying demand, supply, location, and competition characteristics [42]. In the UK, the oil price shocks of the 1970s, for example, had a greater impact on manufacturing, whilst the 1990s shock affected services more [31].

The systemic nature of the 2008 crisis makes the identification of the sectoral impact of the crisis more difficult. Finance and business services had the highest job losses during 2008–2009, whilst manufacturing had its biggest drop in output for the last 30 years [43]. Kitsos and Bishop [1] did not find statistically significant effects of employment in a range of sectors on the resilience of UK Local Authority Districts, whilst Lee [27], focussing on UK cities, found that high employment shares in either employment in financial services or manufacturing negatively affected the crisis impact.

Bristow et al. [44] examined economic resilience across Europe and found mixed results on the effect of manufacturing and a positive impact of employment in services on economic resilience, whilst Hill et al. [16] suggested that, in the US, employment in durables' manufacturing had a negative impact during the downturn period and a positive impact during recovery.

Similarly inconclusive is the evidence on specialisation and diversity. Diversity would be expected to reduce the impact of a crisis during the recession stage (in a similar manner to portfolio diversification), whilst specialisation could increase output and employment growth at a greater pace during the recovery stage [45,46]. However, several studies failed to identify a statistically significant effect on economic resilience for either specialisation or diversification [1,27,47], whilst Di Caro [48] and Li et al. [49] found a positive effect of diversity on resilience.

Two possible and interlinked explanations are provided for the above inconclusive evidence. The first is offered by Martin et al. [31], who suggested that the importance of industrial structures on a crisis' outlook has decreased since the 1970s. The increasing complexity of economic activities means that downturns can increasingly affect a larger number of industries, and hence their negative effects are traversing across the log established industrial classifications. Simultaneously, though, this increasing complexity means that more nuanced understandings are needed in order to unravel the relationship between local industrial structures and economic resilience.

In this sense, the latest approaches move beyond the traditional understanding of local industrial structures as the share of employment in a certain industrial code towards notions that attempt to understand the relationship between industries at a local level. Rocchetta and Mina [6], for example, used the notion of technological coherence reflected by the cognitive proximity of patenting activity in UK NUTS3 regions. They found that places with higher technological coherence exhibited better resilience performance, even when accounting for traditional measures of relatedness.

This paper aims to contribute to this discussion by considering the notion of the embeddedness of local industrial structures and its relationship to regional economic resilience. It is the first time these concepts have been considered together. This is partly due to the current state-of-the-art in the relevant literature as well as the fact that it is the first time we have a dataset that can approximate industrial relationships at the subnational level. Below, we outline the impact channels through which embeddedness is expected to affect resilience performance, as well as our theorisation on these impacts, before moving on to the methodology of measuring embeddedness.

2.2. Embeddedness and Resilience

The value of embeddedness of local economic structures is featured in a range of different literatures in economics and economic geography. Territorial embeddedness and geographical proximity may give rise to positive externalities and reduce risk. However, over-embeddedness may also lead to lock-in effects and a lack of dynamism. Consequently, it is hypothesised that embeddedness and economic resilience have an inverted U-shaped relationship where resilience is increasing with embeddedness up to a point, after which increased embeddedness reduces a system's capacity to overcome a shock.

In 2002, Parr [50] and Parr et al. [7] built on the work of Ohlin [51], Isard [52], and Robinson [53] to unpack agglomeration economies into six categories. Figure 1 summarises their work considering externalities on the basis of:

- Scale, scope, and complexity (vertical categories);
- Whether it is internal or external to the firm (horizontal dichotomy);
- Spatial constraint (darker shades more spatially constrained externalities).

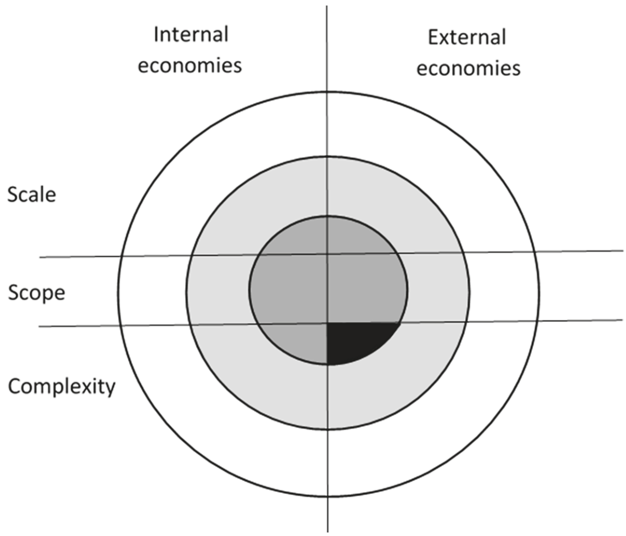

Figure 1. Categorisation of agglomeration economies according to Parr and Parr et al. [7,50,54].

This paper focuses on the less examined, bottom right quadrant of spatially constrained complexity externalities or "activity-complex economies" [7] (p. 677). These denote economies that are derived from the collocation and the interaction of firms at the local level (e.g., locally embedded economic structures). The increased embeddedness can thus lead to reduced transport costs, the use of by-products as intermediate inputs, an improvement of communication, and reduction of hierarchy coordination costs [55]. In addition, it can lead to reduced need for inventories and more just-in-time production.

In the Global Production Networks literature, these externalities have been captured by the notion of territorial embeddedness. This type of embeddedness increases the interactions of local agents and leads to increased institutional thickness and trust. These in turn raise the probability of tacit knowledge diffusion [56–58].

In regional economics, embeddedness reflects the spatial proximity of different industries and actors. This proximity increases the potential for recombination of existing knowledge and gives rise to relatedness, both of which are crucial for innovative activity. In this sense, locally embedded economic systems increase knowledge diffusion and foster untraded interdependencies that generate growth [8,9].

From the above, it is clear that there is extensive literature on the benefits of geographically embedded industrial structures on local economies via numerous localised externalities. These benefits are particularly important during economic downturns. Externalities that lead to cost reductions decrease the average unit cost and allow local industries and firms to remain competitive at times of heightened competition. Similarly, externalities that increase trust and knowledge flows may assist diffusion of resilience strategies and increase innovation that generates new products and services, which ensures the sustainability of business.

However, when local economic systems are too embedded, they are liable to suffer from lock-in effects [8,9,56]. The lack of external knowledge flowing into a local economy may have adverse effects on its long-term innovative activity and competitiveness. An indicative example is given by Grabher [9] on the Ruhr area where the main elements of its successful industrial district were the ones that locked it into "rigid specialisation". During a recession, a locked-in economy may at first avoid the crisis impact, but in the medium-term, it would be expected to suffer greater loss of employment or economic growth due to lack of adaptive capability.

It is then expected that embeddedness and resilience will have a relationship where resilience will increase together with embeddedness up to a point, after which more embedded industrial structures will exhibit reduced resilience performance. This relationship has not been examined to date, mainly due to our lack of data approximating the embeddedness of local economic systems. In this paper, we use a newly developed dataset to identify the magnitude of linkages within NUTS2 regions in the UK and examine the aforementioned hypothesis. The next section outlines how we measure embeddedness and an attempt to empirically test our hypothesis.

3. Data and Operationalisation

Before examining the relationship between embeddedness and resilience, it is crucial to operationalise the concepts and describe the database used in the empirical examination. Similar to the majority of resilience studies, we use labour market performance to approximate resilience. Our approach allows each region to have a region-specific crisis whilst we elicit resilience by examining the effect of embeddedness on labour market performance during the crisis years.

In particular, we use regional employment growth as our dependent variable and fixed-effects panel data methods with a dummy variable taking the value of 1 when a region has negative employment growth and 0 otherwise. This method allows us to control for all the region-specific time-invariant characteristics. In addition, the crisis dummy variable enables us to control for the effect of the explanatory variables on the dependent one during a downturn, revealing the relationship between embeddedness and economic resilience.

It is worth mentioning that this is one of a multitude of ways to approximate resilience, with other notable methods being the ones of Martin [18] and Lagravinese [59], who measured resilience by comparing regional to national labour market performance. In our case, the interest is in identifying the effect of embeddedness on resilience by comparing the performance of a region to itself rather than comparing regions to each other. This method is similar to that of Rocchetta and Mina [6] in the sense that it measures the effects on resilience via an interaction with a crisis dummy, and it is similar to that of Sensier et al. [22] in that it allows regions to individually have a downturn instead of being determined by national performance.

As discussed above, the local industrial structure is expected to be a significant determinant on an area's resilience performance [18,60]. In his seminal work on regional economic structure and sensitivity to shocks, Conroy [60] also suggested that the reaction of each region to a crisis would depend on the degree of what he called "sectoral inter-relatedness". These ripple effects (due to the sectoral interdependencies) are considered crucial in explaining how the economic structure affects the resilience performance of places and is represented in our paper in the embeddedness or the domestic production ratio concept [61].

The notion and its measurement below indicate the share of local production that is generated by using local inputs. It reflects the importance of intermediate sectoral inter-relatedness over the total production, the direct linkages in the production process, as well as the technology of production by sectors (how "independent" the intermediate inputs used in local production are). Thus, embeddedness can be defined as:

$$Emb_j = \frac{\sum_{i=1}^{n} Z_{ij}^{d}}{\sum_{i=1}^{n} Z_{ij}^{d} + Z_{ij}^{m}} \quad (1)$$

where Z is the intermediate flows between sectors i and j (n being the total number of sectors), d stands for domestic flows (e.g., transactions between sectors within the same region), and m represents imported inputs from outside the region.

Following the discussion in the previous section, in a context where production processes are more and more fragmented into separate activities and countries specialize more and more in particular stages of production [62], having a higher embeddedness ratio could lead to different results. It could be positive, meaning that a higher proportion of inputs from within the region could help avoid exposure to external shocks; on the contrary, it could have negative effects if it means lower productivity and the incapability to participate in international markets, limiting their potential economic growth.

The most suitable framework for analysing the domestic or the imported content of the sectoral structure is a multiregional I–O table [61]. As can be seen in Figure 2, this two-region case shows the intermediate flows between region *r* and region *s* (inter-regional flows) but also the transactions between the sectors within regions *r* and *s* (intra-regional flows).

	Region r	Region s	Private and public final demand	Exports	Total output
Region r	$Z_{ij}^{d\,rr}$	$Z_{ij}^{m\,rs}$	F_i^r	E_i^r	X_i^r
Region s	$Z_{ij}^{m\,sr}$	$Z_{ij}^{d\,ss}$	F_i^s	E_i^s	X_i^s
Primary inputs	V_j^r	V_j^s			
Total inputs	X_j^r	X_j^s			

Figure 2. Representation of a multiregional input–output framework.

The data used in measuring embeddedness come from the only database that provides interregional trade data at a subnational level. This is the recently published EUREGIO [63,64]. In relation to our study, it provides spatially disaggregated I–O information for 37 NUTS2 UK regions (2006 NUTS2, see Table A6 in the Appendix A) at a 14 sector disaggregation (see Table A7 in the Appendix A) and data on imports and exports by country/region of origin and destination (as a multiregional I–O framework). It was constructed using the World Input–Output Database (WIOD) [65] as the original information (which was based on national accounts) combined with Eurostat's regional accounts on NUTS2 sectoral value-added, investment, and consumption levels. The information for the interregional trade data comes from the PBL Netherlands Environmental Assessment Agency, the only fully consistent database on trade in goods and services at the NUTS2 regional level (for 2000). Updates of this interregional trade flows are produced using freight transport data from Eurostat (for goods) and business flight ticket information (for services).

The measure of sectoral embeddedness described in Equation (1) is used to provide a single indicator of local economic embeddedness for each region. To do this, we aggregate the weighted sectoral embeddedness using the ratio between the output of each sector over the total output of the regional economy as a weight:

$$\overline{Emb} = \frac{\sum_{j=1}^{n} w_j \, Emb_j}{\sum_{j=1}^{n} w_j} \quad (2)$$

where the weight can be defined as $w_j = X_j^r / \sum_{j=1}^{n} X_j^r$, with X_j^r being the output by sector *j* for each region *r*.

The rest of the variables used in the analysis below refer to the identification of a crisis year as well as selected control variables from the existing literature. As discussed, a new approach is introduced in identifying the crisis. Dummy variable *Crisis* takes the value of 1 when a region experiences negative employment growth rates and 0 otherwise. In this way, it is possible to measure the crisis on each region separately and expand the identification of a crisis year within our sample beyond the 2008 financial crisis. As a result, this approach allows each region to have a crisis year throughout the whole time period of our dataset, enabling us to measure the effect of local embeddedness on a region's labour market performance.

Furthermore, we control for a set of characteristics expected to explain regional employment growth. The effects of entrepreneurship on employment growth are accounted for by measuring firm births per 1000 population (FB_pop) and using Value Added Tax (VAT) registrations and the Office for National Statistics' (ONS) Business Demography data. Economic growth is accounted for by considering GVA growth (Growth) for each region, whilst the level of skills is controlled by variables measuring the share of the population with a National Vocational Qualification level 4 and above (NVQ4+) and those without any (NO_NVQ) to account for the effects of human capital on employment generation. Finally, we use population density (Pop_den) to proxy Jacobs' externalities arising from diversification of economic activity and its benefits to employment growth. A summary of the explanatory variables used in the analysis and their main descriptive statistics is shown in Table 2. In addition, Table A8 in the Appendix A shows a correlation matrix between these variables, trying to provide a clearer picture of the possible association between them. As can be seen, embeddedness is highly correlated to higher entrepreneurship rates and greater population densities. This is expected in the sense that more urbanised or denser areas would be expected to offer greater industrial mix and opportunities for purchasing local inputs, whilst they would also exhibit higher entrepreneurship rates. In order to alleviate any multicolinearity concerns, we introduce the control variables one at a time.

Table 2. Descriptive statistics of the explanatory variables.

Variable	Obs.	Mean	Std. Dev.	Min	Max
Emb	396	0.487	0.152	0.056	0.811
Emb_sqr	396	0.260	0.133	0.003	0.658
Emb_man	396	0.087	0.039	0.006	0.172
Emb_man_sqr	396	0.009	0.007	0.000	0.030
Emb_agr	396	0.007	0.005	0.000	0.023
Emb_agr_sqr	396	0.000	0.000	0.000	0.001
Emb_con	396	0.043	0.013	0.007	0.069
Emb_con_sqr	396	0.002	0.001	0.000	0.005
Emb_ser	396	0.328	0.129	0.031	0.751
Emb_ser_sqr	396	0.124	0.097	0.001	0.564
Crisis	396	0.328	0.470	0.000	1.000
FB_Pop	396	3.656	1.215	1.562	10.218
Growth	396	0.038	0.030	−0.057	0.119
NVQ4+	396	25.966	5.251	17.300	48.400
NO_NVQ	396	14.140	3.537	7.400	23.600
Pop_den	396	5.804	1.258	2.197	9.207

The independent variables include our embeddedness measure *Emb* and its square term *Emb_sqr* as well as their sectoral equivalents for manufacturing *(Emb_man* and *Emb_man_sqr)*, agriculture *(Emb_agr* and *Emb_agr_sqr)*, construction *(Emb_con* and *Emb_con_sqr)* and services *(Emb_ser* and *Emb_ser_sqr)*. They also include a *Crisis* dummy variable as well as entrepreneurship *FB_pop*, economic growth *Growth*, human capital *NVQ4+* and *NO_NVQ* and population density *Pop_den*.

The method we use to identify the effect of embeddedness on economic resilience in our panel is a fixed-effects regression. This allows us to control for the unobserved time-invariant characteristics of different regions and is expressed by the following equation:

$$Empgrow_{i,t} = \alpha + \beta_1 * Emb_{i,t} + \beta_2 * Emb\_sqr_{i,t} + \beta_3 * Crisis_{i,t} + \gamma_1 * Emb_{i,t} * Crisis_{i,t} + \gamma_2 * Emb\_sqr_{i,t} * Crisis_{i,t} + \delta_j * {}_{i,t} + u_i + \varepsilon_i \quad (3)$$

where $Empgrow_{i,t}$ is the employment growth in region i and year t, $Emb_{i,t}$ is the weighted measure of local economic embeddedness, and $Emb_{i,t} * Crisis_{i,t}$ is its interaction term that allows us to control for the effect of embeddedness during a downturn. Moreover, to test whether the effect of embeddedness on resilience is linear, we add the squared term of embeddedness interacted with the crisis dummy variable $Emb\_sqr_{i,t} * Crisis_{i,t}$. This shows us whether the relationship in question has any inflexion points, thus supporting our hypothesis. Finally, ${}_{i,t}$ is the vector of control variables discussed above, whilst u_i and ε_i are the region-specific fixed effects and the error term, respectively.

To examine the relationship between embeddedness and resilience, we set out to test two hypothesis. The first considers the effect of embeddedness on employment growth. This allows us to identify the direct connection between them. We expect that this relationship is curvilinear, suggesting that embeddedness is beneficial to employment growth up to an inflexion point, after which the relationship turns negative. The second hypothesis looks at the moderating effect of economic crisis on the embeddedness and employment growth relationship. This means that embeddedness becomes more significant during recession conditions since it can enhance resilience up to a point, after which increased embeddedness leads to worse resilience performance.

The two hypothesis can be summarized as follows:

Hypothesis 1 (H1). *There is an inverted U-shaped relationship between local industrial embeddedness and regional employment growth.*

Hypothesis 2 (H2). *An economic crisis moderates the inverted U-shaped relationship between local industrial embeddedness and regional employment growth.*

4. Results

Overall, the results support our hypothesis that local economic embeddedness has an inverted U-shaped relationship to employment growth. During crisis years, this relationship is reinforced, and embeddedness contributes to regional resilience up to a point, after which the effect turns negative. Our estimation strategy starts by considering the non-linear effect of embeddedness and its squared term on employment growth controlling for different regional determinants (Table 3). This first set of results includes pre and post-crisis periods, allowing for more longitudinal variation. Following this, we incorporate the moderating effect of economic recession by adding the interaction terms of $Emb_{i,t}$ and its squared term with $Crisis_{i,t}$. This set of specifications allows us to isolate the effect of embeddedness on resilience during a shock (Table 4).

Table 3. The effect of embeddedness on employment growth during 2000–2010.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Emb	0.552	0.575 **	0.561 **	0.539 **	0.504 **	0.464 *	0.455 **
	(0.602)	(0.235)	(0.218)	(0.211)	(0.218)	(0.224)	(0.204)
Emb_sqr	−0.229	−0.491 *	−0.437	−0.463 *	−0.500 *	−0.462	−0.445 *
	(0.563)	(0.253)	(0.243)	(0.231)	(0.262)	(0.276)	(0.242)
Crisis		−0.0355 ***	−0.0346 ***	−0.0335 ***	−0.0328 ***	−0.0331 ***	−0.0331 ***
		(0.00527)	(0.00563)	(0.00589)	(0.00580)	(0.00579)	(0.00587)
FB_pop			0.00329 *	0.00320 *	0.00530 ***	0.00535 ***	0.00525 ***
			(0.00150)	(0.00151)	(0.00161)	(0.00143)	(0.00147)
Growth				0.0587 **	0.0238	0.0203	0.0224
				(0.0238)	(0.0334)	(0.0344)	(0.0305)
NVQ4+					−0.00131 **	−0.000107	−0.000264
					(0.000477)	(0.000881)	(0.00122)
NO_NVQ						0.00200 **	0.00204 **
						(0.000734)	(0.000663)
Pop_den							0.0318
							(0.0860)
Constant	−0.202	−0.133 **	−0.153 ***	−0.138 **	−0.0837 *	−0.134 **	−0.314
	(0.148)	(0.0521)	(0.0460)	(0.0449)	(0.0396)	(0.0506)	(0.487)
Observations	396	396	396	396	396	396	396
N_g	36	36	36	36	36	36	36
sigma_e	0.0292	0.0239	0.0238	0.0238	0.0237	0.0236	0.0237
sigma_u	0.0574	0.0331	0.0372	0.0317	0.0277	0.0245	0.0571
Rho	0.795	0.657	0.709	0.640	0.577	0.518	0.853

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Fixed-effects regressions with robust standard errors in parentheses. The dependent variable is employment growth. The independent variables include our embeddedness measure *Emb* and its square term *Emb_sqr*, a *Crisis* dummy variable as well as entrepreneurship *FB_pop*, economic growth *Growth*, human capital *NVQ4+* and *NO_NVQ* and population density *Pop_den*.

In Table 3, results from specifications 1–8 show that the effect of $Emb_{i,t}$ on employment growth is positive and significant, whilst its squared term $Emb\_sqr_{i,t}$ is negative (at the 10% level), indicating an inverted U-shaped relationship during the total years of our panel. Our results yield coefficients consistent in sign and significance when gradually incorporating a set of control variables, which suggests a robust relationship.

Table 4 incorporates a set of model specification results including the interaction of the embeddedness variable with the crisis dummy $Emb_{i,t} * Crisis_{i,t}$ and the same holds for its squared term $Emb\_sqr_{i,t} * Crisis_{i,t}$. These interactions allow us to isolate the effect of embeddedness during recession conditions (negative employment growth). Again, the gradual introduction of a set of control variables important to our understanding of regional resilience does not alter our main results.

Table 4. The effect of embeddedness on resilience during shocks.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Emb	0.0919	0.424 ***	0.407 **	0.384 **	0.355 *	0.319	0.317
	(0.0587)	(0.123)	(0.135)	(0.161)	(0.181)	(0.195)	(0.195)
Crisis	−0.0805 ***	−0.0938 ***	−0.0932 ***	−0.0929 ***	−0.0921 ***	−0.0916 ***	−0.0916 ***
	(0.0138)	(0.0121)	(0.0129)	(0.0139)	(0.0141)	(0.0141)	(0.0142)
Crisis#Emb	0.0952 ***	0.182 ***	0.183 ***	0.188 ***	0.190 ***	0.187 ***	0.187 ***
	(0.0248)	(0.0383)	(0.0423)	(0.0466)	(0.0473)	(0.0485)	(0.0496)
Emb_sqr		−0.327 ***	−0.266 **	−0.292 **	−0.327 **	−0.293	−0.290 *
		(0.100)	(0.103)	(0.121)	(0.146)	(0.162)	(0.155)
Crisis#Emb_sqr		−0.115 **	−0.113 **	−0.120 **	−0.126 **	−0.122 **	−0.122 **
		(0.0370)	(0.0424)	(0.0468)	(0.0478)	(0.0502)	(0.0523)
FB_Pop			0.00361 **	0.00352 **	0.00538 ***	0.00544 ***	0.00542 ***
			(0.00130)	(0.00132)	(0.00163)	(0.00148)	(0.00148)
Growth				0.0607 **	0.0295	0.0262	0.0266
				(0.0206)	(0.0218)	(0.0228)	(0.0208)
NVQ4+					−0.00117 **	−0.0000524	−0.0000818
					(0.000499)	(0.000993)	(0.00126)
NO_NVQ						0.00186 *	0.00187 **
						(0.000846)	(0.000797)
Pop_den							0.00593
							(0.0787)
Constant	−0.0261	−0.103 **	−0.124 **	−0.108 *	−0.0602	−0.107	−0.141
	(0.0289)	(0.0375)	(0.0433)	(0.0510)	(0.0621)	(0.0836)	(0.428)
Observations	396	396	396	396	396	396	396
N_g	36	36	36	36	36	36	36
sigma_e	0.0231	0.0231	0.0230	0.0229	0.0229	0.0228	0.0228
sigma_u	0.0201	0.0324	0.0378	0.0316	0.0265	0.0239	0.0292
rho	0.430	0.663	0.730	0.656	0.574	0.523	0.621

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Fixed-effects regressions with robust standard errors in parentheses. The dependent variable is employment growth. The independent variables include our embeddedness measure and its squared term interacted with the crisis dummy variable as well as entrepreneurship, economic growth, human capital, and population density.

In this case, the variables of interest are *Crisis#Emb* and *Crisis#Emb_sqr*. As can be seen, the crisis variable moderates the inverted U-shaped relationship between embeddedness and employment growth. The statistically significant and positive coefficients for *Crisis#Emb* indicate that, during a crisis year (negative regional employment growth), more embedded local economic systems exhibit reduced recession impacts and higher resilience. However, the statistically significant and negative coefficients for *Crisis#Emb_sqr* suggest that this positive relationship holds up to a certain degree of embeddedness, after which more embedded systems exhibit lower employment growth, higher recession impact, and worse resilience performance. Finally, the fact that the coefficients on *Emb* and *Emb_sqr* lose their statistical significance in Table 4 suggests that the relationship observed between embeddedness and employment growth in Table 3 is mainly driven by the effect of the former on the latter during recession times.

With regards to the control variables, entrepreneurship (proxied by firm births per 1000 inhabitants) has its expected positive effect on employment growth, whilst GVA growth exhibits a positive effect that is lost once the human capital and the population density variables are introduced. The lower statistical significance found when introducing more control variables is likely due to the structure of our panel (n = 36, t = 11). However, the results on embeddedness and its squared term are consistent across all robustness checks in the whole range of specifications. These suggest that the inverted U-shaped relationship between embeddedness and employment growth is influenced by the variable crisis in such a way that it increases the importance of the former to the latter and reveals a similar relationship between embeddedness and resilience.

Industrial Analysis

Beyond the embeddedness of the total regional economy, we also consider the effects of the embeddedness of specific sectors. This is because it is likely that the embeddedness of manufacturing, services, agriculture, or construction industries may affect resilience in a different way. To estimate the embeddedness of each sector, we use the formulas:

$$Emb_{man} = \sum_{j=ss3}^{ss8} w_j\, Emb_j \tag{4}$$

$$Emb_{ser} = \sum_{j=ss10}^{ss15} w_j\, Emb_j \tag{5}$$

$$Emb_{agr} = Emb_{ss1} \tag{6}$$

$$Emb_{con} = Emb_{ss9} \tag{7}$$

Running similar model specifications (see Appendix A Tables A2–A5), the findings suggest that, except for agriculture, the embeddedness of manufacturing, services, and construction sectors follow a similar pattern. Their embeddedness is positively associated with employment growth during the crisis period, whilst the negative coefficient on the squared term suggests an inverted U-shaped relationship. The effects remain stable across different specifications.

5. Discussion

We analyse the relationship between embeddedness and regional resilience by focusing on the impact of the former on employment generation. Our findings reveal the existence of a curvilinear relationship between local embeddedness and employment growth, which is becoming more pronounced during crisis years. These results suggest there is a "tipping point" in this relationship. Embeddedness is beneficial to resilience up to a point, after which increased embeddedness is detrimental to the capacity of a place to avoid or overcome a shock. This means that the right amount of embeddedness can assist a region to mitigate the negative effects of a downturn and hence contribute to its resilience.

This is in accordance with our hypothesis and theorisation. Embedded systems seem to enjoy the positive externalities of complexity that are geographically constrained. Simultaneously, more embedded systems also have the negative effects of lock-in. At the inflexion point, these negative effects become greater, and the total impact of embeddedness on resilience becomes negative.

The strongest policy implication of these results is that local governments should aim to better understand the actual level of embeddedness in their areas. Then, they should attempt to influence it in order to maximise the resilience capacity of their locality. Our research highlights the importance of embeddedness for resilience by proxying it using the best data that are currently available. However, local deep dives clarify relationships and highlight specific action points. It is also worth noting that the above is only one measure in a suite of tools policymakers may use to improve resilience in their areas. These other tools are related to drivers of resilience such as human capital and diversification that have previously been identified [1,27,35].

The paper is subject to limitations that open avenues for further research. The notion of embeddedness examined here looks only into the input relationships in a local economy, paying scant attention to the historical patterns of embeddedness or the role of local competitive conditions. Future alternative measures could reflect embeddedness by taking into account forward links (e.g., output relationships) or a combination of the two. In addition, the expansion of the panel with data from other NUTS2 regions and/or time periods will assist us in validating and generalising the findings beyond UK regions.

6. Conclusions

This paper examines the role of local economic embeddedness on regional resilience. The 2008 crisis prompted a breadth of research on why some places perform better than others during a downturn. This literature identified important drivers of resilience such as the supply of skills, agency, and other socio-economic characteristics [1,20,66], but gaps still remain on the effects of industrial structures and, in particular, their qualitative characteristics on the resilience performance of local economies.

We contribute to the recent stream of literature of regional resilience [2,6,31] by using the concept of external economies of complexity [7] in order to understand how the embeddedness of a local economic system can improve resilience in an area. We suggest that the external economies of complexity can decrease the unit cost and as such increase the resilience of local firms. However, at the same time, we expect that too-embedded systems may suffer from lock-in effects that would be detrimental to economic resilience.

To reflect embeddedness, we devise a measure that uses a novel dataset. The EUREGIO provides insight into the input–output relationships among sectors in UK NUTS2 regions and hence allows us to approximate the degree to which the inputs in a region come from within the region. We then test the effect of embeddedness and its squared term on employment growth and further examine this relationship during negative employment growth conditions using fixed-effects panel regressions. In this way, we draw significant conclusions on the relationship between embeddedness and resilience.

The results support our hypothesis. We find that embeddedness has a positive effect on employment growth when employment growth is negative (downturn period), whilst the negative coefficients on the squared term suggest that this is an inverted U-shaped relationship. This means that embeddedness improves resilience up to a point, after which more embedded systems tend to have worse resilience performance. Recession seems to accentuate this non-linear effect.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Sustainable development goals related to resilience.

Goal nr.	Short description	Resilience as ...
1	No Poverty	capacity to shield local populations from the effects of a crisis
3	Good Health and Well-being	ability to ensure health and well-being is not negatively affected by a shock
4	Quality Education	a direct outcome of quality education
8	Decent Work and Economic Growth	a catalyst for decent work and economic growth
9	Industry, Innovation, and Infrastructure	an enabler of continuous investment in innovation and infrastructure
10	Reduced Inequalities	a facilitator to reduce inequalities
11	Sustainable Cities and Communities	a contributor to sustainable cities and communities
12	Responsible Production and Consumption	a framework for responsible production and consumption
17	Partnership for Goals	an example of multi-stakeholder endeavour

Source: Authors' elaboration.

Table A2. The effect of manufacturing embeddedness on resilience during shocks.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Emb_man	−0.0418	0.0920	0.361	0.279	0.0360	−0.0285	−0.0285
	(0.0767)	(0.228)	(0.277)	(0.317)	(0.532)	(0.541)	(0.541)
Crisis	−0.0611 ***	−0.0848 ***	−0.0840 ***	−0.0837 ***	−0.0833 ***	−0.0827 ***	−0.0827 ***
	(0.0163)	(0.0196)	(0.0198)	(0.0202)	(0.0204)	(0.0207)	(0.0207)
Crisis#Emb_man	0.295 *	1.037 **	1.083 **	1.095 **	1.092 **	1.063 **	1.064 **
	(0.153)	(0.391)	(0.391)	(0.402)	(0.406)	(0.415)	(0.415)
Emb_man_sqr		−0.108	−0.741	−0.451	0.242	0.368	0.368
		(1.017)	(1.058)	(1.191)	(1.834)	(1.858)	(1.861)
Crisis#Emb_man_sqr		−4.537 **	−4.800 **	−4.899 **	−4.916 **	−4.747 **	−4.747 **
		(1.848)	(1.864)	(1.922)	(1.955)	(2.002)	(1.999)
FB_Pop			0.00565 **	0.00541 **	0.00593 **	0.00583 ***	0.00583 ***
			(0.00194)	(0.00206)	(0.00188)	(0.00177)	(0.00174)
Growth				0.0321	0.0199	0.0180	0.0179
				(0.0240)	(0.0261)	(0.0260)	(0.0248)
NVQ4+					−0.000921	0.00000042	0.00000194
					(0.00103)	(0.00125)	(0.00138)
NO_NVQ						0.00177 **	0.00176 **
						(0.000744)	(0.000722)
Pop_den							−0.000345
							(0.0564)
Constant	0.0225 **	0.0115	−0.0278	−0.0237	0.0137	−0.0301	−0.0282
	(0.00764)	(0.0114)	(0.0220)	(0.0241)	(0.0585)	(0.0663)	(0.312)
Observations	396	396	396	396	396	396	396
N_g	36	36	36	36	36	36	36
sigma_e	0.0234	0.0232	0.0229	0.0229	0.0229	0.0229	0.0229
sigma_u	0.00620	0.00977	0.0168	0.0155	0.0121	0.0107	0.0104
rho	0.0656	0.151	0.349	0.313	0.218	0.179	0.171

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Fixed-effects regressions with robust standard errors in parentheses. The dependent variable is employment growth. The independent variables include the embeddedness of manufacturing and its squared term interacted with the crisis dummy variable as well as entrepreneurship, economic growth, human capital, and population density.

Table A3. The effect of services embeddedness on resilience during shocks.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Emb_ser	−0.0545	0.197	0.100	0.0864	0.160	0.270	0.271
	(0.0399)	(0.164)	(0.212)	(0.213)	(0.238)	(0.226)	(0.229)
Crisis	−0.0706 ***	−0.0938 ***	−0.0935 ***	−0.0927 ***	−0.0919 ***	−0.0914 ***	−0.0914 ***
	(0.0148)	(0.0119)	(0.0130)	(0.0141)	(0.0134)	(0.0129)	(0.0129)
Crisis#Emb_ser	0.110 **	0.294 ***	0.301 ***	0.304 ***	0.302 ***	0.295 ***	0.295 ***
	(0.0389)	(0.0568)	(0.0628)	(0.0695)	(0.0661)	(0.0652)	(0.0657)
Emb_ser_sqr		−0.352	−0.362	−0.317	−0.296	−0.391	−0.398
		(0.217)	(0.226)	(0.223)	(0.249)	(0.232)	(0.241)
Crisis#Emb_ser_sqr		−0.312 ***	−0.325 ***	−0.325 ***	−0.323 ***	−0.313 ***	−0.314 ***
		(0.0737)	(0.0839)	(0.0931)	(0.0885)	(0.0882)	(0.0906)
FB_Pop			0.00415 **	0.00411 *	0.00557 **	0.00547 ***	0.00540 ***
			(0.00185)	(0.00185)	(0.00180)	(0.00165)	(0.00168)
Growth				0.0738 ***	0.0352	0.0291	0.0315
				(0.0218)	(0.0269)	(0.0293)	(0.0255)
NVQ4+					−0.00120 **	0.0000242	−0.000109
					(0.000462)	(0.000810)	(0.00114)
NO_NVQ						0.00218 **	0.00221 **
						(0.000964)	(0.000914)
Pop_den							0.0263
							(0.0755)
Constant	0.0366 **	−0.00202	0.0152	0.0110	0.0116	−0.0747	−0.224
	(0.0132)	(0.0287)	(0.0377)	(0.0380)	(0.0399)	(0.0622)	(0.427)
Observations	396	396	396	396	396	396	396
N_g	36	36	36	36	36	36	36
sigma_e	0.0233	0.0232	0.0230	0.0230	0.0229	0.0228	0.0228
sigma_u	0.00713	0.0163	0.0205	0.0179	0.0158	0.0175	0.0438
rho	0.0856	0.331	0.442	0.379	0.324	0.370	0.787

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Fixed-effects regressions with robust standard errors in parentheses. The dependent variable is employment growth. The independent variables include the embeddedness of services and its squared term interacted with the crisis dummy variable as well as entrepreneurship, economic growth, human capital, and population density.

Table A4. The effect of agriculture embeddedness on resilience during shocks.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Emb_agr	0.721	3.480	4.687 **	4.668 **	3.902 *	3.912 *	3.837 *
	(0.943)	(1.949)	(1.886)	(1.829)	(1.997)	(1.973)	(2.008)
Crisis	−0.0362 ***	−0.0367 ***	−0.0366 ***	−0.0347 ***	−0.0343 ***	−0.0347 ***	−0.0346 ***
	(0.00761)	(0.00594)	(0.00599)	(0.00702)	(0.00692)	(0.00657)	(0.00645)
Crisis#Emb_agr	0.0299	0.129	0.266	0.201	0.237	0.349	0.307
	(0.398)	(0.776)	(0.759)	(0.667)	(0.770)	(0.802)	(0.830)
Emb_agr_sqr		−130.6	−136.9	−125.3	−96.83	−116.2	−107.2
		(115.1)	(114.4)	(115.3)	(114.9)	(121.6)	(120.7)
Crisis#Emb_agr_sqr		−2.517	−8.897	−6.435	−3.031	−12.13	−10.56
		(52.18)	(52.31)	(45.28)	(49.52)	(53.23)	(55.44)
FB_Pop			0.00375 **	0.00394 **	0.00613 ***	0.00599 ***	0.00587 ***
			(0.00133)	(0.00137)	(0.00157)	(0.00143)	(0.00150)
Growth				0.0720 *	0.0279	0.0232	0.0278
				(0.0347)	(0.0434)	(0.0440)	(0.0368)
NVQ4+					−0.00125 ***	−0.0000216	−0.000290
					(0.000347)	(0.000710)	(0.00118)
NO_NVQ						0.00201 **	0.00205 **
						(0.000719)	(0.000653)
Pop_den							0.0468
							(0.0984)
Constant	0.0142 **	0.00517	−0.0162 *	−0.0208 *	0.00806	−0.0502	−0.315
	(0.00569)	(0.00482)	(0.00878)	(0.0106)	(0.0173)	(0.0318)	(0.533)
Observations	396	396	396	396	396	396	396
N_g	36	36	36	36	36	36	36
sigma_e	0.0240	0.0240	0.0239	0.0239	0.0237	0.0237	0.0237
sigma_u	0.00708	0.0102	0.0154	0.0161	0.0161	0.0122	0.0618
rho	0.0801	0.152	0.292	0.312	0.315	0.210	0.872

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Fixed-effects regressions with robust standard errors in parentheses. The dependent variable is employment growth. The independent variables include the embeddedness of agriculture and its squared term interacted with the crisis dummy variable as well as entrepreneurship, economic growth, human capital, and population density.

Table A5. The effect of construction embeddedness on resilience during shocks.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Emb_con	0.440	1.370	1.086	0.806	0.900	0.773	0.755
	(0.324)	(0.971)	(0.828)	(0.951)	(1.138)	(1.035)	(1.029)
Crisis	−0.0730 ***	−0.101 ***	−0.101 ***	−0.101 ***	−0.0994 ***	−0.0992 ***	−0.0994 ***
	(0.0202)	(0.0202)	(0.0208)	(0.0220)	(0.0220)	(0.0216)	(0.0218)
Crisis#Emb_con	0.863 *	2.695 ***	2.708 ***	2.803 ***	2.749 ***	2.747 ***	2.761 ***
	(0.394)	(0.702)	(0.717)	(0.767)	(0.758)	(0.742)	(0.758)
Emb_con_sqr		−7.774	−6.244	−4.600	−5.262	−4.094	−3.717
		(10.55)	(9.495)	(10.26)	(11.73)	(10.87)	(10.97)
Crisis#Emb_con_sqr		−25.14 ***	−25.37 ***	−26.67 ***	−25.87 ***	−26.06 ***	−26.31 ***
		(6.947)	(6.874)	(7.407)	(7.157)	(7.032)	(7.298)
FB_Pop			0.00255 *	0.00276 *	0.00507 **	0.00513 ***	0.00498 ***
			(0.00134)	(0.00131)	(0.00171)	(0.00152)	(0.00155)
Growth				0.0700 ***	0.0227	0.0198	0.0236
				(0.0213)	(0.0237)	(0.0260)	(0.0228)
NVQ4+					−0.00131 ***	−0.000175	−0.000412
					(0.000301)	(0.000718)	(0.00111)
NO_NVQ						0.00188 **	0.00194 **
						(0.000790)	(0.000695)
Pop_den							0.0443
							(0.0906)
Constant	−0.000410	−0.0249	−0.0252	−0.0203	0.00402	−0.0489	−0.300
	(0.0145)	(0.0229)	(0.0209)	(0.0243)	(0.0309)	(0.0459)	(0.484)
Observations	396	396	396	396	396	396	396
N_g	36	36	36	36	36	36	36
sigma_e	0.0234	0.0233	0.0233	0.0232	0.0231	0.0230	0.0231
sigma_u	0.0113	0.0163	0.0148	0.0131	0.0156	0.0142	0.0671
rho	0.189	0.327	0.288	0.240	0.312	0.276	0.894

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Fixed-effects regressions with robust standard errors in parentheses. The dependent variable is employment growth. The independent variables include the embeddedness of construction and its squared term interacted with the crisis dummy variable as well as entrepreneurship, economic growth, human capital, and population density.

Table A6. UK regions included in EUREGIO.

Region Number	Code	Region Name
R220	UKC1	Tees Valley and Durham
R221	UKC2	Northumberland Tyne and Wear
R222	UKD1	Cumbria
R223	UKD2	Cheshire
R224	UKD3	Greater Manchester
R225	UKD4	Lancashire
R226	UKD5	Merseyside
R227	UKE1	East Riding and North Lincolnshire
R228	UKE2	North Yorkshire
R229	UKE3	South Yorkshire
R230	UKE4	West Yorkshire
R231	UKF1	Derbyshire and Nottinghamshire
R232	UKF2	Leicestershire Rutland and Northants
R233	UKF3	Lincolnshire
R234	UKG1	Herefordshire Worcestershire and Warks
R235	UKG2	Shropshire and Staffordshire
R236	UKG3	West Midlands
R237	UKH1	East Anglia
R238	UKH2	Bedfordshire Hertfordshire
R239	UKH3	Essex
R240	UKI1	Inner London
R241	UKI2	Outer London
R242	UKJ1	Berkshire Bucks and Oxfordshire
R243	UKJ2	Surrey East and West Sussex
R244	UKJ3	Hampshireand Isle of Wight
R245	UKJ4	Kent
R246	UKK1	Gloucestershire Wiltshire and North Somerset
R247	UKK2	Dorset and Somerset
R248	UKK3	Cornwall and Isles of Scilly
R249	UKK4	Devon
R250	UKL1	West Wales and The Valleys
R251	UKL2	East Wales
R252	UKM2	North Eastern Scotland
R253	UKM3	Eastern Scotland
R254	UKM5	South Western Scotland
R255	UKM6	Highlands and Islands
R256	UKN0	Northern Ireland

Table A7. Sectors included in EUREGIO.

Code	Sector Name
ss1	Agriculture
ss2	Mining quarrying and energy supply
ss3	Food beverages and tobacco
ss4	Textiles and leather, etc.
ss5	Coke, refined petroleum, nuclear fuel, and chemicals, etc.
ss6	Electrical and optical equipment and Transport equipment
ss8	Other manufacturing
ss9	Construction
ss10	Distribution
ss11	Hotels and restaurant
ss12	Transport storage and communication
ss13	Financial intermediation
ss14	Real estate, renting and business activities
ss15	Non-Market services

Table A8. Correlation matrix of the explanatory variables used in the analysis.

	Emb	Emb_sqr	Emb_man	Emb_man_sqr	Emb_agr	Emb_agr_sqr	Emb_con	Emb_con_sqr	Emb_ser	Emb_ser_sqr	Crisis	FB_Pop	Growth	NVQ4+	NO_NVQ	Pop_den
Emb	1															
Emb_sqr	0.96	1														
Emb_man	0.43	0.26	1													
Emb_man_sqr	0.3	0.16	0.96	1												
Emb_agr	0.09	−0.04	0.54	0.5	1											
Emb_agr_sqr	0.06	−0.04	0.41	0.38	0.95	1										
Emb_con	0.72	0.58	0.51	0.33	0.28	0.18	1									
Emb_con_sqr	0.66	0.57	0.39	0.22	0.2	0.12	0.97	1								
Emb_ser	0.94	0.97	0.13	0.01	−0.13	−0.12	0.56	0.54	1							
Emb_ser_sqr	0.82	0.93	−0.08	−0.15	−0.25	−0.2	0.33	0.35	0.95	1						
Crisis	−0.04	−0.07	−0.02	−0.04	0.06	0.04	0.03	0.02	−0.05	−0.08	1					
FB_Pop	0.49	0.58	−0.11	−0.13	−0.04	−0.04	0.09	0.1	0.59	0.67	−0.15	1				
Growth	0.03	0.05	0.09	0.12	−0.01	−0.02	−0.02	−0.01	0.01	0.03	−0.36	0.07	1			
NVQ4+	0.06	0.22	−0.52	−0.48	−0.24	−0.2	−0.28	−0.24	0.26	0.42	0.02	0.6	−0.13	1		
NO_NVQ	−0.09	−0.14	0.06	0.05	−0.3	−0.23	−0.05	−0.09	−0.09	−0.12	−0.06	−0.39	0.15	−0.63	1	
Pop_den	0.72	0.73	0.06	−0.04	−0.43	−0.37	0.41	0.39	0.8	0.76	−0.05	0.37	−0.02	0.06	0.3	1

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Agglomeration Economies in Small Cities and Business: The Impact of the Great Recession in Aragón (Spain)

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Abstract: In this paper, we analyze the effects of productive specialization and productive diversity on employment growth at the local level during the Great Recession in Aragon, a NUTS II region in Spain. This region is characterized by (i) a high population density in the capital city (around half of the total population), giving rise to a very uneven population distribution and therefore a lot of small cities and municipalities, and (ii) a large proportion of small businesses (95% of the firms in this region have fewer than ten employees). We use annual data from 2000 to 2015 and panel data models, and grouped local business activities into three main categories: industry, construction and services. Our results show that, during this period, local specialization in any of these activities hurt local employment growth, whereas diversity had a non-significant effect on employment growth. Only in the case of services did we obtain a positive effect of diversity on local employment growth, which was restricted to the most populated cities (i.e., cities with more than 3000 inhabitants). Therefore, only diversity in services activities located in large cities contributed to employment growth during the Great Recession.

Keywords: local employment; agglomeration economies; small and medium-sized enterprises (SMEs), small cities; Aragón

1. Introduction

The last few years of Spanish economic history have been convulsive, with a series of events (an economic crisis, a financial crisis, and a sovereign debt crisis) that generated high unemployment rates and negative economic growth (Banco de España [1]). Most experts do not hesitate to describe this period as one of the most severe economic crises in history, known as the 'Great Recession'. Although the current recovery phase is characterized by intense job creation and economic growth, during the worst years of the crisis (2012–2013), unemployment rates were above 25%, leaving Spain with the second-highest unemployment rate in Europe (after Greece), which was triple that of the pre-crisis period, 8.3% in 2006 (source: Spanish National Institute of Statistics, *Instituto Nacional de Estadística*).

The impact of the crisis was uneven among regions and sectors; some regions had higher or lower unemployment rates than the country's average, and the manufacturing and construction sectors were hit particularly hard. In this paper, we focus on job growth in Aragón, one of the NUTS 2 regions of Spain, called Autonomous Communities (NUTS regions are the European Union's standard classification of European regions at different geographical levels of aggregation (1, 2, and 3); the acronym NUTS comes from the French term *Nomenclature des unités territoriales statistiques*).

In particular, we study the effects of productive specialization and productive diversity on employment growth at the local level.

Aragón has an area of 47,720 km^2 and a population of almost 1.4 million. At 28 inhabitants per km^2, it is one of the most sparsely populated regions in the country; therefore, most of its cities (also called municipalities) are small. Figure 1 shows its geographical location within Spain. The map shows the territorial boundaries of the country's various NUTS 3 regions (also known as provinces) of the country. Aragón is located in northeast Spain, and is composed of three provinces: Huesca in the north, Zaragoza in the center, and Teruel in the south. As the map indicates, the region enjoys a privileged location that is halfway between the country's two main centers of activity: Madrid, Spain's capital, and Catalonia, with which it shares its eastern border. To the north, Aragón is bordered by France, Spain's most important trading partner. From an economic perspective, Aragón has a higher per capita income than the country's average and a below-average unemployment rate. Figure 2 shows the evolution of the unemployment rate in Aragón and Spain during the last crisis; the temporal evolutions of both rates are similar, although the level of unemployment was always lower in Aragón. Within Aragón, unemployment rates in Huesca tend to be lower than the region's average in most periods, whereas Zaragoza's rates are similar to the average. Finally, unemployment levels are more volatile in Teruel than in the other two provinces.

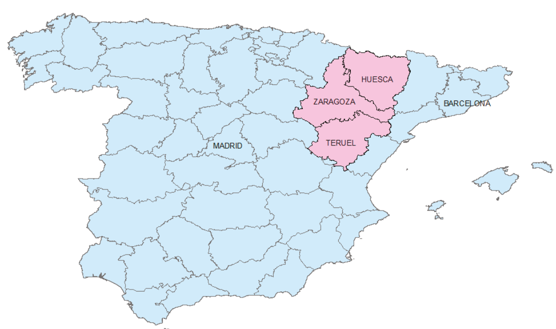

Figure 1. Geographical location of Aragón within Spain.

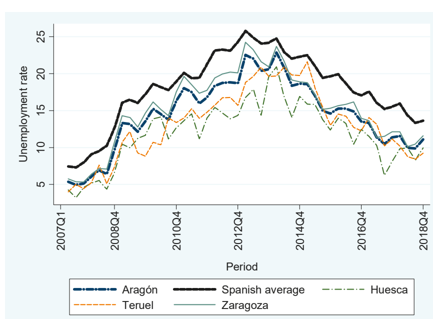

Figure 2. Unemployment rates in Aragón and Spain. Notes: Quarterly data. Source: Labor Force Survey, *Instituto Nacional de Estadística*.

There are two special characteristics of Aragón that justify our interest. First, despite the region's vast territory, its economic activity and population are highly concentrated. The three provincial capitals (especially Zaragoza) account for more than half the population of the entire region (57% in 2017). This enormous inequality means that most cities are small. Although the key determinants of growth among cities have been studied extensively, little attention has been paid to the effects of urban agglomeration in small places (Partridge et al. [2]).

Additionally, economic activity in Aragón is also quite unequally distributed; the Zaragoza province contributes on average 85% of the gross value added (GVA) and 80% of the jobs, whereas Huesca contributes 10% of the GVA and 13.5% of the employment and Teruel contributes 5% of the GVA and 6.5% of the workers. Therefore, the distribution of firms is also very fragmented, with many firms located in Zaragoza city.

Secondly, one of the peculiarities of the Aragonese (and Spanish) economy is the importance of small- and medium-sized enterprises (SMEs). Nevertheless, despite the importance of SMEs in many developed countries, microbusinesses have been systematically overlooked in the urban economics literature (Houston and Reuschke [3]). Micro enterprises account for 95.4% of the Aragonese business sector: 54.5% have no salaried workers and 40.9% have fewer than ten workers. The proportion of small companies (those with between 10 and 49 workers) is 3.9%, of medium companies (between 50 and 249 workers) is 0.6%, and of large companies (with more than 250 workers) is a mere 0.1%, according to the last Report on the Economic and Social Situation of Aragón [4].

Considering this geographic-economic pairing of small cities and small businesses, both small dimensions that are often neglected in the literature, we question whether the theoretical advantages of business concentration (called agglomeration economies) contributed to local growth in Aragón during the Great Recession. To study this, we analyzed the effects of the agglomeration economies on job growth at the local level. Supposedly firms and workers benefit from spatial concentration; therefore, we expect that both productive specialization and diversity positively affect local employment growth, but the special features of the Aragonese case (small cities and SMEs) could generate different results.

The rest of this article is organized as follows. In Section 2, we briefly review the literature on agglomeration economies. In Section 3, we present the database used in this study. Section 4 explains the methodology used, while Section 5 comments on the results obtained and Section 6 concludes.

2. Literature Review

There are two basic types of agglomeration economies: localization economies that relate to concentration within a specific sector (i.e., productive specialization) and urbanization economies that operate through the general concentration of economic activity (i.e., productive diversity, with a lot of firms from different industries). Localization economies include those external factors that come from the economic sector in which the activity is conducted: reductions in transport costs, economies of scale, specialized labor markets, or the creation of an industrial atmosphere capable of generating innovation in these fields and its rapid diffusion (knowledge spillovers). These are the so-called Marshall-Arrow-Romer external effects. Urbanization economies incorporate those external effects that do not emanate from within the company or the sector to which the company belongs, but from the location: economies of diversity, qualities of cities or regions (for example, infrastructure), or access to an efficient and skilled labor market. These spillovers between different industries at the city level were firstly documented by Jacobs [5] and later by Glaeser et al. [6] and Henderson et al. [7] for cities in the United States (US).

The theoretical underpinnings of agglomeration economies date back to what Marshall called industrial districts (Marshall [8]). Marshall observed several advantages to industrial concentration, such as (i) the availability of skilled labor, (ii) the availability of intermediate goods, and (iii) the ease of exchanging knowledge of products, processes, and innovations. More recent theoretical models have further developed the concept of agglomeration economies to adapt it to the current situation, such as the theoretical model of Duranton and Puga [9] with micro-foundations, where the authors identified three mechanisms for the transmission of the effects of company density: sharing, matching, and learning.

Theoretically and empirically, the focus tends to be on manufacturing, because it is of the greatest interest due to its traditional relationship with economic growth and its capacity to pull up the rest of the economy. However, we will also consider services, which tend to be more spatially concentrated (by their very nature, they have a high potential for codependence and agglomeration and seek to be close to their sources of demand), and construction. The construction sector in Aragón was a key player in the process of economic expansion until 2007, even more so than in the rest of Spain, but it was also the worst-affected sector during the crisis, along with industry, according to the Socio-economic Report for the Decade 2001–2010 in Aragón [10].

The two pioneering papers that initiated the study of agglomeration economies in the 1990s, Glaeser et al. [6] and Henderson et al. [7], focused on the impact of local determinants on employment growth in the US at the industry and city levels from a dynamic perspective. Although over time, many studies have attempted to identify the role of agglomeration effects on wages, productivity, or firm location decisions, a considerable portion of the literature has focused only on the effects of local sectoral specialization and diversity on local employment. Combes and Gobillon [11] reviewed the empirical literature on agglomeration, highlighting the diversity of results obtained when the studied outcome variable studied was local employment growth. Combes [12] established, for France, that the size of the local market has a positive effect on the growth of industrial employment for manufacturing industries, but a negative effect on services. For Spain, Viladecans-Marsal [13] found that the effect of market size's on industrial employment was not significant in three of the six sectors analyzed. For Germany, Blien et al. [14] found that the local market size had a positive effect on industrial employment growth for both the manufacturing and service industries. Mameli et al. [15] concluded that total employment has a positive impact on industrial employment growth after pooling together manufacturing and services using Italian data (the literature on agglomeration economies is wide; see the meta-analysis by Melo et al. [16] and the survey by Combes and Gobillon [11]).

3. Data

To conduct this study, we use the geographical data of all Aragonese firms, considering their main activities according to the National Classification of Economic Activities CNAE-2009 (the Spanish version of the EU Statistical Classification of Economic Activities, NACE Rev. 2). The sample of firms is provided by the Iberian Balance Sheet Analysis System (*Sistema de Análisis de Balances Ibéricos*, SABI) database, which contains comprehensive general information and annual accounts for companies (i.e., corporations) in Spain and Portugal. The SABI data source also provides detailed geographical information on the locations of firms. We aggregated the employment data for Aragonese companies by their municipal location, for almost 600 Aragonese municipalities. Aragón has 731 municipalities: 202 are located in Huesca, 236 in Teruel, and 293 in Zaragoza; our sample size is slightly smaller because there are some municipalities (154) that do not have employment information from any company and are, therefore, excluded from the sample.

It is worth noting that the literature on the industrial spatial distribution usually focuses on the location of establishments (i.e., working centers), whereas our sample includes the locations of headquarters, which is something different. Moreover, in some cases, it is possible that the location of the headquarters is merely instrumental, and that the center of activity is located in another place (or even in another region within Spain), for instance, because of tax incentives. However, we are confident that, given that taxation in Aragón is not particularly business-friendly compared to that of the neighboring regions, and the vast majority of companies in Aragón are SMEs (95.4% are micro enterprises), both concepts (headquarters and production establishments) will coincide in most cases.

Table 1 shows the number of companies by Activity, the most aggregated section of the CNAE-2009 classification, which includes large general groups of activities. The sections are arranged in alphabetical order. Section G (wholesale and retail trade; repair of motor vehicles and motorcycles) is the most important activity in terms of the number of firms engaged in it (22% of the total and 19.89% of the total number of workers, respectively), followed by construction (Section F) and manufacturing (Section C), which is the activity that occupies the majority of the workers (32.64%). Almost half of the total number of companies in Aragón (48.90%) in 2017 and around 60% of the total number of workers were engaged in these three activities. After these, there are other activities in the services sector with a significant number of firms (but a much lower share of employees): professional, scientific, and technical activities; real estate activities; and hospitality (Sections M, L, and I, respectively). Finally, the importance of the primary sector must be highlighted: more than 1000 firms and 4.8% of workers throughout Aragón are engaged in Section A (agriculture, hunting, fishing and forestry). The remaining activities are quantitatively less important as they present much lower numbers of firms and workers.

Sectoral employment data correspond only to salaried workers; therefore, self-employed workers are excluded from this study due to the lack of available statistical data by municipality and sector. Official data regarding workers by activity sector at the aggregate municipality level are not available from the social security records. They are available at the NUTS 3 region level and for other sub-regional levels, such as the *comarcas*, but even in these cases, there is a break in the historical series in 2010, when there was a change in the official classification of activities from the former classification (CNAE-1993) to the current one (CNAE-2009). Therefore, if we used the social security records, our research period should start (or end) in 2010. What is available at the municipality level is aggregate total employment data, which we use in the preliminary analysis carried out in Section 5.

The sustained surge in self-employment since 2000 in many countries has largely gone unnoticed by policy makers and economic developers (Goetz and Rupasingha [17]), though many recent studies document the importance of the self-employed on regional economic growth (Glaeser et al. [18]; Stephens and Partridge [19]; Stephens et al. [20]). Regarding the relationship between self-employment and agglomeration economies, Cai [21] found, using US data, that urbanization decreases and localization increases the hours that the self-employed work. Furthermore, an important characteristic of small businesses as regional economic engines is job creation; Henderson and Weiler [22] showed that the impact of entrepreneurship on job growth is greater in areas that are more urbanized.

Table 1. Distribution of firms by Activity Section in 2017, CNAE-2009 classification.

	Firms	% of Firms	% of Salaried Workers
SECTION A: Agriculture, hunting, fishing and forestry	1378	6.16	4.80
SECTION B: Mining and quarrying	95	0.42	0.60
SECTION C: Manufacturing	2632	11.77	32.64
SECTION D: Electricity and gas supply and air conditioning	448	2.00	0.16
SECTION E: Water supply, sanitation activities, waste management and decontamination	66	0.30	0.92
SECTION F: Construction	3376	15.10	7.93
SECTION G: Wholesale and retail trade; repair of motor vehicles and motorcycles	4924	22.03	19.89
SECTION H: Transport and storage	887	3.97	6.97
SECTION I: Hotels and restaurants	1315	5.88	5.02
SECTION J: Information and communication	465	2.08	2.30
SECTION K: Financial and insurance activities	529	2.37	0.51
SECTION L: Real estate activities	1759	7.87	1.06
SECTION M: Professional, scientific and technical activities	2053	9.18	3.68
SECTION N: Administrative and support service activities	699	3.13	5.13
SECTION P: Education	330	1.48	1.38
SECTION Q: Health and social work activities	494	2.21	4.65
SECTION R: Arts, entertainment and recreation	453	2.03	1.27
SECTION S: Other service activities	448	2.00	1.11
SECTION T: Private households with employed persons	1	0.00	0.00
SECTION U: Extra-territorial organizations and bodies	2	0.01	0.00
Total	22,354	100	100

Note: Data source: SABI, software version 72.00 updated to 08/08/2017.

Therefore, given the quantitative importance of the self-employed, who represent around 20% of the total number of workers registered with social security in the Aragonese economy, it is possible that we have underestimated the effects of the different agglomeration economies on employment. In Section 5, we carry out some estimations using the total number of workers and the number of self-employed people by city, confirming that, at least when using the aggregate number of workers, agglomeration economies seem to have a stronger effect on self-employment growth than on total employment growth. Hence, our results, based on sectoral data from salaried workers, should be considered as the lower bound of the possible effects of agglomeration economies on employment.

The period considered in this study is from the year 2000 to 2015. This period (16 years) allows us to make a long-term estimate of the effect of agglomeration economies and also covers an entire economic cycle, including boom periods, such as the first half of the 2000s, and the Great Recession that began in 2008 and extended until almost the end of 2015.

4. Methodology

In this study, we follow the work of Combes [12] on agglomeration economies in France by using data from firms and employment in Aragón. More recently, this empirical strategy and the selection of variables are fully explained and discussed in the excellent survey of Combes and Gobillon [11]. Therefore, the empirical strategy and selection of variables in our study is similar to that of Combes [12], with one important difference: we use panel data rather than cross-sectional data because we have annual observations.

The first empirical question is: how can agglomeration economies be quantified at the local level? Our aim is to examine whether the external effects of sectoral concentration are important for employment growth at the local level. The most obvious way to establish such effects is to observe the growth of the sectors in different municipalities and analyze the sectors with the fastest growth. Therefore, the observation unit is every sector in each municipality; we define the variable to be explained as the relative growth of employment:

$$y_{ict} = ln\left(\frac{emp_{ict}}{emp_{ict-1}}\right) - ln\left(\frac{emp_{it}}{emp_{it-1}}\right), \quad (1)$$

where emp_{ict} is the employment in sector i in municipality c at time t and emp_{it} is the total employment in that sector in Aragón at time t. As Combes [12] explained, choosing this variable means that we are not trying to explain why the growth of a sector in a given municipality is x%, but why it is y% higher or lower in this place than the growth level of that sector in all of Aragón.

Once the variable is defined, we establish the indices to measure localization economies (productive specialization) and urbanization economies (productive diversity) at the sectoral and municipal levels. The measure of specialization (spe_{ict}) related to localization economies is as follows:

$$spe_{ict} = \frac{emp_{ict}/emp_{ct}}{emp_{it}/emp_{t}}, \quad (2)$$

where emp_{ct} is the total municipal employment and emp_t is the total employment in Aragón, all measured during year t. This is the ratio between the proportion (or percentage) of employment in the sector i in municipality c and the proportion of employment in that same sector in the Aragonese economy. Thus, if a municipality is more specialized in a particular sector than the Aragonese economy is, the index will take a value greater than one. Conversely, if the share of employment in that sector in the municipality in question is less than the total share of that sector in the Aragonese economy, the index will have a value of less than one.

The productive diversity (div_{ict}) of urbanization economies is usually measured (Combes [12]; Henderson et al. [7]) through the inverse Herfindahl index, which is constructed from the share of the different sectors within local employment, except for the sector to be considered. This variable is normalized by the same index constructed for the total of Aragón:

$$div_{ict} = \frac{1/\sum_{i^*=1,i^*\neq i}^{i}\left(emp_{i^*ct}/(emp_{ct}-emp_{ict})\right)^2}{1/\sum_{i^*=1,i^*\neq i}^{i}\left(emp_{i^*t}/(emp_{t}-emp_{it})\right)^2}, \quad (3)$$

where i is the number of productive sectors. The numerator is at its maximum value when all the sectors except the one under consideration (which we call i*) are of the same size in the municipality. This index reflects the sectoral diversity of sector i in municipality c and, therefore, is not necessarily related to the level of specialization of the analyzed sector. Keep in mind that with this definition, we obtain a different measure of diversity for each sector in each municipality.

In addition to the two indices that measure specialization and productive diversity at the municipal level representing localization and urbanization economies, respectively, the literature suggests introducing additional variables. Since large companies are more capable of internalizing some of the local effects than are small companies, Glaeser et al. [6] suggested incorporating the average size of firms within the local industry as an additional determinant of localization economies. Normalizing by the average size of the companies in the same sector in Aragón, we consider the following:

$$size_{ict} = \frac{emp_{ict}/n_{ict}}{emp_{it}/n_{it}} \tag{4}$$

where n_{ict} is the number of companies in industry i in municipality c at time t and n_{it} is the total number of companies in the sector i in Aragón in the same year t. Since Equation (4) is a ratio between the average size of the companies in the sector in municipality c and the average size of the companies in the same sector in Aragón, a value higher than one will indicate that the companies in that sector in municipality c are larger in size (more employees) than the average for the sector in Aragón, whereas if the ratio is less than one, it signifies that the companies in that sector in municipality c are smaller than the average in Aragón for the sector. As indicated earlier, most Aragonese companies are SMEs; therefore, this ratio is specifically intended to control the effect of company size in the case of large companies because the extreme employment values (compared to the majority of the sample, who are SMEs) could bias the analysis.

Finally, Combes [12] suggested that in order to simultaneously control the differences between cities, it is relevant to consider the density of total employment in these cities with the following indicator:

$$den_{ct} = \frac{emp_{ct}}{area_c}, \tag{5}$$

where $area_c$ is the geographical area of the municipality measured in km^2.

Table 2 shows the descriptive statistics of the dependent variable (relative employment growth) and the different indices by sector. The statistics are calculated by considering all the sectoral values available for all the municipalities. If we look at employment growth, the sector with the highest growth (on average) in this period is construction, whereas manufacturing includes the most extreme values (the highest maximum and the lowest minimum growth). Manufacturing is the more specialized sector at the local level, whereas the highest diversity is found in the service activities. Finally, construction is the sector with the highest mean number of firms at the local level, although their average size is the lowest; in contrast, manufacturing has the lowest mean number of firms by municipality, but their average size is the largest.

Once these variables and indicators of business diversity and concentration are defined, we can estimate the econometric model where the variable to be explained is employment growth in sector i in municipality c in year t (Equation (1)) and the explanatory variables have been defined in Equations (2) to (5). The basic econometric model would be as follows:

$$\begin{aligned} y_{ict} = {} & \beta_0 + \beta_1 lnspe_{ict} + \beta_2 lndiv_{ict} + \beta_3 lnsize_{ict} + \beta_4 lnden_{ct} \\ & + \delta_i + \eta_t + Prov_c + \varepsilon_{ict} \end{aligned} \tag{6}$$

where δ_i denotes the sectoral fixed effects (FEs), η_t are time FEs (yearly time dummies from 2000 to 2015), $Prov_c$ indicates provincial FEs (at the NUTS 3 level), and ε_{ict} is the error term.

Table 2. Descriptive statistics by sector.

All Sectors				
Index	Mean	Standard deviation	Minimum	Maximum
Relative employment growth	0.01	0.46	−5.94	4.38
Specialization	12.06	66.41	0.01	6651.8
Diversity	0.44	1.35	3.14×10^{-7}	124.18
Number of firms	662	710.06	1	2547
Size	0.94	1.54	0.01	42.82
Manufacturing				
Index	Mean	Standard deviation	Minimum	Maximum
Relative employment growth	0.01	0.44	−5.94	4.38
Specialization	14.59	47.28	0.01	1520.5
Diversity	0.4	1.43	3.14×10^{-7}	124.18
Number of firms	273.39	209.04	1	815
Size	0.96	1.68	0.01	42.82
Construction				
Index	Mean	Standard deviation	Minimum	Maximum
Relative employment growth	0.03	0.44	−2.68	3.06
Specialization	6.27	16.93	0.01	359.35
Diversity	0.37	1.97	4.25×10^{-6}	115.52
Number of firms	1865.72	570.59	54	2547
Size	0.88	0.87	0.03	15.41
Services				
Index	Mean	Standard deviation	Minimum	Maximum
Relative employment growth	0.01	0.48	−3.99	3.84
Specialization	12.29	90	0.02	6651.8
Diversity	0.51	0.85	4.99×10^{-6}	43.07
Number of firms	492.41	454.62	2	2023
Size	0.94	1.62	0.01	35.07

Notes: Statistics calculated using all sectoral values available for all municipalities.

However, Model (6) presents several potential econometric problems, and the most important of these is a possible selection bias. In this context, selection bias pertains to economic activities that are only present in some cities. Therefore, for each municipality, it is common to have several productive sectors without any companies, which implies that the number of employees will be zero in those cases.

There are two ways of dealing with these null observations. Some authors include only those cases in the regressions where the variables take values other than zero, but this could lead to biased parameter estimates. Therefore, as Combes [12] did, we adopt an alternative procedure that consists of a two-stage Heckman selection model [23,24], which estimates a Tobit type II model. Therefore, we distinguish between two steps in the estimation.

In the first stage, a Probit model is estimated with a dummy variable that takes the value of 1 if sectoral employment is observed in the municipality, else zero, as a function of the variables available for all cities. As in the second stage our dependent variable is the relative growth rate, which can take positive or negative values, hurdle models (Poisson or other) are discarded. The probability of a municipality having a particular productive sector is estimated using the following equation:

$$Prob(S = 1|Z) = \phi(Z\gamma), \tag{7}$$

where S indicates the sector ($S = 1$, if $emp_{ict} > 0$, else $S = 0$), Z is a vector of municipal explanatory variables, ϕ is the cumulative distribution function with a normal distribution, and γ is a vector of unknown parameters to be estimated. In our case, the explanatory variables are a constant, population density and the percentage of the population of Aragón that represents the population of the municipality (both variables in logarithms), and a series of fixed sectoral and provincial effects (provincial FEs are included because, due to multicollinearity in this case, it is not possible to include FEs at the municipal level). This estimate allows the construction of a new variable, called the inverse Mills ratio (IMR), which captures the magnitude of the bias and is incorporated into Model (6) as an additional explanatory variable to correct the aforementioned selection problem. Moreover, considering the annual time dimension of our data, this Probit model is estimated for each of the 15 years of the panel data, following the instructions of Semykina and Wooldridge [25], to correct selection bias in panel data.

In the second stage of the Tobit type II model, the following econometric model is estimated by ordinary least squares (OLS):

$$\begin{aligned} y_{ict} = \beta_0 + \beta_1 lnspe_{ict} + \beta_2 lndiv_{ict} + \beta_3 lnsize_{ict} + \beta_4 lnden_{ct} + \\ +\beta_5 IMR_{ict} \times \eta_t + \delta_i + \eta_t + Prov_c + \xi_{ict} \end{aligned} \tag{8}$$

The difference between Models (6) and (8) is that the IMR is included in Equation (8) to correct for selection bias. Furthermore, as recommended by Semykina and Wooldridge [25], given our panel data, the IMR interacts with the annual time fixed effects (η_t).

The second potential problem that this empirical strategy could present is that the OLS estimates are consistent but inefficient. Therefore, as Combes [12] recommends, in the second stage, Model (8) will be estimated by maximum likelihood (ML), which is efficient.

Finally, given that the different indicators are constructed from the same sectoral employment values in each municipality, there could be multicollinearity in our model. To control this, we calculate the variance inflation factor (VIF) that quantifies the intensity of multicollinearity from the OLS estimates of Model (8). The results reveal that there is no multicollinearity as the VIF always remains within the limits suggested in the literature (the VIF results are not shown in the Tables, but they are available from the authors upon request, along with the OLS estimates, which provide very similar results).

5. Results

As a preliminary analysis, let us consider the agglomeration effects on total employment growth by municipality. Total employment data come from the social security records, including both salaried workers and the self-employed. As mentioned above, unfortunately, these data are not available disaggregated by activity at this geographical level, but they can be useful for analyzing general trends at the municipality level. The sample period is slightly shorter and begins in 2003. Moreover, the indices that capture the possible agglomeration effects must be simplified because, at this point, we are not yet considering observations by sector. Thus, specialization is measured through the standard Krugman specialization index; to measure diversity, we use the inverse Herfindahl index constructed from the share of all the different sectors within local employment. The average size represents the mean firm size of all the firms in the municipality relative to the mean firm size in Aragón, and the density of total employment by city is calculated as in Equation (5). Therefore, at the aggregate municipal level $spe_{ct} = \sum_{i=1}^{I} \left| \frac{emp_{ict}}{emp_{it}} - \frac{emp_{ct}}{emp_t} \right|$, $div_{ct} = \frac{1/\sum_{i=1}^{I} (emp_{ict}/(emp_{ct} - emp_{ict}))^2}{1/\sum_{i=1}^{I} (emp_{it}/(emp_t - emp_{it}))^2}$, and $size_{ct} = \frac{1}{I} \sum_{i=1}^{I} \left(\frac{emp_{ict}/n_{ict}}{emp_{it}/n_{it}} \right)$ in municipality c at time t. As no index takes the value zero in any case, the logarithm is taken for all the variables.

Table 3 reports the results for total employment growth. To be consistent with the sectoral estimations, city-fixed effects are not included; furthermore, Combes and Gobillon [11] argue against including local FEs. Columns (1) to (3) include total employment and all municipalities. When the whole period is considered (column 1), positive and significant coefficients are obtained for both specialization and diversity, although the effect of localization (specialization) is much greater (five times) than that of urbanization (diversity). Regarding the rest of the variables, the coefficient for the average firm size is negative and significant, whereas the effect of employment density is not significant. Actually, the coefficients of these last two variables (average size and employment density) are not significant in most of the estimated models.

If we split the period before and after the beginning of the crisis in 2008, different results can be observed. The positive effect of specialization on total employment growth is more than two times higher in the period before the crisis, 2003–2007 (column 2), than in the crisis and subsequent recovery period, 2008–2015 (column 3). Furthermore, diversity changes from significant and positive in the period before 2008 (column 2) to not significant in the aftermath of the crisis (column 3). However, if we focus on larger cities with more than 3000 inhabitants (46 municipalities), where agglomeration economies should be stronger, the results change and we only obtain significant evidence of agglomeration effects on total employment growth (columns 4 to 6) in the period before the crisis (column 5), with a positive and significant effect of diversity. This indicates that, for the large cities and when considering total employment, the effect of diversity was more important than that of specialization (the specialization coefficient is only significant at the 10% level).

Finally, we consider relative growth in self-employment (columns 7 to 9), again focusing on the largest cities. As mentioned above, our sectoral employment data only include salaried workers and omit the self-employed. Thus, these aggregate estimates can give us some intuition regarding the importance of agglomeration economies on self-employment. What we find is that positive and significant coefficients are obtained for both specialization and diversity in all periods, though the effect of specialization is much greater than that of the diversity. Another shift is observed again in the magnitude of the coefficients before and after the beginning of the crisis in 2008, indicating a weakening in the strength of agglomeration economies in the aftermath of the recession. The important finding; however, is that the coefficients of the specialization and diversity variables in the self-employment regressions (columns 7 to 9) are clearly higher than those obtained using total employment (columns 1 to 6), meaning that agglomeration economies have stronger effects on self-employment growth than on total workers' growth. Therefore, because our forthcoming analysis that considers sectoral local data includes only salaried workers, these results should be interpreted with caution, i.e., they should be considered as the lower bound of the possible effects of agglomeration economies on employment.

Next, we move to the estimation of agglomeration effects on local employment considering sectoral data. We estimate Model (8) separately for the manufacturing, construction, and services sectors (Tables 4–6, respectively), using the CNAE-2009 classification of activities for the whole period from 2000 to 2015. When using sectoral local data, changes in the coefficients across periods are not dramatic, so only results for the whole period 2000–2015 are reported in Tables 4–6. The subperiod-specific results are available from the authors upon request. All the tables have a common structure, with 5 columns representing 5 different specifications of Model (8). In columns (1) to (3), the sample of all the available municipalities is used but controls are introduced progressively: column (1) only includes the explanatory variables defined in equations (2) to (5); column (2) includes year FEs, where the changes that could be due to the temporal evolution of the variables (factors such as the economic cycle, the evolution of migratory patterns, etc.) are controlled and the IMR interacts with the time-based dummies, as recommended by Semykina and Wooldridge [25], sectoral FEs are included to control for unobservable factors at the sectoral level that could influence employment growth at the local level, and regional FEs are defined using the *comarca* spatial unit; the 33 *comarcas* are a sub-regional division between municipalities and the NUTS 3 regions that group nearby municipalities. In column (3), we use the NUTS 3 regions (provinces) to define the regional FEs; as the results using *comarcas* and provinces are very similar in all cases, in columns (4) and (5) we only report those results that were obtained using the NUTS 3 regional FEs.

Table 3. Results for aggregate employment growth.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent: Growth	Total workers	Total workers	Total workers	Total workers	Total workers	Total workers	Self-employees	Self-employees	Self-employees
in Period:	2003–2015	2003–2007	2008–2015	2003–2015	2003–2007	2008–2015	2003–2015	2003–2007	2008–2015
Municipalities:	All	All	All	Pop. ≥ 3000	Pop. ≥ 3000	Pop. ≥ 3000	Pop. ≥ 3000	Pop. ≥ 3000	Pop. ≥ 3000
Specialization	0.020 ***	0.031 ***	0.013 ***	0.015	0.045 *	−0.010	0.082 ***	0.110 ***	0.054 ***
	(0.004)	(0.007)	(0.005)	(0.018)	(0.024)	(0.020)	(0.015)	(0.024)	(0.014)
Diversity	0.004 ***	0.007 ***	0.001	0.005	0.020 **	−0.008	0.028 ***	0.039 ***	0.018 ***
	(0.001)	(0.002)	(0.001)	(0.007)	(0.008)	(0.008)	(0.006)	(0.011)	(0.005)
Size	−0.009 ***	−0.008 *	−0.010 **	0.008	0.031 **	−0.005	0.002	0.017	−0.008
	(0.003)	(0.004)	(0.004)	(0.009)	(0.013)	(0.010)	(0.009)	(0.017)	(0.007)
Density	−0.002	−0.004 *	−0.000	−0.003 *	−0.009 **	0.000	0.001	−0.003	0.004
	(0.001)	(0.002)	(0.002)	(0.002)	(0.004)	(0.002)	(0.004)	(0.005)	(0.003)
Regional FE (NUTS 3)	Y	Y	Y	Y	Y	Y	Y	Y	Y
Time FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	5933	2450	3483	494	186	308	494	186	308
Municipalities	577	577	577	46	46	46	46	46	46
R^2	0.098	0.093	0.039	0.305	0.561	0.121	0.603	0.396	0.367

Notes: Logarithm is taken for all variables. All models include a constant. Robust standard-errors in brackets, clustered by municipality. Significant at the * 10%, ** 5%, *** 1% level.

The remaining two columns correspond to estimates in which all the controls are included, but subsamples of municipalities are used for robustness testing. In column (4), the estimate is made after excluding Zaragoza city from the sample of municipalities. As indicated earlier, Zaragoza city accounts for a large amount of Aragón's economic activity (almost half of the total companies), so we check if the results obtained in the other estimates correspond only to the importance of Zaragoza. Finally, column (5) uses a subsample of 46 municipalities with more than 3000 inhabitants; we have carried out tests with other population thresholds and verified that, from this threshold of 3000 inhabitants, the results do not change if other minimum population levels are considered. By focusing on the most populated cities, we exclude the least-populated municipalities from the analysis, which are usually rural areas where the economies of agglomeration would not be sufficiently strong to generate any significant effect. Finally, note that the high sample sizes (the number of observations at the bottom of each column) correspond to the number of municipalities (almost 600) multiplied by the number of different activities (at the two-digit classification) in each case within each main activity (manufacturing, construction, and services) and by the number of years (which is 15 because one observation is lost when working with growth rates).

Table 4. Manufacturing results (activities 10-33 CNAE-2009).

	(1)	(2)	(3)	(4)	(5)
Municipalities:	All	All	All	Excluding Zaragoza	Population ≥ 3000
Specialization	−0.020 ***	−0.031 ***	−0.030 ***	−0.031 ***	−0.030 ***
	(0.004)	(0.005)	(0.005)	(0.005)	(0.007)
Diversity	−0.001	0.002	0.001	0.000	−0.007
	(0.004)	(0.005)	(0.004)	(0.004)	(0.006)
Size	−0.048 ***	−0.044 ***	−0.044 ***	−0.045 ***	−0.050 ***
	(0.005)	(0.006)	(0.006)	(0.006)	(0.011)
Density	−0.008 ***	−0.005	−0.003	−0.003	−0.005
	(0.002)	(0.004)	(0.003)	(0.003)	(0.005)
IMR×Year	N	Y	Y	Y	Y
Time FE	N	Y	Y	Y	Y
Regional FE (NUTS 3)	N	N	Y	Y	Y
Regional FE (*comarcas*)	N	Y	N	N	N
Sectoral FE	N	Y	Y	Y	Y
Observations	12,820	12,820	12,820	12,475	5829
Log Likelihood	−7438.526	−7330.318	−7346.534	−7296.857	−3441.353

Notes: Logarithm is taken for all variables. All models include a constant. Robust standard-errors in brackets, clustered by sector and municipality. Significant at the * 10%, ** 5%, *** 1% level.

Table 5. Construction results (activities 41-43 CNAE-2009).

	(1)	(2)	(3)	(4)	(5)
Municipalities:	All	All	All	Excluding Zaragoza	Population ≥ 3000
Specialization	−0.018 **	−0.032 ***	−0.031 ***	−0.031 ***	−0.044
	(0.007)	(0.009)	(0.009)	(0.009)	(0.040)
Diversity	0.001	−0.000	−0.001	−0.001	−0.016
	(0.004)	(0.005)	(0.004)	(0.004)	(0.012)
Size	−0.130 ***	−0.132 ***	−0.128 ***	−0.128 ***	−0.148 ***
	(0.011)	(0.013)	(0.012)	(0.012)	(0.046)
Density	−0.002	0.001	0.000	0.000	−0.018
	(0.004)	(0.006)	(0.005)	(0.005)	(0.014)
IMR×Year	N	Y	Y	Y	Y
Time FE	N	Y	Y	Y	Y
Regional FE (NUTS 3)	N	N	Y	Y	Y
Regional FE (*comarcas*)	N	Y	N	N	N
Sectoral FE	N	Y	Y	Y	Y
Observations	6164	6164	6164	6119	779
Log Likelihood	−3432.856	−3331.414	−3344.037	−3341.081	−307.100

Notes: Logarithm is taken for all variables. All models include a constant. Robust standard-errors in brackets, clustered by sector and municipality. Significant at the * 10%, ** 5%, *** 1% level.

Table 6. Services results (activities 49-96 CNAE-2009).

	(1)	(2)	(3)	(4)	(5)
Municipalities:	All	All	All	Excluding Zaragoza	Population ≥ 3000
Specialization	−0.011 ***	−0.027 ***	−0.025 ***	−0.037 ***	−0.040 ***
	(0.004)	(0.005)	(0.005)	(0.006)	(0.008)
Diversity	0.004	0.001	0.001	0.001	0.013 **
	(0.003)	(0.004)	(0.003)	(0.004)	(0.006)
Size	−0.104 ***	−0.107 ***	−0.105 ***	−0.099 ***	−0.110 ***
	(0.006)	(0.007)	(0.007)	(0.007)	(0.011)
Density	0.001	−0.006	0.001	0.001	0.008 *
	(0.003)	(0.004)	(0.003)	(0.003)	(0.004)
IMR × Year	N	Y	Y	Y	Y
Time FE	N	Y	Y	Y	Y
Regional FE (NUTS 3)	N	N	Y	Y	Y
Regional FE (*comarcas*)	N	Y	N	N	N
Sectoral FE	N	Y	Y	Y	Y
Observations	14,374	14,374	14,374	13,753	7989
Log Likelihood	−9280.180	−9067.900	−9089.257	−8915.978	−4951.565

Notes: Logarithm is taken for all variables. All models include a constant. Robust standard-errors in brackets, clustered by sector and municipality. Significant at the * 10%, ** 5%, *** 1% level.

Table 4 shows the results for the industrial sector (branches of activity 10–33 according to the CNAE-2009 classification). This is the basic sector in our analysis, since the positive effects of agglomeration economies are traditionally linked to industrial activity. Aragón has a marked industrial character; its Gross Domestic Product and employment (23% and 19%, respectively) are higher than the average values for Spain [4]. The model in column (1) shows significant negative effects of specialization, size, and density. As we introduce controls, the density coefficient loses significance, but the other two variables do not, and they remain negative and significant in all the estimated models (columns 1 to 5). With respect to the coefficient of the variable that measures productive diversity, it is not significant in any case.

Therefore, we obtain a negative effect of specialization (localization economies) for industrial employment at the municipal level and no significant effect of productive diversity (urbanization economies). These results are robust, even when subsamples are considered (when excluding Zaragoza or considering only municipalities with more than 3000 inhabitants). Although there is no theoretical model that predicts a negative effect of localization economies on employment, other studies also obtained coefficients with the same sign. For instance, Combes [12] obtained the same result in his analysis of French urban areas, and Blien et al. [14] and Mameli et al. [15] also found negative effects in Germany and Italy, respectively.

Although we do not find an explanation for this coefficient in the theory of agglomeration economies, Combes [12] suggested looking for an answer in the evolution of the cycle of the considered sector at the aggregate level. His explanation is that highly specialized production implies little flexibility and worse adaptability of products, technologies, and infrastructures when the sector is in decline. We believe this explanation fits perfectly with the analyzed period (2000–2015), which included a significant reduction in employment in the industrial sector during the Great Recession. Thus, the Aragonese municipalities that were more specialized in manufacturing suffered greater reductions in employment than the Aragón average. Alternatively, Combes and Gobillon [11] suggest that this negative result may arise from a strong mean reversion that more than compensates for the positive agglomeration effects.

Finally, local average size has a significant negative effect in all cases. This negative sign provides evidence against economies of scale in the industrial sector, although it could also be a reflection of the evolution of the life cycle of industries or also represent the Aragonese business structure with its absolute dominance of SMEs in the industrial sector. Combes [12] and Blien et al. [14] also find that the presence of larger firms reduces employment growth in both manufacturing and service activities in France and Germany, respectively.

Next, we analyze the construction sector (branches of activity 41 to 43 according to the CNAE-2009 classification), one of the sectors that was badly affected by a reduction in employment during the recent economic crisis. Employment in construction in Aragón decreased since the beginning of the crisis in 2008 and did not increase again until 2015. Table 5 shows the estimates for the branches of activity of the construction sector. The results are similar to those of industrial activities: while the specialization coefficient is negative and significant, the coefficient of the variable that measures productive diversity is not significant in any case. Our interpretation of this result is that, once again, the negative effect on sectoral employment reflects the poor evolution of the sector during the crisis period; however, the exception is the model that uses a subsample of the most populated municipalities (column 5), where the effect of specialization is not significant either. This could indicate that in large cities, the construction sector is not capable of generating economies of agglomeration of either type (localization or urbanization). Furthermore, the variable measuring the average size of companies in the sector has, again, a significant negative effect in all cases, which we interpret as evidence that economies of scale are not present in the construction sector.

Finally, Table 6 presents the results for the services sector (branches of activity 49 to 96 according to the CNAE-2009 classification), which accounts for around 67% of the total employment and production of the Aragonese economy and the greatest rate of employment creation in recent years, especially since 2014.

We obtain two results common to those obtained for the other sectors: on the one hand, we observe a negative and significant effect of specialized production, which we can link to the destruction of jobs during the Great Recession, and on the other hand, we observe a negative and significant coefficient of the average size of the companies, which would once again reflect the predominance of SMEs in the Aragonese economy.

The different result shown in Table 6, which is specific to the services sector, is the positive and significant effect of productive diversity when we use the sample that includes the most-populated municipalities (column 5). This positive effect on sectoral employment can be considered favorable evidence of urbanization economies over sectoral employment: an increase in diversity in the different branches of the services sector would generate increases in employment in other branches of the sector in the same municipality, indicating supply and demand links between the different activities of the services sector. However, these results would indicate that for this positive effect to be generated, a certain economic scale or municipality size is necessary (at least 3000 inhabitants). Combes and Gobillon [11] point out that it is not unusual that productive diversity shows mixed effects on local employment growth; for instance, Combes [12] finds that the same diversity measure has a positive impact on employment growth in service activities and a negative one in most manufacturing industries in France, and Viladecans-Marsal [13] finds positive, negative and nonsignificant effects of diversity on employment for different Spanish industries in the same period.

6. Conclusions

In this study, we test the strength of agglomeration economies for a Spanish region characterized by its small cities and companies. Focusing on the differentiation between localization (specialization) and urbanization (diversity) economies, the effects of industrial concentration and diversity on employment growth at the municipal level are analyzed using panel data from 2000 to 2015, including the Great Recession period.

We estimate the effect of agglomeration economies on sectoral employment at the local level for the branches of activity of each of the main activity sectors, finding a negative and significant effect of specialization in the three major sectors of activity (manufacturing, construction, and services). Bearing in mind that the period of analysis includes the Great Recession that began in 2008 and entailed a considerable decrease in employment in these sectors, our results could indicate that the Aragonese municipalities that were more specialized in these sectors suffered higher unemployment rates than the Aragón average.

With respect to urbanization economies, we did not find any significant effect on any of the productive sectors, except for a positive effect on job creation in service sector activities when we restrict the analysis to municipalities with more than 3000 inhabitants. Therefore, the greater the diversity in the different branches of the services sector, the greater the growth in employment in other branches of the sector in the same municipality, provided that it is a large municipality—implying the existence of supply and demand links between different activities of the services sector. Therefore, only diversity in services activities located in large cities contributed to employment growth during the Great Recession.

However, these results should be taken with caution for three reasons. First, the sectoral analysis only considers salaried workers because self-employment data are not available. Our results using aggregate workers by municipality show that the effect of agglomeration economies is higher on self-employment growth than on total workers growth, suggesting that, if we could include the self-employed in the sectoral analysis, the coefficients of the productive specialization and diversity variables could be greater. Second, as most of the firms in Aragón are SMEs, the benefits from agglomeration may be more difficult to turn into employment growth, our dependent variable. For instance, Houston and Reuschke [3], studying microbusiness growth, concluded that cities provide benefits to microbusinesses for turnover growth, but not for employment growth. Third, employment growth is not the only indicator of economic growth. Although employment is a local outcome of interest, especially for policymakers, currently, most of the studies focus on productivity (Combes and Gobillon [11]. The relationship between these two variables can be positive or negative; for instance, increases in productivity may not directly imply employment growth if the firms are SMEs. Finally, in terms of adaptability, other variables could be more suitable than employment growth to evaluate if a sector has evolved or adapted poorly or properly, e.g., technological change (innovation, automation), relocation, or transformation.

To sum up, we obtain evidence that there are limited economies of localization and urbanization, but these are restricted only to the largest municipalities in Aragón. On the one hand, this could be because agglomeration economies require a minimum scale, which we put at 3000 inhabitants. For smaller municipalities, we did not find any significant effect during the considered period. However, our results are limited to the 2000–2015 period, which prevents us from predicting what the result would have been if the economic conditions of the period had not been so negative. If the economic environment had been one of job creation rather than destruction, agglomeration economies would have been strengthened, rather than attenuated.

On the other hand, if we have found some positive effect of agglomeration economies during an adverse economic period, it is possible that in periods of economic prosperity, the agglomeration economies could have played a key role in job creation. This is relevant for Aragón, as this region has a high concentration of economic activity and population in the capital, Zaragoza, and the agglomeration trend had lasted for several decades. The possible external effects generated by this agglomeration (positive or negative) should not be ruled out either since they would need to be quantified because if they persist, they can lead to an increasingly unbalanced distribution of economic activity.

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The Differentiated Influence of Technology Absorption on Regional Economic Growth in China

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Abstract: Technology absorption based on technology input–output is a main source of regional economic growth, and it can be one of the mechanisms to achieve regional sustainable development. In order to explore the influence mechanism and effects of regional technology absorption on economic growth, this paper classifies 30 provinces (including municipalities and autonomous regions) in China into technology input areas and technology output areas. With economic data from 2000 to 2016, this paper adopts the Hausman test and conducts an empirical study using regression analysis of fixed effect and random effect. The result shows that: (1) compared to technology output areas, technology absorption has a greater effect on economic growth in technology input areas; and (2) in general, all of these different types of technology transactions contribute to promoting regional economy. In technology output areas, the promoting effects of four different technology transactions on economic growth are sequenced from strong to weak as following: technology development, technology consultation, technology service, and technology transfer, while in the technology input areas, the promotion effect on economic growth from strong to weak is technology development, technology service, technology consultation, and technology transfer.

Keywords: technology absorption; technology transaction; economic growth; technology input-output

1. Introduction

Regional technology absorption is a sustainable process of technology evaluation, introduction and assimilation, transformation practice, and re-development. Technology absorption can be driven by universities, scientific research institutions, enterprises, governments, and technology intermediary service agencies. Regional technology absorption has the characteristics of resource integration, spatial heterogeneity, high adaptability to the enterprise, and center openness, and is seen as an important driving force for economic growth [1].

Sustainable development requires that development meets present needs without imposing a threat to the needs of future generations. It is a harmonized development of economy, resources, and environmental protection. The ability and effect of a region's sustainable development and resilience to shocks are restricted and influenced by many factors. Among them, technology is one of the important driving forces for region resilience and sustainable development. On one hand, it plays a huge role in expanding economic scale, improving labor productivity, and economic benefits. In addition, technology innovation and transfer help accelerate the adjustment of industrial structure that promote the optimization and upgrading of industrial structure and contribute to the sustainable development of the economy. On the other hand, various technologies have been used to improve the urban resilience in the process of building a smart city [2,3]. For example, resource and energy consumption can be reduced fundamentally through the application of alternative energy technologies, new energy exploration technologies, and energy-saving clean technologies, thus providing guarantees for the urban energy resilience [4] and improved resource utilization efficiency.

However, the development of technology may harm the environment as well. Not all technologies bring about sustainable development. For example, solar photovoltaic power generation is a source of green power, but the production of photovoltaic panels generates a large amount of wastewater and gas, which is harmful to the environment. But specifically, new technologies have started being recognized in the environmental conservation phase [5]. The application of high technology has brought about more advances in environmental pollution control technologies and enhanced the ability to deal with pollution. With the improved energy consumption structure and reduced pollutant emissions through technology application, environmental sustainability can be achieved. With the sustainable development of economy, resources, and environment, regional sustainability can be achieved.

In recent years, the scale of China's technology market has expanded greatly. There are 29 major standing technology (property rights) trading institutions and 11 national technology transfer regional centers currently. In 2016, a total of 320,437 technology contracts were signed. The transaction volume of technology market increased from 7.25 billion Yuan in 1988 to 1140.7 billion Yuan in 2016. Major technology contracts accounted for more than 70% of the total volume of nationwide technology contracts. The motivation of the study is that there are still problems in the process of technology transfer and transaction in China, such as low efficiency in technology conversion, imperfect trading mechanism, and inefficiency in promoting economic growth. All of the above can attribute to low absorption capacity of regional technology.

As regard to regional technology absorption research, Yifu Lin believes that in a relatively short period of time, technology introduction and its spillover effect can bridge the technological gap between underdeveloped and developed countries [6]. Cantwell et al. point out that, in a relatively underdeveloped economy, technology absorption, through which economic development can be achieved, plays a dominant role in technology transaction. In a developed economy, the technology market can be advanced through technology output [7]. When choosing the indicators, the regional flow of the volume of technology transaction contract is used to reflect regional technology absorption capability. Different types of technology trading contracts in different regions have diverse effects on economic growth. For example, technology development contracts have the greatest impact on economic growth in China's eastern region, and technology service contracts have the least impact on economic growth in China's western region [8]. In general research, the use of extensive panel data always leads to a universal rule that the location of the subject and intermediary in the technical network will often affect the speed and convenience of access to technical resources [9]. Therefore, when analyzing the relationship between regional technology absorption and economic growth, in order to eliminate the heterogeneity of technology transactions in various regions, the classification of technology input areas and output areas can better predict the effects of technology absorption on economic growth [10].

In summary, the existing research about the impact of regional technology on economic growth needs to be further deepened and expanded. First, the research on the influence mechanism of technology absorption on regional economic growth needs to be enhanced. Second, insufficient consideration is given to the regional heterogeneity in technology absorption. In most existing studies, geographical regions are classified through provincial and municipal dimensions, which leads to the inability of relating findings in interpreting regional differentiation phenomenon, and thus hinders both the research and the formulation of regional innovation policies.

In view of this, the main research questions in the study are as follows: first, based on the NR relationship theory, the influence mechanism of technology absorption on the economic growth in China's technology input and output areas are analyzed. Second, how do the different types of technology transactions of technology absorption affect the economic growth in China's technology input and output areas. From the above research, we can understand the overall situation of technology input and output in the technology market of China. Based on empirical results and relevant expert opinions, we propose policy recommendations at the end of the paper, which are conducive to the enhancement of regional technology absorption capacity, the improvement of technological innovation capability and regional economic resilience capability, and the realization of sustainable economic development goals.

2. Theoretical Construction

The theoretical analysis of technology transfer is the basis for constructing the mechanism of regional technology absorption on economic growth. In the areas of technology transfer research, Montebbio and Sterzi point out that regional technology transfer is not the movements of technology in time and space, but independent input and output of technology, and redevelopment that can facilitate transformation of technology achievement into productivity [11]. Geographical distance, the level of economic development, inter-regional technology homogeneity levels, and social and cultural similarity can affect regional technology absorption and transfer [12–15]. Since the 1960s, the idea of "the co-evolution" has gradually been applied to the study of building technology transfer networks [16,17]. Subsequently, Criscuolo and Narula [18] suggested that different stages of technological development need to be achieved through technology transfer, but the technology transfer strategies required at each stage are different.

Saito Yu, a Japanese scholar, put forward the hypothesis of demand and resource relationship when doing a research on international technology transfer, which is also called "NR relationship theory". This hypothesis made a reasonable explanation for the driving mechanism of research technology absorption. The theory holds that the demand for a certain technology or product is the main motivation for a country to engage in international economic transactions. In addition, the mismatch between N (need) and R (resource) will restrict national economic development. There are two ways to resolve this contradiction: domestic technology innovation or absorption of advanced foreign technology [19]. Although the theory is based on international technology transfer, its viewpoint can serve as a reference when study the driving mechanism of regional technology absorption: the incompatibility between demand and resources is an important motivation for regional technology absorption. In this paper, regional technology absorption is divided into technology input and technology output, while, at the same time, the objects of technology input and output which are also the objects of technology transaction, are divided into four types: technology development, technology transfer, technology consultation, and technology service. The mechanism of regional technology absorption on economic growth from the perspective of technology demand side (enterprise) is shown in Figure 1.

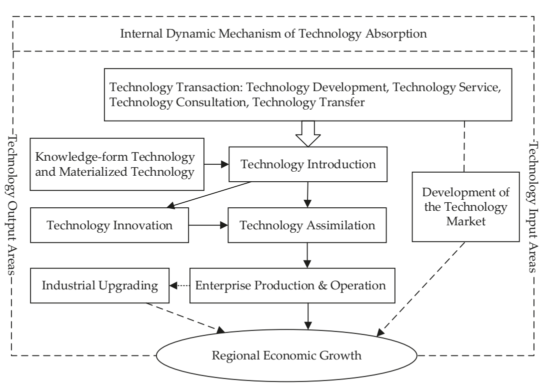

Figure 1. The influence mechanism of regional technology absorption on economic growth.

First of all, technology absorption is an important way for the two sides of technology supply and demand to coordinate and adapt to each other, and it has a positive effect on regional economic growth (theoretical assumption 1). The reason is that enterprises, as a demand side of technology, need to introduce new technologies to achieve economic goals such as better economic scale, larger regional market share, and to pursue social and environmental goals. The introduction of technology asks for scientific findings support and talent support from universities or scientific research institutions. The introduced technologies are mainly materialized technologies and knowledge-form technologies [20]. The assimilation and innovation of technology is the core part of regional technology absorption. The level of capital, talents, industrialization level of scientific research findings, and the technology itself all together determine the ability of technology assimilation and innovation. As seen from Figure 1, the three stages of technology absorption are technology introduction, technology innovation, and technology assimilation.

At the technology introduction stage, taking into consideration product technology demands and adaptability, research abilities of universities and research institutions, as well as technology level, enterprises decide which partnering institutions to work with and what technologies to bring in; at the technology innovation stage, enterprises improve and optimize technology by considering their own product characteristics, thus promoting technological innovation, and further enhancing the core competitiveness of products; at the technology assimilation stage, the operating processes of the enterprise, for example, strategic positioning of product markets, process innovation, personnel management and product production, are integrated with new technologies. Finally, the redeveloped technology is applied to the production and operation, and ultimately promotes the growth of the regional economy. In addition, the productization of technology will promote industrial upgrading and affect regional economic development indirectly. The process of technology introduction itself can enhance the development of the technology market, indirectly promoting regional economic development and construction of a national innovation system [21].

Secondly, in both scenarios of technology input and technology output, technology absorption can promote regional economic growth, but the influence mechanism is different (theoretical assumption 2). The reason is that for the technology input areas, there is not only the input of the technology but also the output of the technology, and the technology input capability is stronger than the technology output capability. Most of the technology input areas are characterized by lack of local technical resources, low transformation efficiency of local technological achievements, and deficiency in industrial upgrading. Therefore, it is urgent for enterprises to absorb technology to achieve integration in traditional industries, and to make the product market more competitive, so as to realize sustainable regional economy growth. Similarly, for the technology output areas, the capability of technology output is stronger than the capability of technology input. Most of the technology output areas are characterized by strong technological independent innovation capability, large proportion of scientific and technological talents, and high scientific and technology input support. The enterprises in the areas of technology output face tighter competition and higher risk with insufficient local technology resources. According to "NR relationship theory", strong technology input capability is also required in technology output areas. Theoretically, technology absorption, in both the technology input and output areas, plays an important role in regional economic growth.

Finally, there are many types of transaction objects in the technology market, all of which have positive effects on regional economic growth (theoretical assumption 3). The technological progress in developing economies are realized mainly through domestic R&D, inter-regional technology purchase, introduction of foreign technology, and foreign direct investment [22]. In addition, patents may facilitate transactions in technology by either: the appropriation effect and the disclosure effect [23]. Among them, technology development is the core carrier of enterprise technology innovation, which is conducive to the advent of new materials, new processes, and new products. In addition, it also plays an important role when enterprises cooperate with universities and scientific research institutions, governments, intermediaries, etc. Technology transfer can make the product upgrade more efficient and help to protect the technology rights of the transfer parties, and thus guarantee the interests of both parties. Technology consultation is a fundamental element of technology transaction activities, which requires a high level of specialty. Enterprises can conduct assessment of new technology through technology consultation, and risks incurring from development and adoption of new technology can thus be alleviated effectively. Technology service runs through the entire technology operation process from pre-sales service to after-sales services, making full use of social intellectual resources to solve various technical problems in the transformation of technological achievements. Theoretically, in the chain of technology transaction, the technology diffusion in patent trading will present a mode of cooperation [24]. In addition, technology development, technology transfer, technology consultation, and technology service all contribute to economic growth.

3. Model and Data

3.1. Model Building

Based on the above theoretical analysis and combined with the Solow economic growth model, this study constructs a model of technology absorption affecting regional economic growth. According to the general form of the Cobb–Douglas production function: $Y = AK^{\alpha}L^{\beta}$, where Y is the output, A is the technical level, K is the capital stock, L is the labor, α is the output elasticity of capital, and β is the output elasticity of the human input. On the basis of the general form of Cobb–Douglas, Solow separated the contribution rate of technological progress to economic growth. The logarithm is taken on both sides of the equation, and the equation becomes: $G_Y = G_A + \alpha G_K + \beta G_L$, where G_Y represents the growth rate of output, G_A represents the growth rate of technological progress, indicating the growth rate of capital investment, G_L represents the growth rate of labor input, and α represents the production elasticity of capital, and β represents the output elasticity of human input. Based on the Solow economic growth model, this paper builds model 1 for technology absorption of economic growth as follows:

$$Y_{it} = \alpha_{it} + \beta_{1i}K_{it} + \beta_{2i}L_{it} + \beta_{3i}TA_{it} + \varepsilon_{it} \tag{1}$$

where Y_{it} represents the regional GDP, K_{it} represents the capital stock, L_{it} represents the human input, TA_{it} represents the technology absorption, α_{it} represents the cross-sectional coefficient of different cross-sectional heterogeneity, β_i represents the regression coefficient, and ε_{it} represents the random error.

In order to further distinguish the degrees of influence of different types of technology trading contracts in different areas on economic growth, the panel model 2 is constructed as follows:

$$\begin{gathered} Y_{it} = \alpha_i + \varphi_i TA_{it} + \varepsilon_{it} \\ TA_{it} = TD_{it} + TT_{it} + TC_{it} + TS_{it} \end{gathered} \tag{2}$$

where TD_{it} indicates technology development, TT_{it} indicates technology transfer, TC_{it} indicates technology consultation, and TS_{it} indicates technology service. Since the natural logarithmic transformation of the data does not change the nature of the original data, the trend can still be linearized, and because the above units of the selected variables have large differences, to avoid the influence of heteroscedasticity, natural logarithmic is applied to all variables.

3.2. Division of Study Areas

The 30 provinces (municipalities and autonomous regions) in China (excluding Tibet and Taiwan) are classified into two areas: technology output areas and technology input areas. This division can help to further analyze the influence of technology absorption on economic growth with consideration to technology itself. It has practical value for developing technology markets and emerging innovative economies. The standard for classifying the technology input and technology output areas in this paper is based on the technology transaction contracts in various regions of China in the period of 2001 to 2017 (National Technical Market Statistics Annual Report). By deducting the average transaction volume of input technology from the average transaction volume of output technology in each region, this article classifies the regions of a positive value as technology output areas, and the regions of a negative value are classified as technology input areas. According to the above method, as shown in Figure 2, the areas of technology output includes Beijing, Shanxi, Shanghai, Hubei, Tianjin, Anhui, and Heilongjiang; regions such as Fujian, Jiangsu, Inner Mongolia, and Hebei are classified into technology input areas.

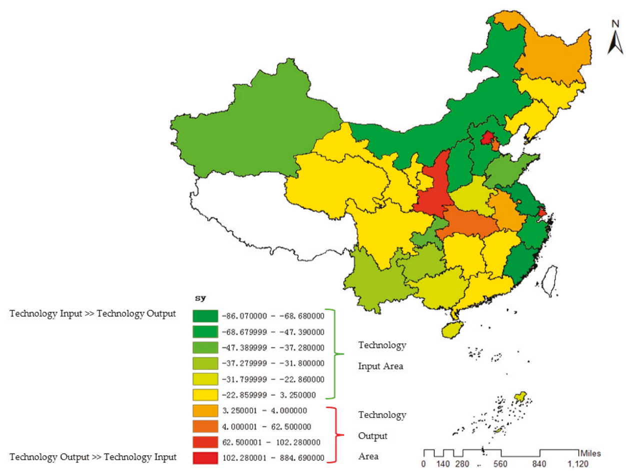

Figure 2. Division of technology input and output areas.

3.3. Data

First, the regional GDP (Y). In order to eliminate the influence of price factors, the GDP deflator will be used to deflate the nominal GDP, and the actual GDP of 30 provinces (municipalities and territories) in 2000–2016 (excluding Tibet and Taiwan) will be obtained with a base year of 2000.

Second, the capital stock (K). In this paper, the calculation method of capital stock refers to the estimate of K by Haojie Shan [25]. First, the year 2000 is selected as the base period and actual capital stock in 2000 is estimated using the following:

$$K_{2000} = \frac{I_{2001}/P_{2001}}{\left[\left(\frac{I_{2005}/P_{2005}}{I_{2001}/P_{2001}}\right)^{0.2} - 1\right] + \delta} \tag{3}$$

Then, the actual capital stocks for each year during 2001 to 2016 in each region are estimated through Equation (4):

$$K_t = K_{t-1}(1-\delta) + \frac{I_t}{P_t} \tag{4}$$

where the depreciation rate, δ, is 10.96%, I_t represents the nominal fixed capital formation amount, and P_t represents the fixed asset investment price index (2000 = 1).

Third, the human resources investment (L) is expressed by the total number of employees in each region in each year. Compared to the labor force population of previous studies, the total number of employees in this paper is easy to obtain and more accurate in reflecting factor input of economic growth.

Fourth, the technology absorption (TA) is expressed by the transaction volume of technology inflow region. The reason to use contract transaction volume is that it can reflect the capability of a region to introduce and digest technology through the technology market.

Finally, the technology development (*TD*) is expressed by the transaction volume of technology development contract for technology inflow area. The technology transfer (*TT*) selects the transaction amount of technology transfer contract for technology inflow area. The technology consultation (*TC*) is expressed by the transaction volume of technology consultation contract for technology inflow area. The technology service (*TS*) is expressed by the transaction amount of technology service contract for technology inflow area. Similarly, these indicator data also remove the impact of price factors.

The data of China's *Y*, *K*, *L*, *TA*, *TD*, *TT*, *TC*, and *TS* during the period of 2000 to 2016 are selected to perform analysis. The statistics are shown in Table 1.

Table 1. Descriptive statistics.

Variable	Technology Output Areas				Technology Input Areas			
	Obs	Mean	Max	Min	Obs	Mean	Max	Min
LNY	119	8.263	8.835	7.402	391	8.045	9.718	5.574
LNK	119	9.609	10.991	7.942	391	9.417	11.779	6.399
LNL	119	6.575	7.455	5.330	391	6.242	8.253	3.347
LNTA	119	13.536	16.408	11.107	391	12.739	15.781	8.940
LNTD	119	12.551	15.327	10.027	391	11.662	14.904	7.936
LNTT	119	11.507	14.301	9.295	391	9.614	13.073	5.370
LNTC	119	10.209	13.332	8.031	391	10.589	14.779	5.998
LNTS	119	12.473	15.897	9.833	391	11.791	14.907	7.474

Note: *Y* represents the regional GDP (Data source: China Statistical Yearbook (2001–2017) from www.stats.gov.cn) (Unit: 100 million yuan); *K* represents the capital stock (Data source: China Statistical Yearbook (2001–2017) and China City Statistical Yearbook (2001–2017), from www.stats.gov.cn) (Unit: 100 million yuan); *L* represents the human resources investment (Data source: China Statistical Yearbook (2001–2017) from www.stats.gov.cn) (Unit: 10,000 people); *TA* represents the technology absorption (Data source: National Annual Report on Technical Market Statistics (2001–2017), from www.chinatorch.gov.cn) (Unit: 10,000 yuan); TD, TT, TC, TS represent the technology development, the technology transfer, the technology consultation, and the technology service (Data source: China Science and Technology Statistical Yearbook (2001–2017), from National Bureau of Statistics of China (NBS)) (Unit: 10,000 yuan) respectively. All variables have been transformed using natural logarithms.

4. Results

4.1. Multicollinearity Test

In the setting of the model, there may appear multiple co-linearity, resulting in an insignificant regression result. Therefore, the data needs to be co-linearity diagnosed before the regression. The collinearity diagnosis results of the data are shown in Table 2.

Table 2. Collinear statistics.

Variable	Technology Output Areas				Technology Input Areas			
	Model 1		Model 2		Model 1		Model 2	
	Tolerance	VIF	Tolerance	VIF	Tolerance	VIF	Tolerance	VIF
K	0.507	1.972			0.212	4.707		
L	0.497	2.012			0.213	4.689		
TA	0.642	1.558			0.293	3.410		
TD			0.154	6.485			0.378	2.649
TT			0.770	1.299			0.450	2.223
TC			0.180	5.557			0.567	1.764
TS			0.100	9.970			0.607	1.648

Note: "Blank" in the table means no such item. VIF = variance inflation factor.

In general, the multiple co-linearity between data can be determined by observing the tolerance and the variance inflation factor (VIF) of the variables. It can be seen from Table 2 that the tolerances of the variables in both models are greater than 0.1 and the VIF is less than 10, indicating that there is no multiple co-linearity between the data, and can be directly added to the regression model.

4.2. Model Estimation and Hausman Test

In the empirical study of panel data, there are three commonly used models: mixed effect model, fixed effect model, and random effect model, while fixed effect model and random effect model are the two most used models. The Hausman test is a test method that weighs consistency and validity in the significance test of the difference in parameter estimators. This study finds that the results of the mixed estimation model are poor, and the results of the fixed effect model and the random effect model are better. Therefore, the Haussmann test was performed on model 1 and model 2 of the technology output areas and the technology input areas. The null hypothesis for Hausman test is:

Hypothesis 1 (H1). *Difference in coefficients not systematic.*

The results are shown in Table 3.

Table 3. Hausman test.

Test Type	Chi-Sq. Statistic	Chi-Sq. Df	Prob.
Technology output areas (Model 1)	23.647	3	<0.001
Technology output areas (Model 2)	1.391	4	0.846
Technology input areas (Model 1)	824.811	3	<0.001
Technology input areas (Model 2)	65.635	4	<0.001

4.3. Results of the Fixed-Effect Regression and the Random-Effect Regression

According to the Hausman test results, except for model 2 in the technology output areas, the significance *p*-values of the other three models were less than 0.001, that is, the null hypothesis is rejected. All of the three models adopted the fixed effect model, while the *p*-value of model 2 of the technology output areas was 0.846, so this model needs to adopt a random effect model. The results are shown in Tables 4 and 5.

Table 4. Results of fixed-effect regression in technology output and input areas (model 1).

Variable	Technology Output Areas				Technology Input Areas			
	Coef.	Std. Err.	*t*	*p* > |*t*|	Coef.	Std. Err.	*t*	*p* > |*t*|
C	5.786 ***	0.222	26.041	<0.001	5.949 ***	0.071	83.296	<0.001
LNK	0.142 ***	0.042	3.380	0.001	0.173 ***	0.010	16.930	<0.001
LNL	0.086 *	0.050	1.722	0.088	−0.003	0.019	−0.159	0.874
LNTA	0.041	0.033	1.234	0.220	0.038 ***	0.009	4.255	<0.001
R^2	0.953				0.995			
Ra^2	0.950				0.995			
F	247.577				2856.572			
F. Prob	<0.001				<0.001			

Note: *, *** denote the results at 10% and 1% significance level.

Table 5. Results of fixed-effect regression in technology input areas and random effect in technology output areas (model 2).

Variable	Technology Output Areas				Technology Input Areas			
	Coef.	Std. Err.	*t*	*p* > |*t*|	Coef.	Std. Err.	*t*	*p* > |*t*|
C	6.054 ***	0.211	28.675	<0.001	5.760 ***	0.081	71.096	<0.001
LNTD	0.090 ***	0.018	4.973	<0.001	0.091 ***	0.010	8.789	<0.001
LNTT	0.012	0.015	0.834	0.406	0.021 ***	0.008	2.723	0.007
LNTC	0.044 **	0.020	2.225	0.028	0.025 ***	0.009	2.789	0.006
LNTS	0.039 *	0.020	1.975	0.051	0.065 ***	0.008	8.114	<0.001
R^2	0.747				0.990			
Ra^2	0.738				0.990			
F	84.059				1452.219			
F. Prob.	<0.001				<0.001			

Note: *, **, *** denote the results at 10%, 5%, and 1% significance level.

It can be seen from observation of Table 4 that capital stock has a significant positive impact on economic growth. The model regression coefficient of technology absorption and regional economy in technology input areas is 0.038 (1% significance level), indicating that in the technology input areas, technology absorption can promote regional economic growth. This is consistent with the theoretical assumption 1 and theoretical assumption 2 in the section of theoretical construction. However, in technology output areas, the effect of technological absorption on economic growth cannot be determined.

The possible reasons for this result are, firstly, in the technology market in technology output areas, the transaction contracts which reflect technology absorption capability are mainly the ones that can obtain instant short-term effects. The long-term economic growth will depend more on capital and technology output; secondly, technology output regions such as Beijing, Shanghai, Anhui, Hubei, and other provinces tend to show knowledge spillover effects, which have slowed down the effect of technology absorption on economic growth in the long run; thirdly, in recent years, a series of regional innovation and coordinated development strategies aimed at creating new regional innovation cores and promoting regional collaborative innovation were adopted at the national level, such as "Beijing–Tianjin–Hebei coordinated development", "Yangtze Economic Belt", and the construction of the "National Science and Technology Innovation Center" and the "Innovative City". Scientific and technological concentration regions and economic belts are gradually formed, which has a radiation effect on their surrounding provinces, resulting in higher demand for technology, thus in turn, further enhancing the technology absorption capacity of technology input areas. The contribution of technology absorption to economic growth has gradually increased.

By observing the results of Table 5, it can be seen that all of the different technology transaction activities in the technology output areas and technology input areas have positive effects on economic growth, which is consistent with the theoretical assumption 3 in the section of theoretical construction. Among them, technology development plays the most significant role. In technology output areas, the effect of technology transfer on economic growth is not obvious, and technology consultation and technology service have a certain positive effect on economic growth. In technology input areas, all of four types of contracts have greatly promoted regional economic growth.

In addition, by observing Tables 4 and 5, it can be concluded that most of the independent variables in the model passed the *t*-test with significance levels of 90%, 95%, and 99%. After observing the F test results of the model, a significance level α of 0.05 was chosen. As can be seen from Table 4 to Table 5, the significance *p*-values (F. Prob) of the four model F statistics were less than 0.001, so the hypothesis is rejected. All of the regression equations of the four models pass the 95% significance level F test. Finally, in order to observe the goodness-of-fit of the model, the significance of the regression effect of the model can be observed through the coefficient of determination R^2 statistic. The closer the value is to 1, the smaller the proportion of random error, and the better the fitness of regression equation to the sample observation value. It can be seen from Tables 4 and 5 that the adjusted R^2 (Ra^2) of the four models are all good. The two regression models in technology output areas are superior to models in technology input areas.

4.4. Robust Test

Considering that the estimation method may affect the model, this paper will not follow the Hausmann test results. Random effect analysis was applied to model 1 in the technology output areas, and to model 1 and model 2 in the technology input areas. Fixed-effect analysis was applied to model 2 in the technology output areas. Regression analysis was done after the above steps, and the regression result was observed after the replacement of estimation method. It was found that the overall significance of the model was still high, and the *t*-test of most variables had a high overall fit, while the random effect model was slightly lower than the fixed-effect model. In summary, the regression model selected in this paper considers the variable and model estimation, and the overall robustness was high, indicating that the results of the above model were good and had analytical significance.

5. Conclusions and Policy Recommendations

Based on the sample data of 30 provinces (municipalities and autonomous regions) in China (excluding Tibet and Taiwan) from the year of 2000 to the year of 2016, this study combines a Hausman test with an empirical study on fixed-effect regression and random-effect regression. This study compares the impact of technology absorption on regional economic growth in China's technology output areas and technology input areas. The main conclusions are as follows.

The empirical results of this paper are not quite consistent with the results of some other scholars. The results of some other scholars show that technology absorption will promote GDP growth in both technology input and output areas [10,26]. While the results of this paper show that, in the technology input areas, technology absorption can promote regional economic growth, in technology output areas, the effect of technological absorption on economic growth cannot be determined. The possible reasons are technology output areas appear to have more knowledge spillover effects, which drags the effect of technology absorption on economic growth in the long run. Besides, major strategies such as scientific and technological innovations formulated at the national level help form scientific and technological concentration regions and economic belts geographically, and the radiation effect has promoted the demand for technology in neighboring provinces, which has increased the contribution of technology absorption to economic growth in technology input areas.

Different types of technology transaction contracts have different contributions to the economic growth in these two areas, and it is consistent with the empirical results of previous studies [8]. Generally speaking, the overall effect of technology development is the strongest, while the effect of technology transfer is the weakest. The reason may be that technology development is the source of technology absorption, which plays an important role in developing new products and new business scopes, keeping and expanding market share, and accelerating talent training. In addition, technology transfer is most complicated in four types of technology transactions. Restricted by legislation and obligation, and by scope of objects, the contribution rate of technology transfer to economic growth is the smallest [27].

In addition, policy recommendations also arise from this study.

Firstly, in order to improve the capability of regional technology innovation and economic resilience, regional technology transfer agglomeration and diffusion centers should be established to optimize technology transfer and transaction market environment, and to increase the quantity and quality of different technologies. At the same time, the long-term mechanism of transforming technology resources or advantages into economic advantages should be studied positively. It is important to combine the regional innovation environment with innovation resource endowments to fully push forward the "five chains integration", which are the innovation chain, the industry chain, the capital chain, the talents chain, and the policy chain.

Secondly, the promoting effect of technology absorption on economic growth should be enhanced in technology input areas. This can help make up for the deficiency of technology absorption chain, improve service system of technology transfer, and promote dynamic integration of absorbed technology with local innovation resources. It is noted that for the technology output areas, a sound technology transfer platform should be established to strengthen local transfer of technology resources. Narrow-minded local protectionism on technology innovation should be abandoned to facilitate integration of cross-regional technology transfer into industry technology transfer.

Thirdly, quality of technology absorption is as important as quantity of technologies. Policies that are conducive to resource conservation and environmental protection should be carefully made. Policy-making support tools can be used when making policies. For example, the Future-Oriented Technology Assessment will be beneficial to building possible alternative technologies that can be applied to the future, and make better-informed decisions regarding the shape of the trajectory of technological development of a particular region.

In the end, the limitation of this paper is that there are few evaluation methods for the classification of technology input areas and technology input areas, and there is a lack of comparison between them.

Besides, it is difficult to know the advantages and disadvantages of the selected evaluation methods. In addition, this paper does not analyze technology absorption in internal provinces of technology input areas and technology output areas and the model design could be improved. Furthermore, this paper does not predict the development model of future technology absorption. Future research could be done based on the above information.

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Capital Structure across Italian Regions: The Role of Financial and Economic Differences

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Abstract: The objective of this article is to analyse how regional financial and economic differences influence the capital structure decisions of small and medium-sized enterprises (SMEs). Specifically, this paper considers the regional financial and economic differences in four ways: the development of the financial sector in the region, bank market concentration, the financial cost of obtaining funds, and regional economic development. For this purpose, we used unbalanced panel data from 26,504 SMEs across the 20 Italian regions and over the period from 2004 to 2010. This work is completed with an analysis of a no-crisis (2004–2007) and a crisis period (2008–2010). The results show that the regional differences in the degree of financial sector development, banking concentration, and local economic situations have a significant impact on the leverage level of SMEs, while the cost of obtaining funds is only relevant during a period of economic stability. These results suggest that insights can be derived from data disaggregation at the regional level inside the same country. These regional divergences in the capital structure of SMEs could influence regional economic resilience.

Keywords: capital structure; SMEs; regional financial sector; financial development; banking concentration; costs of funding; financial crisis; panel data; regional economic resilience

1. Introduction

There is a broad and thorough body of literature that has investigated capital structure decisions since the work of Modigliani–Miller [1]. Within this context, there is an extensive line of research that analyses the institutional framework in which businesses operate. It is important to highlight that the institutional environment is defined, among other aspects, by the degree of the development of financial systems and the level of efficiency of legal systems. In this way, La Porta et al. [2] and Rajan and Zingales [3] are the first to show the importance of institutional context in explaining firm leverage.

The studies that analyse the impact of institutional factors by carrying out cross-country samples of small and medium-sized enterprises (SMEs) have been conducted by Giannetti [4], Utrero-González [5], and Hernández-Cánovas and Koëter-Kant [6]. Giannetti [4] shows that favoured creditor rights ensure stricter enforcement, associated not only with higher leverage but also with a greater availability of long-term debt. Utrero-González [5] finds, for a sample of European countries, that prudent banking regulation is positively connected with industry indebtedness, indicating that prudent rules make it easier for firms to access credit markets. Finally, Hernández-Cánovas and Koëter-Kant [6] find that SMEs in countries that protect their creditors and enforce existing laws are more likely to obtain long-term bank debt.

There are a few studies that focus their research on a regionalised approach. These studies highlight differences in the level of debt across regions due to discrepancies between the regional institutional systems. These differences should be considered mainly in terms of the financial system and the level of economic development [7–9].

The aim of this paper is to analyse how regional differences in the financial and economic context influence the capital structure decisions of SMEs. Our hypothesis is that the connection between SMEs and the local system in which they operate is particularly intense, despite the high degree of openness towards foreign countries that usually exists today. Though most of the studies in the literature have not yet incorporated a regionalised approach into their analyses, we believe that this approach allows for a better identification of the relationship between the institutional factors and the capital structure of SMEs. This regional study contributes to this growing area of regional research and explores several aspects that could influence regional resilience.

To accomplish the purpose of the paper, we use unbalanced panel data from 26,504 SMEs across the 20 Italian regions and over the period from 2004 to 2010. It is essential to discover why the capital structure of SMEs varies from region to region and identify which factors influence the financial choices of these companies. This research is especially relevant in all countries that have regional differences, since the policymakers might seek to eliminate the asymmetries between regions and strengthen regional resilience.

We utilise the Italian case for a variety of reasons. First, according to Charron et al. [10], Italy is the country with broad institutional differences across regions and a huge regional discrepancy in its level of economic activity. As outlined by Sarno [11], the companies located in the south of Italy use more internal resources to finance growth than firms in the northern Italian regions due to the more-strongly binding financial constraints in the south of Italy. This result is reinforced by La Rocca et al. [7], who highlight that a significant difference exists in the capital structure of SMEs between the north and south macro areas of Italy and that this difference is explained by institutional factors.

This article contributes to the literature in different forms. Notably, this work complements previous research (such as La Rocca et al. [7] and Palacín-Sánchez, di Pietro [9]) by considering together four factors to appreciate regional financial and economic differences: the development of the financial sector in the region, bank market concentration, the financial cost of obtaining funds, and regional economic development. One of the principal contributions of this paper is the introduction of the variable of the financial cost of obtaining funds, which, as far as we know, is used here for the first time as an explanatory variable in a regional capital structure study. In our opinion, this variable is especially important in cases such as Italy that present large differences across regions. Because the recent financial crisis has had an impact on capital structure decisions, the crisis effect on the explanatory variables is studied. Thus, the factors are analysed during both the no-crisis period (2004–2007) and the crisis period. This research allows us to focus more on regional economic resilience in the recent crisis [12], since the common view is that SMEs suffered from strong credit restriction during the crisis. This is consistent with the observations from the Bank Lending Survey of the Central European Bank stating that banks have, during the crisis, adopted a more severe policy for their loans to SMEs [13]. The remainder of the paper is organised as follows: Section 2 presents the literature and our testable hypotheses. Section 3 illustrates the dataset, the variables, and the descriptive statistics. Section 4 presents the econometric model. Section 5 discusses the results and concludes the study.

2. Literature Review and Testable Hypotheses

We present a review of the financial and economic institutional factor literature and its relationship to the capital structure of firms. We focus on four main aspects: the development of the financial sector in the region, bank market concentration, the financial cost of obtaining funds, and regional economic development.

2.1. Development of the Financial Sector

In recent years, many studies have considered the financial sector as one of the institutional factors that can affect financial decisions. According to Beck et al. [14], financial sector development and economic development are the most important institutional factors to explain cross-country variations in financing obstacles. Through a survey of responses from over 4000 firms in 54 countries, they found that, on average, firms located in countries with a more developed financial system have fewer obstacles in obtaining external funds. Like Beck et al. [14], Nivorozhkin [15] finds a positive relation between leverage and the proxy used for financial development. This relation was one of the arguments that Cornelli et al. [16] advanced to explain the lower leverage of eastern companies compared to western companies in Europe. According to these authors, the eastern countries use less debt due to the lack of financial supply caused by the underdeveloped financial system.

A majority of the previous studies that take into account the development of the financial sector usually carry out international comparisons [4,5,17–21]. However, recent studies such as La Rocca et al. [7] and Palacín-Sánchez and di Pietro [9]. use the development of the financial sector to explain regional differences inside one country since, theoretically, the same relation should exist in less developed regions within a country characterised by large regional differences. Both studies highlight the positive role of a developed financial sector on the use of debt, especially long-term debt.

In the specific case of Italy, the banking system is organised with national banks that have branches throughout the country and with small independent local banks that operate in a restricted area. Historically, Italy has been characterised by restrictive regulations in the geographical mobility of their banks and, coupled with the peculiarities of their industrial structure based largely on a network of small and medium-sized enterprises, local banks have been a primary agent in the development of local economies.

Considering previous studies, our primary hypothesis is as follows:

H1. *A developed financial sector has a positive effect on SME leverage.*

2.2. Banking Market Concentration

The effect of the banking market's concentration on capital structure has been widely studied. Considerable research suggests that a concentrated banking sector should facilitate credit access. In this regard, Petersen and Rajan [22] affirm that more concentrated banking makes it is easier for lenders to internalise the benefits of dealing with financially constrained firms. Corvoisier and Gropp [23] show that a concentrated bank market is the result of efficient banks better exploiting growth opportunities. However, they also find that, in this case, banks apply higher interest margins for loans and, consequently, offer more-expensive financing.

Alternatively, there is a group of studies that conclude that a greater banking market concentration may be linked to less credit availability. Beck et al. [14] determine that this linkage may create difficulties for SMEs to obtain financing. Boot and Thakor [24] find that a more competitive bank system encourages lenders to build up stronger relations with clients to mitigate asymmetry information problems.

Studies from a regional perspective evidence that differences between regional financial sectors can help explain divergences in their capital structures, particularly concerning SMEs. Palacín-Sánchez and di Pietro [9] show that a more concentrated regional banking sector has a negative influence on a firm's leverage, based on a sample of Spanish SMEs, and Coccorese [25] concludes that a bank's market power is quite different across different regions in Italy due to the structure of the local banking markets. There are few branches and, in general, less competition between banks that exist in more-concentrated markets.

According to previous studies, the relation between banking market concentration and SME leverage is unclear. Thus, we divide the second of our hypotheses in two:

H2a. *A concentrated banking market has a negative impact on SME leverage.*

H2b. *A concentrated banking market has a positive impact on SME leverage.*

2.3. Cost of Debt

The cost of debt directly affects capital structure. This effect depends on three components: the general level of the interest rate, the default risk premium, and the firm's tax rate. In this sense, Leland [26] and Goldstein et al. [27] demonstrate that a firm's optimal capital structure is extremely sensitive to changes in interest rates. More recently, Deesomsak et al. [28] show that changes in interest rates can affect capital structure, since firms are more likely to use debt when the cost of borrowing is low. Bas et al. [29] and Bartholdy and Mateus [30] conclude that when the interest rate increases, firms are less willing to use leverage to finance new investments because of the increase in the cost of borrowing. Nevertheless, according to Deesomsak et al. [28], interest rates also incorporate inflation expectations. Thus, firms could be expected to shift from equity to debt financing when interest rates are increasing. In this case, the level of interest rates is expected to be positively related to leverage. There is an extensive line of more specific research that studies the effect of the stochastic interest rate on capital structure ([31,32]).

The cost of debt is especially relevant in Italy since the interest rates applied by the bank sector vary significantly according to the region. In general, Italy is divided into two areas, the Centre-North and the Centre-South. In the Centre-North, the interest rate applied is on average lower than is the interest rate applied in the Centre-South. The difference in interest rates is explained, at least in part, by a different credit risk, which is higher in the south. According to the Bank of Italy [33], the irrecoverable debts on bank loans ratio in all south regions is higher than the corresponding national average.

Taking into account that Italy does not experience high inflation in the periods of study, we formulate our third hypothesis as follows:

H3. *The cost of debt has a negative impact on SME leverage.*

2.4. Development of Economy

The relation between the development of the economy and the capital structure has been widely analysed ([17–19,28], among others). There is a group of works that analyse, within a single country, differences in the capital structures between regional economies [7,9,22].

In Italy, where national economic growth slowed significantly in the 2004–2010 period, regional economic growth was significantly different among regions.

According to the research referred to above, economic growth could influence the investment opportunities for SMEs and, therefore, SMEs could need new funds to take advantage of these opportunities. Hence, our fourth hypothesis is as follows:

H4. *Regional economic growth has a positive effect on SME leverage.*

3. Data and Empirical Methodology

3.1. Data

Firm data are obtained from the Company Accounts Data Service (CADS) database, which includes information on more than 135,000 Italian businesses operating in all industry sectors and has been available since 1982 (CADS is provided by Centrale dei Bilanci—a company set up jointly by the Bank of Italy, the ABI—Italian Banking Association—and other leading Italian banks. The company collects highly disaggregated balance sheets, income statements and cash-flow statements, and detailed information on the characteristics of Italian companies. CADS is highly representative of the population of Italian firms, covering over 50% of the value added by those companies included in the Italian Central Statistical Office's Census). The firms selected conform to the European Commission's definition of SMEs (European Union Recommendation, 2003/361/CE) for every year under consideration in the 2004–2010 period (several employees in the [10, 250) range and total sales in the [2, 50) million euros range). The final dataset is an unbalanced panel of 26,504 firms for a total number of observations equal to 159,026.

3.2. Variables

In our empirical analysis, the dependent variable is leverage, while the independent variables are divided between regional variables and firm variables. The definitions of these variables are presented below.

3.2.1. Dependent Variable

The dependent variable, leverage, is calculated as the ratio of total financial debt to total debt plus equity (TDR) (trade credit is excluded). This variable has been widely used in previous studies, such as Van der Wijst and Thurik [34], Michaelas et al. [35], Giannetti [4], Sogorb-Mira [36], Utrero-González [5], La Rocca et al. [7], Degryse et al. [37], and Palacín-Sánchez and di Pietro [9].

3.2.2. Regional Variables

Our paper uses four regional variables (bank branches, banking market concentration, cost of debt, and real economy), of which three are financial variables. The first variable is related to the development of the financial sector and measures the degree of development of the Italian regional banking sector by using as a proxy the number of regional bank branches per 10,000 inhabitants (Nº Branches). This indicator has been taken from the Bank of Italy. Following Petersen and Rajan [38], La Rocca et al. [7], and Palacín-Sánchez and di Pietro [9], the number of branches is linked to the degree of the relationship between banks and SMEs. Therefore, the greater the number of branches, the better the relationship and the less asymmetric the banking system information. Consequently, it is easier for SMEs to be financed. Therefore, we anticipate a positive relationship with leverage.

The second financial variable is a proxy of the regional banking market concentration (Lerner). The index was established by Coccorese and Pellechia [39] and is equivalent to a Lerner index on a regional basis. This index is an appropriate indicator of market competition [9,40]. Carbó et al. [40] highlight that the Lerner index is a superior measure of market power. This index varies between 0 and 1, with a zero value meaning high competition in the banking sector, while a value equal to 1 signifies the existence of market power. As stated above, due to the reduced negotiation power and lower geographical mobility capacity of SMEs, especially in Italy, we expect a negative association between the two variables.

The third financial variable is related to the regional cost of debt. This variable is measured as the interest rate spread paid on cash loans, taking as a benchmark the average interest rate paid in the Centre-North part of the country (Int_diff). The data source is the Bank of Italy. As we have previously mentioned, we expect a negative relation with leverage.

Finally, the fourth regional variable is related to the real economy. We use the average annual growth rate in GDP per capita by region (gdpg_regio). Regional GDP growth is commonly used as a control variable for the economic situation. This variable comes from the Italian Statistics Office (ISTAT).

3.2.3. Firm-Level Variables

Our paper uses six firm-level variables as proxies for size, asset structure, profitability, growth, risk, and age. All of these variables have been used in previous capital structure studies.

The Size of firm (SIZE) is measured as the logarithm of total assets [7,37]. The Asset structure (AS) is net fixed assets divided by the total assets of the firm [3,4,7,18,19]. The Profitability (PROF) is defined as the ratio between the earnings before interest, taxes, amortization, and the depreciation and total assets [3,7,19,36]. Growth (GROWTH) is measured as growth of the assets, calculated as the annual percentage change of the total assets of the firm [37]. Business risk (RISK) is defined as the within standard deviation of earnings before interest and taxes for each firm divided by its book value of total assets ([18,19,41]). Finally, the age of the firm (AGE) is measured as the logarithm of the number of years that the firm has been operating [7]. According to previous studies on capital structure in SMEs (e.g., [9]), the leverage of firms has a positive relationship with firm size, asset structure, and growth, and a negative relationship with profitability, business risk, and age. Moreover, to control for variation across business sectors, sectoral dummies are also added. Table 1 summarises the explanatory variables considered in the current study and their expected signs.

Table 1. Explanatory variable signs.

Classification	Explanatory Variable	Notation	Hypotheses and Expected Signs	Data Source
Regional variables				
Financial variable	Bank branches	No.Branches	H1 (+)	Bank of Italy [33]
Financial variable	Lerner index	Lerner	H2a (-) H2b (+)	Coccorese and Pellechia [39]
Financial variables	Regional cost of debt	Int_diff	H3 (-)	Bank of Italy [33]
Economy variable	Real economy	gdpg_regio	H4 (+)	Italian Statistics Office (ISTAT)
Firm-level variables	Size of firm	SIZE	+	CADS
	Asset structure	AS	+	CADS
	Profitability	PROF	-	CADS
	Growth	GROWTH	+	CADS
	Business risk	RISK	-	CADS
	Age of firm	AGE	-	CADS
Control variable	Sectoral dummy			

3.3. Descriptive Statistics

Table 2 presents the average ratio of the total debt for each of the 20 regions of Italy and the average regional variables across regions. All variables are estimated by region as the temporal average over the period from 2004 to 2010. The average total debt ratio of Italy is 30.2% for the total sample of Italian SMEs. On the other hand, by comparing, region by region, the level of debt for firms in the sample, geographical differences can first be assessed. Campania has the lowest total debt ratio (26%), whereas Umbria has the highest (32%). Moreover, these differences are also statistically significant according to the analysis of variance (ANOVA) carried out (Bartlett's test for equal variances: chi2(19) = 302.3125; Prob > chi2 = 0.000). A Wilks' lambda test of means for each variable is also displayed, and the null hypothesis of no difference is rejected with a probability of 0%. In other words, all variables are statistically different from the mean at the region basis. Overall, SMEs in southern Italy use fewer external funds than do SMEs in northern Italy. This result is consistent with Coccorese [25]. It is also worth mentioning the marked difference across regions for all the indicators. The number of bank branches varies from the 2.63 for Calabria to 9.13 for Trentino Alto Adige. As far as the Lerner index is concerned, the regions in the south of Italy present the highest values, denoting a more concentrated banking market. Basilicata presents the greatest value (0.27), compared to Lombardy, which has the lowest (0.13). With respect to the interest rate spread, SMEs located in Calabria pay an interest rate 1.34% higher than the Centre-North average. On the other hand, in Trentino Alto Adige, SMEs pay an interest rate 0.35 lower than the Centre-North average. With regard to the real economy (gdpg_regio), Lazio and Veneto are the regions with the highest growth, while Campania has the lowest growth. Overall, differences are noted between financial and economic factors across regions. It remains to be ascertained whether these regional differences impose any statistically significant effect on the financing decisions of SMEs

Table 2. Average regional variables across regions. TDR, total debt plus equity.

Region	TDR	No.Branches	Lerner	Int_diff%	gdpg_regio
Abruzzo	0.302	5.114	0.217	0.6000	0.00191
Basilicata	0.281	4.200	0.274	0.8048	−0.0030
Calabria	0.267	2.634	0.269	1.341	−0.0035
Campania	0.267	2.788	0.216	0.952	−0.0044
Emilia Romagna	0.266	8.086	0.149	−0.162	0.007
Friuli VG	0.294	7.688	0.152	−0.059	0.004
Lazio	0.312	4.884	0.149	0.252	0.008
Liguria	0.287	6.188	0.189	0.164	0.004
Lombardia	0.269	6.635	0.132	−0.055	0.000
Marche	0.298	7.558	0.158	0.0741	0.003
Molise	0.288	4.460	0.271	1.0411	−0.001
Piemonte	0.309	6.026	0.150	0.209	−0.001
Puglia	0.271	3.435	0.213	0.756	−0.002
Sardegna	0.287	4.095	0.219	0.577	0.001
Sicilia	0.267	3.495	0.217	0.770	0.000
Tuscany	0.276	6.605	0.158	0.181	0.004
TrentinoAA	0.312	9.136	0.170	−0.356	0.007
Umbria	0.317	6.338	0.203	0.2637	−0.000
ValleDAosta	0.324	7.773	0.249	0.2535	0.008
Veneto	0.282	7.264	0.168	−0.0316	0.009
Wilks' lambda test of means (F statistic)	193.39	2.5×10^5	9274.50	24024	149.86
Italy	0.302	6.398	0.1963	0.1209	0.003

Figure 1 shows a map of Italy in which the regions whose average ratio of total debt is under the national average (in red). This map highlights the marked difference in the use of debt between the north and the south of Italy.

Figure 1. Total debt ratio under and above the national average.

Finally, Table 3 displays the correlations between all study variables. Despite the statistical significance due to the high number of observations, the absolute values of correlation coefficients are quite low—well below the benchmark of 30%. The only exceptions are the correlations between No.Branches, Lerner, and Int_diff. These regional financial variables are those that do not have firm-level variability. The variance inflation factor (VIF), which is estimated to test possible problems of collinearity, presents 7.41 as the highest value, a result that is below the limit denoting multicollinearity problems (10).

Table 3. Correlation Matrix.

Variables	TDR	SIZE	AS	Profit	Risk	Growth	AGE	No.Branches	lerner	Int_dif	gdpg_regio
TDR	1										
SIZE	0.1332***	1									
AS	0.1091***	0.1159***	1								
Profit	−0.1659***	−0.0190***	0.0196***	1							
Risk	−0.0316***	−0.0486***	−0.0087**	−0.0288***	1						
Growth	−0.0093**	0.1056***	−0.0251***	0.0765***	−0.0164***	1					
AGE	−0.0264**	0.1385***	0.1142***	−0.0040**	−0.0195***	−0.0530***	1				
No.Branches	0.0487***	0.0109**	−0.0390***	0.0370***	−0.0024	−0.0230***	0.0957***	1			
Lerner	−0.0022**	−0.0124**	0.0778***	−0.0351***	−0.0155***	−0.0032	−0.0722***	−0.5230***	1		
Int_dif	−0.0341***	−0.0117**	0.0656***	−0.0490***	−0.0055*	0.0151**	−0.1022***	−0.6587***	0.5845***	1	
gdpg_regio	0.0009	−0.0523***	−0.0933***	0.0579***	0.0104***	0.0808***	−0.0630**	0.0343**	−0.0853**	−0.0975***	1

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

3.4. Econometric Model

The empirical model is specified as follows:

$$TDR_{it} = \beta_0 + \beta_1 No.Branches_{rt} + \beta_2 Lerner_{rt} + \beta_3 Int_{diff_{rt}} + \beta_4 gdpg_{rt} + \beta_5 SIZE_{it} + \beta_6 AS_{it} + \beta_7 PROF_{it} + \beta_8 GROWTH_{it} + \beta_9 RISK_{it} + \beta_{10}\mathrm{AGE} + \mu_i + \varepsilon_{it} \quad (1)$$

where i is the firm, r is the region, and t is the time period. The term μ_i represents the unobservable individual effects, while ε_{it} is the possible heteroscedastic random error.

This paper exploits many advantages of using panel data to test the hypotheses stated in Section 2. We are able to consider individual unobservable firm heterogeneity (such as managerial ability and other nonmeasurable specificities of companies—possibly correlated with some explanatory variables) and the changes in the model's variables over time. Hence, as we mentioned above, we base our inference on data that are more informative about the financial behaviour of SMEs. This approach leads to an estimation that is less affected by collinearity problems and is more efficient.

The empirical model is first estimated by using fixed effects (within data transformation) and random effect estimators to take the individual effects into account. We believe that the hypothesis of the random effect estimator that firm-level variables are not correlated with the unobservable individual effects is quite a strong assumption. The Hausman test is carried out to ascertain whether the individual effects are fixed or random. In our analysis, this test confirms that the fixed effects model is appropriate, while the random effect model runs the risk of not being consistent. Therefore, we will present only the results of estimations with a fixed effect model. The Breusch–Pagan test rejects the null hypothesis of the constant variance of the errors. For this reason, clustered standard errors are used to address the problem.

Second, to handle the potential endogeneity problems of some explanatory variables, we use the two-stage least squares within estimator (2SLS-IVwithin). We test for the possibility that the firm-level variables (except age of firm) are endogenous, i.e., simultaneously correlated with the error term. This new regression uses the first lag of asset structure, size of firm, profitability, risk and growth as instrumental variables.

Finally, as a third estimator, we apply the Hausman–Taylor method to have an estimator that can explicitly control for sectors and regional dummies (the within transformation of the other two estimators does not allow the introduction of time invariant variables). This also allows us to take into consideration in our specification sector and regional dummies (i.e., measurable individual effects that cannot be estimated by the fixed effect method based on the within transformation), and, at the same time, to also handle the potential endogeneity problems described above. Nevertheless, a second Hausman test that compares the estimation of IV2SLS and the Hausman–Taylor estimator highlights that only the former is a consistent estimator in this case.

4. Results and Discussion

4.1. Baseline Model Results

Table 4 presents the estimates of our empirical specification. In commenting on the results, special attention will be devoted to the regional variables. Overall, the results obtained by the three estimators are similar, and, more importantly, almost all the regional variables are significant.

The proxy of regional financial development (N° Branches) is significant and has a positive sign. Therefore, the positive relation between financial development and debt is confirmed, fulfilling our first hypothesis. This result is consistent with that of La Rocca et al. [7] and Palacín-Sánchez and di Pietro [9]. Unlike La Rocca et al. [7], we use panel data instead of a one-year cross section, enabling us to control for change in the N° Branches across years.

The Lerner variable is significant for the three estimators, and the sign of the coefficient is negative, indicating that less competition in the banking sector has the effect of a lower use of debt by SMEs. Thus, we confirm our second hypothesis *H2a*. This result is consistent with Boot and Thakor [24], Beck et al. [14], and Palacín-Sánchez and di Pietro [9].

The interest rate spread paid on cash loans with the Centre-North (Int_diff) has a negative, but not significant, sign in all the regressions. The disincentive of a high interest rate for SMEs to apply for external funding is perhaps difficult to capture at the regional level. It is more probable that different SMEs inside the same region can obtain heterogeneous borrowing conditions depending on their own default risk, the availability of collateral, and the degree of asymmetric information. Another possibility is that credit rationing during the 2008–2010 crisis made it difficult to obtain loans on any terms. This possibility is why it is interesting to divide what is shown by the estimates before and after the crisis.

Finally, as the regional GDP growth (gdpg_regio) is always significantly positive, we validate our fourth hypothesis—in regions with relatively higher economic growth, firms use bank debt more intensively to finance their investments. This result is consistent with Demirguç-Kunt and Maksimovic [17], Booth et al. [18], De Jong et al. [19], and Palacín-Sánchez and di Pietro [9].

Table 4. Estimation results.

Variables	Fixed Effects Clustered St. error	IV2SLS	Hausman-Taylor
Constant	−0.083 *** (−2.44)	−0.036 *** (−2.14)	−0.099 *** (−2.56)
No.Branches	0.002 ** (4.47)	0.002 *** (3.89)	0.004 *** (4.15)
Lerner	−0.36 ** (−2.47)	−0.21 ** (2.33)	−0.111 *** (−3.84)
Int_diff	−0.007 (−0.59)	−0.005 (−0.69)	−0.019 (−0.33)
gdpg_regio	0.085 *** (8.24) (−4.01)	0.030 *** (6.46) (3.81)	0.054 *** (9.11) (−10.82)
SIZE	0.049 *** (39.56)	0.035 *** (22.71)	0.049 *** (42.44)
AS	0.018 *** (5.15)	0.191 *** (6.36)	0.012 *** (3.85)

Table 4. *Cont.*

Variables	Fixed Effects Clustered St. error	IV2SLS	Hausman-Taylor
PROF	−0.219 *** (−60.87)	−0.221 *** (−53.57)	−0.215 *** (−64.35)
GROWTH	−0.016 *** (−19.82)	−0.012 *** (−11.57)	−0.015 *** (−19.93)
RISK	0.012 *** (6.23)	0.012 *** (5.87)	0.013 *** (6.67)
AGE	−0.0006 ** (−0.66)	−0.0009 *** (−3.23)	−0.0009 *** (−6.53)
Sector dummies	No	No	Yes
Regional dummies	No	No	Yes
F-statistic	511.75 ***		
Wald test		163000 ***	6738.90 ***
First Hausman Test (Fe vs RE)	265 ***		
Second Hausman Test (FE vs HT)			640.75 ***
Number of Observations	157,625	115,410	157,625

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

With respect to the firm variables, asset structure, size, profitability, and age are significant and have the expected sign. These results are consistent with those of authors such as Michaelas et al. [35], Sogorb-Mira [36], and Degryse et al. [37]. On the other hand, the variable growth and business risk have an opposite sign to the one we expected. The sign of growth suggests that companies use different resources to finance debt to finance their growth, as also shown by Sarno [11]. The mixed sign of business risk was also discussed in earlier empirical evidence [18,19,41]. However, we cannot draw conclusions from this result due to the elementary measurement made from the operational risk, as also happened to Michaelas et al. [37].

4.2. A Comparative Analysis between the No-Crisis and the Crisis Period

During the financial crisis (2008–2010), the Italian banking sector experienced several problems, such as credit rationing, the capitalisation of various entities (including two of the five major banks in the country), and a huge increase in the insolvency ratio.

To examine the possible differences in our regression due to the impact of the economic situation, especially in the regional financial variables, we split the sample into no-crisis (2004–2007) and crisis (2008–2010) periods. The results of this analysis are presented in Table 5.

Table 5 shows certain differences between the two periods with respect to some explanatory variables. The first result to highlight is the significantly negative relation between the cost of debt (int_diff) and the level of debt before the crisis. In other words, as expected, in normal conditions of the debt markets, a higher cost of debt implies less use of debt, which has an important implication, because in Italy, large differences exist among regions. This variable is not significant in the crisis period, perhaps because with the new conditions, access to credit is difficult regardless of price [13]. For the same reason, the No.Branches variable also ceases to be significant in the crisis period, showing that the development of the financial sector loses its influence in the capital structure of SMEs in the context of financial crisis. In contrast, we observe that the regional GDP growth (gdpg-regio) only maintains its statistical significance during the crisis period, suggesting that the regional economy is particularly relevant to explain the level of indebtedness of SMEs in times of crisis. Overall, hypotheses H1 and H3 are not confirmed in the crisis period, hypothesis H2a is confirmed in both periods (no-crisis and crisis), and hypothesis H4 is only confirmed in the crisis period. Firm variables keep their signs and statistical significance. However, the risk variable only maintains its statistical significance in the pre-crisis period.

Table 5. Comparative analysis between the pre-crisis and crisis periods.

Variables	Fixed Effects Clustered St. Error (2004–2007)	Fixed Effects Clustered St. Error (2008–2010)
Constant	−0.369 *** (−8.27)	−0.238 *** (−3.31)
No.Branches	0.011 *** (3.50)	0.0009 (0.811)
Lerner	−0.344 ** (−2.01)	−0.404 ** (−2.39)
Int_diff	−0.045 *** (−3.04)	−0.023 (−1.57)
gdpg_regio	0.024 (0.79)	0.070 *** (6.49)
SIZE	0.078 *** (43.92)	0.065 *** (19.13)
AS	0.194 *** (33.31)	0.154 *** (19.72)
PROF	−0.203 *** (−44.68)	−0.229 *** (−36.72)
GROWTH	−0.010 *** (−10.67)	−0.022 *** (−13.27)
RISK	0.015 *** (4.8)	0.029 (0.89)
AGE	−0.0026 ** (−7.57)	−0.005 *** (−12.49)
Sector dummies	No	No
Regional dummies	No	No
F-statistic	373.5 ***	172.19 ***
First Hausman Test (Fe vs RE)	178 ***	158 ***
Number of Observations	98,278	59,455

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

5. Conclusions

This study aims to offset the lack of a regionalised approach in the identification of the relationship between financial and economic factors in the capital structure of SMEs. Nevertheless, at least in southern Europe, intracountry differences are large. The regional analysis enables better identification of the relationship between institutional factors and the capital structure of SMEs.

Our article empirically analyses the regional financial and economic differences in Italian SME leverage from 2004 to 2010, using an unbalanced panel dataset of 159,026 observations. Our results suggest that differences in the degree of financial sector development, banking concentration, and the local economic situation have a significant impact on the level of leverage for SMEs. These findings are consistent with studies on capital structure that use the regional level and, more generally, with authors who claim that institutional factors influence how firms are financed [4,6,7,9,17,20,42,43]. Three of the four hypotheses formulated have been verified. The estimation results show that a more developed financial system favours the use of debt as a financial source and that a more concentrated banking market reduces the use of debt by SMEs. Moreover, regional economic development has a positive effect on SME debt. However, the hypothesis of the influence of debt costs on leverage has been only partially verified.

Moreover, when we analysed the influence of regional variables, distinguishing between the pre-crisis and the crisis periods, the results show that the cost of debt and the Nº branches have only been verified in the pre-crisis period, and the regional GDP growth maintains only its statistical significance during the crisis period. These differences in the significance of the regional variables support the fact that, currently, the new conditions of access to credit have become more difficult. Therefore, the relationship between these variables and the level of leverage of SMEs depends on the economic situation.

Overall, our research shows that in a country with large regional differences, such as Italy, the decision of how to finance investments involves not only business criteria but also institutional factors, creating a diversity of opportunities depending on where the enterprise is located. Moreover, these regional differences could influence regional economic resilience because the more financial resources available, the greater the capacity to adapt and thrive under adverse environmental conditions. According to our results, it is important to take into account the regional financial system, especially in the case of SMEs, which are more affected by difficulties in accessing financing compared to large companies. This effect is especially important in times of economic instability. Moreover, our findings should be used by policymakers to reduce these differences, since government actions and decision-making are the main factors affecting social resilience, which can be considered a guarantee of regional resilience [12].

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The Determinants of Economic Resilience. The Case of Eastern European Regions

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Abstract: The economic crisis of 2008 strongly affected European countries, many of them slipping into a recession whose depth and manifestation differed substantially from country to country and from region to region. In this context, economists revived the concept of economic resilience of states and regions and focused on identifying and explaining its determinants. The literature investigates ways to enhance economic resilience through appropriate public policies, but the studies conducted so far have several limitations. In order to contribute to this goal, this article analyzes the economic resilience of the regions of seven Eastern European countries (Bulgaria, Hungary, Croatia, Czech Republic, Romania, Slovakia and Slovenia) and its main determinant factors. The results show that, in terms of resistance, Bulgaria, Slovenia and their regions behaved best, while Croatia, Czech Republic, Hungary, Romania and Slovakia (including regions) had a negative evolution. In terms of recovery Bulgaria (and 4 regions out of 6), Romania (5 out of 8 regions) and Slovakia (4 of 4 regions) performed better than the other Eastern countries. The determining factors of resilience for the studied regions concern the size of the manufacturing sector, the services and public administration, entrepreneurship and the human capital represented by tertiary education; agriculture and urban population have no significant influence on regional resilience. We adopt an econometric approach in this study, using the quantile regression for the analysis. Based on these empirical evidences, appropriate proposals have been formulated, useful to both field theorists and practitioners in public policy.

Keywords: Eastern European regions; resistance; recovery; quantile regression; 2008–2009 financial crisis

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1. Introduction

The financial crisis of 2008 hit Europe but manifested itself differently in the states of the Union, some of them being more severely affected and others less so [1]. In addition, at the level of the European NUTS2, (he Nomenclature of territorial units for statistics, abbreviated NUTS (from the French version Nomenclature des Unités territoriales statistiques) is a geographical nomenclature subdividing the economic territory of the European Union (EU) into regions at three different levels (NUTS 1, 2,3) the response to the economic crisis was different, between the regions of different states, and sometimes even between regions of the same state [2]. The causes of the different responses to the crisis of 2008 are thought to include, among others, economic development levels that were not homogeneous in the previous period [3], although at the EU level it was tried, through the common policies, to achieve a convergence and harmonization between states and regions [4]. EU Structural Funds have helped reduce the disparities between Eastern European states and regions compared with Western ones at the level of GDP per capita, but economic development remains uneven [5].

Under the conditions of the severe economic crisis of 2008, a new concept—the concept of resilience—was developed, in order to better understand how to resist and help state and regional economies recover from recessionary shocks. Regional resilience is defined as the ability of a regional economy to cope and recover from various shocks, of economic/political/environmental nature, either by returning to the old path of development or moving on to a new, better one [6]. The concept of resilience, initially used in natural sciences, medicine and engineering to designate shock system resistance and the ability to return to equilibrium, was subsequently taken over and adapted to the economy [7]. In the economy, resilience is considered to be composed of the following elements: resistance (the ability of an economy to cope with shocks); absorption (the ability of an economy to take over a shock), recovery (the ability of an economy to return to its former state) and reorientation (if any, the ability of an economy to structurally change and restore an equilibrium higher than that of the initial state) [8].

Regional economic resilience is the ability of a state's regions to cope with changes in the nature of shocks and disruptions, regardless of their nature (economic, disasters, environment, health), and to use these events to continue their development. Regional economic vulnerability refers to the way in which the economy of a region reacts negatively to shocks. It is a complex and dynamic concept that includes a wide range of potentially disruptive factors: economic, environmental, social.

Regional economic recovery is another methodological concept used in close connection with economic resilience; it shows the capacity of a region to recover/adapt to changes of the nature of external shocks in a shorter period, less harmful to economic values (GDP, employment) and prior to the manifestation of negative phenomena.

The present paper aims to study the economic resilience of seven Eastern European states, among which Bulgaria, Hungary and Romania, and their component regions during the period of the financial crisis of 2008–2009, as well as their subsequent economic recovery, until 2014. The choice of Eastern European countries was made based on similarities between them and the regions; other important aspect were their communist past and their access to the EU in 2004–2007, being recognized that path-dependence can influence the resilience of a system. At the same time, the choice was based on the common economic characteristics of the population and of education, which are both structural.

The seven countries studied are economically similar, Slovenia being the most developed, followed by Czech Republic and Hungary. Romania and Bulgaria are the last ones. The NUTS2 regional division is quite similar: Bulgaria has six regions, Croatia two, Czech Republic eight, Hungary eight, Romania eight, Slovakia four and Slovenia two; in 2008, five regions in Bulgaria, six in Romania and only one in Hungary were the poorest 20 regions in the EU, and in 2014 there was an improvement: only four regions in Bulgaria and five in Romania were in the same top [9–14]. The most developed regions in 2008 were Praha, Bratislavský kraj, Budapest, Zahodna Slovenija and Bucharest-Ilfov, and in 2014, this top remained unchanged. The poorest regions in 2008 were Severozapaden, Yuzhen tsentralen, Severen tsentralen, Yugoiztochen and Nord-Est; likewise, in 2014, the top remained unchanged.

The structural factors that influence the resilience of the regions are among the most diverse: the structure of the economic activity, and especially the industrial heritage [10]; the structure of exports, and in particular the access to strong foreign markets [11]; the quantity of natural, physical and human resources [12]. In particular, the literature shows that the narrow specialization in certain fields of activity negatively influences the resilience of regions and states [13]. The measurement of economic resilience is usually done with the help of macroeconomic indicators, GDP or employment changes [14]. In this study, the resilience measurement will be done taking into account GDP changes for 2008 (the year before the crisis) and 2014 (the year of the crisis exit).

Starting from the asymmetric impact of the recessionary shocks at the regional level, the present study aims to analyze the influence of the economic activity structure on the resilience of the regions of seven Eastern European states (Bulgaria, Croatia, Czech Republic, Hungary, Romania, Slovakia and Slovenia) during the period 2007–2014 of the economic crisis. The aim of our research paper is to measure the resilience of the regions of the seven Eastern European states and to identify the determinants of this phenomenon.

The novelty of this research consists in the following aspects: (a) the choice of the seven Eastern European states, little studied in the literature; (b) the study of the resilience of the 38 component regions of the mentioned states, a study which has not been carried out so far; (c) the analysis of the impact of the economic structure on regional resilience.

The paper will contribute through three directions to the literature on regional economic resilience: first, it separately calculates coefficients for resilience on the two phenomena—resistance and recovery; secondly, it analyzes ex ante and ex post the determinants of resilience; and finally, it calculates the influence of these factors on the resilience of the two components—resistance and recovery.

To achieve the purpose of this study, after the introductory section, Section 2 presents the main ideas developed about regional resilience in the extant literature. Section 3 describes the methodology used to reach the results, Section 4 shows the main results obtained from the analysis and the last section presents the main conclusions of the study.

2. Literature Review

Periodically, the economies of the states are hit by shocks. The effects of these phenomena are different between states and especially between regions, with great differences being observed even within the same state [15]. The literature deals with regional economic resilience, raising legitimate questions: why are some regions affected more by a crisis while others are not? What are the mechanisms that lead some regions to recover faster than others? [16] Although it is used in many areas, the concept of resilience does not have a clear and unanimously accepted definition, but it starts from the broad concept of a system's ability to return to its initial state after a disruptive shock [17,18].

The term of resilience in the economic environment was introduces by [19], studying the economic effects of earthquakes on local communities and shows that this phenomenon represents the process by which a community responds and adapts to external shocks. The pioneers in the development of the concept of economic resilience [20], using a series of macroeconomic indicators: fiscal deficit, inflation, unemployment, good governance; this study classifies the countries, according to their own resilience index, into four categories: best case, worst case, self-made and prodigal sound. The concept of resilience used by [21] at the level of UK regions, adapting the concept of balance and introducing new evolutionary concepts, the regional economies being in a continuous process of change and adaptation. The analysis of a number of US cities by [22] hit by shocks and concludes that there are several common factors, which influence resilience: infrastructure, innovation, skilled workforce, adequate financial system.

The regional development for the EU Member States was studied by [23] for the period 1995–2009 and concludes that the determinants of resilience are extremely varied: infrastructure, human capital, innovation, and urban agglomeration, ultimately leading to strong variations between regions.

The UK regions was analyzed by the [24] for the period 1970–2010 and concludes that resilience is a dynamic process consisting of several stages: resistance, recovery, renewal, and reorientation, with different repercussions on companies, individuals, and institutions. The study of the unemployment phenomenon during four crises made by [25], for the UK regions and for the period 1970–2012 and show that the structure of the economic activities does not have a decisive influence on the phenomenon.

The studies presented above focus mainly on descriptive analyses either of some regions or on analyses limited to regions of Western European states. Eastern European countries and their regions have been extremely poorly analyzed. Although there are several studies, they mainly refer to the comparative analysis of all NUTS 2 EU regions.

The European NUTS 2 regions from the point of view of resilience to unemployment were analyzed by [26], for the period 2002–2013, and shows that there are significant differences between the North-Central and Southern regions, mainly determined by the presence of the manufacturing sector, education and migration flows.

The Regional Competitiveness Index (RCI) was examined by [27], with its own index, similar to the one promoted by the World Bank, and shows that compared to the other two calculations in 2010 and 2013, a number of regions (in France, Germany and Sweden) improved values; those from the Southeast of the continent (Greece, Italy and Portugal) have worsened them; and for those from the East of the continent, the values are similar.

The regions of the EU were studied by [28], proposing a composite index based on five components: community, human capital, labor market, economic performance and innovation, and shows that the resilience process is a long one, in which all social actors must participate.

3. Methodology

The literature has not yet reached a consensus regarding the construction of an indicator to measure regional resilience, although a significant number of studies have tried to do so. In this study, we consider that regional economic resilience is a process composed of two elements: resistance (the ability of a region to cope with a shock) and recovery (the ability of a region to recover as quickly as possible from a shock). The extant literature uses two macroeconomic indicators for the calculation of resilience: GDP and unemployment [29–31]; in this study, we will use GDP as a calculation indicator, because it better reflects the economic impact of shocks, and because unemployment is dependent on GDP.

Another reason for choosing GDP is that the analyzed period is divided into two components: resistance and recovery; GDP reacts faster and more convincingly to shocks, while unemployment has a longer response period to economic shocks. In fact, for the analyzed period, in the respective regions, the economic fall corresponds to the world economic crisis (2008–2009). The same happens in the case of economic recovery, which follows the same global trend, with the regions recovering in 2013–2014 (the last year of the analysis). Unemployment followed a different trajectory for the analyzed regions: into the period of resistance it was gradually decreasing until 2011–2012, and the recovery for some regions lasted until 2017.

The methodology chosen for the analysis in the present study consists of two steps: the first step is to build the resistance index and the recovery index as dependent variables; the second step is a regression analysis, OLS (ordinary least squares (OLS) is a type of linear least squares method for estimating the unknown parameters in a linear regression model) type and quantiles.

However, starting from the established studies in the field, the methodology we have chosen implies the construction of the following resilience index of the studied regions, separately for each of the two periods (first period, resistance, and second period, recovery). The writing of Equations (1) and (2) is based on the established models, used in the literature, and especially in [1,8,12].

$$Resistance = [(EcR_t - EcR_{t-1})/EcR_{t-1} - (EcEU_t - EcEU_{t-1})/EcEU_{t-1}]/|(EcEU_t - EcEU_{t-1})/EcEU_{t-1} \quad (1)$$

$$Recovery = [(EcR_t - EcR_{t-1})/EcR_{t-1} - (EcEU_t - EcEU_{t-1})/EcEU_{t-1}]/|(EcEU_t - EcEU_{t-1})/EcEU_{t-1} \quad (2)$$

where EcR_t is the GDP at the regional level (in millions of euros); $EcEU_t$ is the relative measure of GDP change to compare the regions' performance with that of the EU27 level (in millions of euros); $t-1$ is the initial period of the analysis (year: 2008 for the resistance index and 2009 for the recovery index); t is the end period of the analysis (year: 2009 for the resistance index and 2011 (Bulgaria) and 2014 (Hungary and Romania) for the recovery index). The source of the data used in the paper is Eurostat, and GDP, agriculture, manufacturing, IT and services and gross fixed capital formation (gross fixed capital formation for physical capital) are measured in euros (entrepreneurship), tertiary education and urban population are measured in percentage of the population. Subsequently, in the analysis, these data are used by transformation according to Equations (1) and (2).

The construction of this resilience index was carried out taking into account different studies [32]. The resilient regions are those where the change of GDP is greater than the change of GDP of the EU (resistance > 0 and recovery > 0), and the non-resilient regions are the ones where the GDP change is smaller than the EU's GDP change (resistance < 0 and recovery < 0). In order to ensure the comparability of the data, the EU's GDP change was taken into account, a factor to be reported by all the analyzed regions.

The second step of the analysis is given by investigating the influence of the determinants (agriculture (covers the income of all units involved in agricultural production, NACE2 code A), manufacturing (includes the physical or chemical transformation of materials, substances, or components into new products, NACE2 code C), services (includes activities such as wholesale and retail trade, transport, accommodation and food service activities, information and communication, NACE2 codes G-J), public administration (includes activities of a governmental nature, NACE2 codes O-Q), entrepreneurship (population of active enterprises), tertiary education (population by educational attainment level: the highest level of education successfully completed by the individuals of a given population), physical capital (as gross capital formation) and urban population (percentage of population living in urban areas on the previously calculated dependent variables: resistance index and recovery index).

Agriculture occupies an extremely important place in the economy of these regions, much higher than that occupied in European regions (the average in Bulgaria exceeds 15%, in Hungary 11% and in Romania 14%, with a minimum of 2% in the Budapest region and a maximum of 24.5% in Yuzhen tsentralen); manufacturing exceeds by far the European average (the average in Bulgaria is 18%, in Hungary 16% and in Romania 14%, with a minimum of 7.8% in Dél-Alföld and a maximum of 33.62% in Yugozapaden). The public administration's contribution to the GDP is very different from that of the EU (the average in Bulgaria is 21%, in Hungary 17% and in Romania 12%, with a minimum of 6.1% in Közép-Dunántúl and a maximum of 41.95% in Yugozapaden).

The basic OLS regression is as follows:

$$Resistance_t = \alpha_1 Agriculture_t + \alpha_2 Manufacturing_t + \alpha_3 Services_t + \alpha_4 PublicAdministration_t \\ + \alpha_5 Entrepreneurship_t + \alpha_6 Tertiaryeducation_t + \alpha_7 Physicalcapital_t + \alpha_8 URB_t + \varepsilon_t \tag{3}$$

$$Recovery_t = \beta_1 Agriculture_t + \beta_2 Manufacturing_t + \beta_3 Services_t \\ + \beta_4 PublicAdministration_t + \beta_5 Entrepreneurship_t + \beta_6 Tertiaryeducation_t \\ + \beta_7 Physical\ capitalt + \beta_8 URB_t + \varepsilon_t \tag{4}$$

The quantile regression can be expressed as follows:

$$Resistance_t(\mu) = \alpha_1 Agriculture_t(\varepsilon_t) + \alpha_2 Manufacturing_t(\varepsilon_t) + \alpha_3 Services_t(\varepsilon_t) \\ + \alpha_4 PublicAdministration_t(\varepsilon_t) + \alpha_5 Entrepreneurship_t(\varepsilon_t) + \alpha_6 Tertiaryeducation_t(\varepsilon_t) \\ + \alpha_7 Physicalcapital_t(\varepsilon_t) + \alpha_8 URB_t \tag{5}$$

$$Recovery_t(\mu) = \beta_1 Agriculture_t(\varepsilon_t) + \beta_2 Manufacturing_t(\varepsilon_t) + \beta_3 Servicest(\varepsilon_t) \\ + \beta_4 PublicAdministration_t(\varepsilon t) + \beta_5 Entrepreneurship_t(\varepsilon_t) + \beta_6 Tertiaryeducation_t(\varepsilon_t) \\ + \beta_7 Physicalcapital_t\ (\varepsilon_t) + \beta\ _8 URB_t \tag{6}$$

where $Resistance_t\ (\mu)$ and $Recovery_t\ (\mu)$ are the quartile conditional distribution (μ). To use quantile regression, suppose that there is a uniform conditional distribution for $Agriculture_t\ (\varepsilon t)$, $Manufacturing_t\ (\varepsilon t)$, $Services_t\ (\varepsilon t)$, $PublicAdministration_t\ (\varepsilon t)$, $Entrepreneurship_t\ (\varepsilon t)$, $Tertiaryeducation_t\ (\varepsilon t)$, $Physicalcapital_t\ (\varepsilon t)$, $Urban_t\ (\varepsilon t)$.

4. Results

The financial crisis has influenced regions and states in Eastern Europe differently. Table 1 presents the evolution of GDP in the seven analyzed states (Bulgaria, Croatia, Czech Republic, Hungary, Romania, Slovakia and Romania) during the financial crisis period (2007–2014). As can be seen, the year 2008 represents the maximum point before the crisis for all the studied entities: EU, Bulgaria, Croatia, Czech Republic, Hungary, Romania, Slovakia and Slovenia, and their regions. The year 2009 represents the minimum moment of the crisis for Croatia, Czech Republic, Hungary, Romania and Slovakia, and their regions. Bulgaria has undergone an atypical evolution: at the level of the whole country, the decrease was manifested only in 2009, and at the level of the regions until 2010; later, the recovery period is shorter only until 2011. As for the other six Eastern states (Croatia, Czech Republic, Hungary, Romania and Slovakia), although they have larger economies, the recovery period was longer: 2009–2014; a similar pattern was followed by their component regions.

Table 1. GDP evolution in the 7 East European countries and their regions in 2007–2014 (billions of euros).

GDP	2008	2009	2014	GDP	2008	2009	2014
European Union	13082	12324	14091	Czech Republic	161.31	148.68	161.43
Bulgaria	37.21	37.20	42.87	Praha	41.26	37.94	39.93
Severozapaden	2.93	2.83	3.04	Strední Cechy	17.64	15.91	17.87
Severen tsentralen	3.12	3.06	3.54	Jihozápad	15.77	15.04	16.17
Severoiztochen	4.18	4.02	4.76	Severozápad	13.65	12.92	13.24
Yugoiztochen	4.52	4.59	5.43	Severovýchod	18.88	17.40	18.85
Yugozapaden	17.20	17.58	20.25	Jihovýchod	22.86	21.18	23.86
Yuzhen tsentralen	5.24	5.29	5.83	Strední Morava	15.04	13.88	15.22
Hungary	108.21	94.38	105.90	Moravskoslezsko	16.18	14.36	16.25
Budapest	40.26	36.58	39.13	Croatia	47.99	45.06	43.94
Pest	11.40	9.89	10.97	Jadranska Hrvatska	15.38	14.37	13.95
Közép-Dunántúl	10.83	8.72	10.34	Kontinentalna Hrvatska	32.61	30.68	29.98
Nyugat-Dunántúl	10.74	9.01	11.19	Slovenia	37.92	36.25	36.25
Dél-Dunántúl	6.97	6.10	6.46	Vzhodna Slovenija	16.81	15.90	15.97
Észak-Magyarország	8.08	6.75	7.87	Zahodna Slovenija	21.10	20.35	20.27
Észak-Alföld	10.14	8.95	10.19	Slovakia	66.09	64.09	73.48
Dél-Alföld	9.76	8.34	9.71	Bratislavský kraj	17.71	18.39	20.37
Romania	146.59	125.21	150.45	Západné Slovensko	21.60	20.31	23.68
Nord-Vest	16.70	14.46	17.25	Stredné Slovensko	13.27	12.69	14.42
Centru	16.29	14.07	16.49	Východné Slovensko	13.49	12.68	14.99
Nord-Est	15.52	13.44	15.21				
Sud-Est	15.28	13.35	16.94				
Sud-Muntenia	18.37	16.45	19.56				
Bucuresti-Ilfov	38.38	30.93	40.10				
Sud-Vest Oltenia	11.39	9.98	10.92				
Vest	14.51	12.39	13.85				

Source: Eurostat.

Table 2 presents the resistance and recovery indices, calculated for the regions analyzed according to Equations (1) and (2). For Bulgaria and Slovenia, as well as for their regions, the resistance index is calculated for the period 2008–2010; for the other countries (Czech Republic, Croatia, Hungary, Romania and Slovakia) and their regions, the resistance index is calculated for the period 2008–2009. For the recovery index, the calculation is made according to the period needed to return to the situation in 2008. For Bulgaria and Slovenia and their regions, the economic recovery period is shorter: 2009–2011; for Hungary and Romania, the recovery period is longer: 2009–2014. As can be seen from Table 2, Bulgaria and Slovenia and its regions performed even better than the EU for the resistance period (six Bulgarian regions and two Slovenian regions); on the other hand, the other Eastern countries and their regions (Croatia, two of two regions; Czech Republic, six of eight regions; Hungary, eight of eight regions; Romania, eight of eight regions; Slovakia, two of four regions) have evolved worse than the average of EU regions. For the recovery period, the Eastern countries and their regions recovered at the average of the EU regions: Bulgaria (had only two regions lower than the EU average); Croatia (two of two); Czech Republic (four of eight); Hungary (four of eight regions); Romania (three of eight regions); Slovakia (four of four) and Slovenia (zero of two).

Table 2. Resistance and recovery index.

Regions	Resistance	Recovery	Regions	Resistance	Recovery
Bulgaria	1.084	0.021	Czech Republic	−0.352	−0.101
Severozapaden	0.366	−0.466	Praha	−0.386	−0.451
Severen tsentralen	0.701	0.073	Strední Cechy	−0.691	0.285
Severoiztochen	0.314	0.278	Jihozápad	0.206	−0.212
Yugoiztochen	1.273	0.273	Severozápad	0.080	−0.740
Yugozapaden	1.385	0.060	Severovýchod	−0.357	−0.121
Yuzhen tsentralen	1.181	−0.290	Jihovýchod	−0.266	0.321
Hungary	−1.207	−0.148	Strední Morava	−0.335	0.010
Budapest	−0.576	−0.514	Moravskoslezsko	−0.935	0.373
Pest	−1.289	−0.236	Croatia	−0.055	−1.261
Közép-Dunántúl	−2.362	0.295	Jadranska Hrvatska	−0.130	−1.310
Nyugat-Dunántúl	−1.777	0.689	Kontinentalna Hrvatska	−0.020	−1.237
Dél-Dunántúl	−1.142	−0.590	Slovenia	0.239	−1.012
Észak-Magyarország	−1.854	0.165	Vzhodna Slovenija	0.059	−0.950
Észak-Alföld	−1.019	−0.040	Zahodna Slovenija	0.382	−1.039
Dél-Alföld	−1.512	0.146	Slovakia	0.476	0.533
Romania	−1.518	0.406	Bratislavský kraj	1.667	0.124
Nord-Vest	−1.309	0.343	Západné Slovensko	−0.030	0.737
Centru	−1.354	0.197	Stredné Slovensko	0.238	0.426
Nord-Est	−1.311	−0.084	Východné Slovensko	−0.040	0.907
Sud-Est	−1.182	0.876			
Sud-Muntenia	−0.802	0.318			
Bucuresti-Ilfov	−2.352	1.066			
Sud-Vest Oltenia	−1.131	−0.342			
Vest	−1.522	−0.175			

Source: own calculations.

In the following, we will analyze the influence of the determinants at the level of the regions for the seven Eastern European states. Our analysis starts with the three components: the structure of economic activities (agriculture, manufacturing, services, and public administration), human capital (population and level of education) and physical capital (gross fixed capital formation) [24–26].

The structure of the economic activities is considered an important factor that has influence on the regional economic resilience, by the fact that the regions that have an increased economic diversity can better cope with the economic shocks and recover in a shorter period [27,28]. The same Indicators were taken into account precisely in order to be able to analyze their influence in the two periods of time, resistance and recovery.

As can be seen from Table 3, the diversity of the economy has its mark on the resilience of the regions of the seven Eastern states. For the period of resistance, two economic activities have an influence on the indicator (manufacturing and public administration); instead, two do not influence economic resistance (agriculture and services). For the recovery period, the results are similar, but there is still a change: the place of manufacture is taken by the services sector; agriculture has no influence on the phenomenon of recovery, and the public administration retains its role. Regarding the influence of the sectors between the two periods, it is observed that for the period of resistance, the manufacturing sector has an important role (coefficient of 3.697) and that during the recovery period it will no longer play the same role. The services sector although initially had an influence detected by the regression; for the recovery period, the influence is positive (0.256); public administration shows a greater influence in the first period, of resistance (6.625) compared to the second period of recovery (2.774). Entrepreneurship has a positive and important influence in both periods, 3.401 in the first period, and 0.933 in the recovery period.

Table 3. The determinants of resistance and recovery index (OLS and Quantile regression).

Variable	Resistance				Recovery			
	OLS Estimates	**Quantile Regression Estimates**			**OLS Estimates**	**Quantile Regression Estimates**		
		0.25	0.50	0.75		0.25	0.50	0.75
Agriculture	0.685 (0.42 *)	−0.039 (0.97 *)	1.417 (0.40 *)	−0.115 (0.95 *)	0.775 (0.06 *)	1.183 (0.07 *)	−1.460 (0.19 *)	−0.675 (0.30 *)
Manufacturing	3.792 (0.00 *)	4.406 (0.00 **)	−0.896 (0.61 *)	−1.878 (0.47 *)	1.529 (0.64 *)	0.803 (0.03 *)	1.999 (0.47 *)	−0.191 (0.43 *)
Services	0.751 (0.33 *)	1.185 (0.07 *)	−0.069 (0.94 *)	0.588 (0.54 *)	0.256 (0.04 ***)	0.205 (0.04 ***)	0.019 (0.97 *)	0.031 (0.79 *)
Public Administration	6.625 (0.01 *)	5.694 (0.00 *)	2.264 (0.24 *)	2.101 (0.47 *)	2.774 (0.04 *)	2.024 (0.4 **)	0.734 (0.86 *)	−0.058 (0.86 *)
Tertiary Education	0.182 (0.04 *)	1.722 (0.43 *)	−2.568 (0.44 *)	−2.691 (0.43 *)	0.257 (0.03 *)	1.201 (0.01 *)	0.761 (0.83 *)	0.072 (0.82 *)
Physical capital	0.718 (0.25 *)	0.035 (0.96 *)	0.974 (0.45 *)	3.426 (0.65 *)	0.124 (0.75 *)	0.032 (0.96 *)	1.334 (0.38 *)	0.111 (0.41 *)
Urban	0.002 (0.96 *)	0.015 (0.75 *)	−0.081 (0.30 *)	−0.054 (0.47 *)	−0.146 (0.39 *)	−0.180 (0.51 *)	−0.088 (0.85 *)	−0.005 (0.65 *)
Entrepreneurship	3.401 (0.01 *)	3.124 (0.03 *)	5.477 (0.31 *)	1.380 (0.74 *)	0.933 (0.04 *)	2.899 (0.03 *)	4.392 (0.42 *)	0.648 (0.13 *)
Intercept	0.475 (0.09 *)	0.378 (0.30 *)	0.307 (0.58 *)	−0.005 (0.99 *)	−0.677 (0.01 *)	−0.495 (0.30 *)	−0.039 (0.96 *)	−0.212 (0.00 *)
Number of Observations	38	38			38	38		
R-squared	0.828	0.675			0.501	0.299		
Adjusted R-squared	0.781	0.586			0.364	0.106		

Note: *, **, and *** indicate statistical significance at the 1%, 5% and 10% levels, respectively. Source: own calculations.

From Table 3, we observe that the urban population [29] had no impact on either the resistance index or the recovery (the associated probabilities > 0.05 were 0.96 for resistance and 0.39 for recovery, respectively). In contrast, education [30], represented by tertiary education, influenced in both periods the phenomena of resistance and recovery, the influence being more important in the second period (0.182 for the first period and 0.257 for the second period). The physical capital, represented by the gross fixed capital formation [31,32], did not influence the phenomena of resistance and recovery (the associated probabilities were > 0.05 of 0.25 and 0.75, respectively).

However, the results from quantile regressions should be taken with caution due to the small sample size of our analysis.

5. Discussion and Conclusions

The economic recession related to the crisis of 2008–2009 has produced important changes in the economy of the Eastern European states and their regions, but the impact is different from state to state and from one region to another. Most of the studies on regional resilience have focused on the Western states, the studies on the regions of the Eastern European states being very few and focusing in particular on the overall problems of the economy.

The present study analyzes the phenomenon of regional resilience for seven Eastern European states (Bulgaria, Hungary, Croatia, Czech Republic, Romania, Slovakia and Slovenia) and their regions, compared to the EU region. The analysis was performed for two distinct periods: the period of economic downturn, in which the phenomenon of resistance manifested itself (with the best performers being Bulgaria and Slovenia), and the recovery period, which differed in the analyzed states. This period was smaller in Bulgaria, Czech Republic, Hungary, Romania and Slovakia, compared to Croatia and Slovenia.

Following the analysis, three major conclusions can be drawn. Firstly, agriculture, population and physical capital do not influence resilience and its two components, resistance and recovery. The second conclusion is that the manufacturing and service sectors switched places during the crisis, so that manufacturing was influential in the period of resistance while services became more important in the recovery period. Finally, we noticed that public administration and tertiary education had a positive influence on regional resilience. Public administration played its most important part in the first period, resistance to recovery, while tertiary education did the same in the recovery period.

Based on the analysis, it can be concluded that these Eastern regions have some capacity for economic resilience, more pronounced in Bulgaria and Slovenia, but weaker in other states (Czech Republic, Croatia, Hungary, Romania and Slovakia) and their regions. Separately, on the two components, the regions of Bulgaria and Slovenia show a greater resistance than the regions of the other countries, the phenomenon of the recession settling harder after one year. At the same time, for the recovery phenomenon, the situation is similar: the regions in Bulgaria, Czech Republic, Hungary, Romania and Slovakia have recovered faster (2010–2012), while those in Croatia and Slovenia have been hit much harder (2009–2014).

The limitations of the study are given by the investigation of only seven European countries during a single crisis (2008–2014). However, since previous articles only analyze one country over the same period, this study constitutes an improvement. Nevertheless, future research will require an exploration of all the Eastern European states and their regions for a longer period, if data are available.

The implications for policymakers are that the seven states should focus on determinants with a positive influence on resilience. Thus, the service sector must be developed by stimulating new economic activities, the role of public administration must be improved by increasing its role and efficiency in society and the percentage of population with tertiary education must be increased by improving the quality of education, European sizing of curricula and educational requirements.

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Economic Development and Female Labour Force Participation: The Case of European Union Countries

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Abstract: In this paper, we studied the relationship between female labour force participation and economic development in the 28 countries of the European Union during the period 1990–2016. The analysis was carried out from two different viewpoints: first, we studied all the countries of the EU-28, and second, the evidence was disaggregated into two groups of countries: old (EU-15) and new (EU-13) member estates. The data used came from the World Bank open data repository and Eurostat. The methodology used consisted of the estimation of static (Ordinary Least Squares (OLS) and Fixed Effects (FE)) and dynamic (generalized moments model—GMM) models. Results for all European countries (EU-28) were consistent with the hypothesis which suggests the existence of a U-shaped relationship between female labour force participation and economic development. When the sample was broken down into groups, we found evidence that confirms the feminization hypothesis for the new countries of the EU, but not for the old ones.

Keywords: regional economic development; female labour force; education; static and dynamic models

Subject Classification Codes: O10; O52; J21

1. Introduction

Recently, there has been a growing interest to understand the relationship between female labour force participation (FLFP) and economic development. Different sets of factors may affect FLFP, including country-specific environmental factors and macroeconomic policies, as well as structural shifts and changes in the business cycle.

Indeed, first, women's propensity to participate in the labour market may be related to educational attainment, life expectancy, fertility rates, and unemployment rates. Women's willingness to participate in the labour market may also be influenced by policies that help them reconcile work inside and outside the household. For example, better access to childcare, longer maternity leave, more care services for minors or dependent ascendants and greater flexibility in work arrangements are associated with higher female labour force participation.

Second, FLFP rates can be strongly affected by structural transformations that may shift the types of demand for workers [1]. For example, structural shifts from agriculture to industry are usually accompanied with decreases in FLFP rates, whereas a transition from an industrial-based economy to a more services-oriented economy is commonly accompanied with an increase in the FLFP rate.

Finally, FLFP rates also depend heavily on the state of the business cycle. For example, in most countries, including the European countries most affected by the crisis, labour force participation remained relatively stable throughout the economic downturn [2]. Participation rates of men have declined since the crisis, in line with changes in population age structures and the drag from the global financial crisis, whereas women's participation has increased [1]. The reason seems to be that the "additional worker" effect (as the unemployment rate increases, additional members of the household enter the labour market to support family income) was more intense than the "discouragement effect" (as the rate and the average duration of unemployment increase, the unemployed become discouraged and stop actively seeking employment, leaving the labour force) [3].

On the other hand, the capacity of a country to strengthen labour market resilience to economic shocks depends on many factors, among which is the behaviour of FLFP rates. The cyclical resilience of the labour force in general, and of FLFP in particular, is important since it may serve to support a country's growth potential, encourage wage adjustment in an adverse macroeconomic setting, and, insofar as it is concentrated among older workers, contribute to mitigating the negative impact of population ageing on economic growth and on the sustainability of the pension system [4].

As mentioned above, the study of the relationship between female labour force participation (FLFP) and economic development has recently attracted renewed attention. Pioneering works including Sinha [5], Boserup [6] and Durand [7] proposed the hypothesis that the long-term relationship between economic development and FLFP follows a U shape. The U-hypothesis states that during the early stages of economic development, FLFP tends to decline due to the structural changes in the economy from an agricultural to an industrialized economy, and in later stages of development, FLFP increases as countries undergo the transition into modern economies, fertility rates decline and female education level increases.

Most empirical research confirming the U-hypothesis has involved widespread international comparisons of countries (cross-country, as well as panel data) and has revealed that FLFP is high in low-income countries and high-income countries, and relatively low in middle-income ones [8–14]. Only Gaddis and Klasen [15] have questioned the U-shaped hypothesis using cross-country data for the period 1980–2005. They showed that results are very sensitive to the data sources and estimation methods used.

Some other studies have tested the feminization hypothesis for one country and have found support for the U-shaped relationship (Lahoti and Swaminathan [16] for India; Fatima and Sultana [17] for Pakistan; Olivetti [18] and Goldin [10] for the United States; Tansel [19] for Turkey; and Tilly and Scott [20] for England and France). Time-series evidence for world regional areas is still scarce but most of them have found similar results (Tsani et al. [21] for Southern Mediterranean countries and Verme [22] for the Middle East and North Africa).

This paper explores the relationship between economic development and women's labour force participation testing the U-shaped hypothesis in the context of the European Union (EU) over the period 1990–2016. The methodology used consisted of the estimation of static (Ordinary Least Squares (OLS) and Fixed Effects (FE)) and dynamic (generalized moments model—GMM) models. We also studied how a set of variables affects the relationship between development and FLFP. We included fertility rate, life expectancy, education levels, and unemployment rate. The analysis was carried out from two different views: first, we studied all the countries of the EU-28, and second, the evidence was disaggregated into two groups of countries (which may be viewed as two country clubs): old (EU-15) and new (EU-13) member estates. To the best of our knowledge, this hypothesis had not been tested in this geographical area so far.

The EU, since its foundation in 1957, has gradually increased the number of countries in several waves. With no doubt, the most ambitious enlargement was the so-called big Eastern enlargement (Estonia, Lithuania, Latvia, Poland, Czech Republic, Slovakia, Slovenia and Hungary) along with Cyprus and Malta, which occurred in 2004. Three years later, in 2007 Romania and Bulgaria entered the EU, and Croatia in 2013. Many Eastern countries entered the EU after the fall of the Iron Curtain in 1989, though not before having initiated dramatic structural transformations of their economies to change from a communist society to a market economy. The far-reaching reforms included liberalization of trade and prices, changes in the labour market, enterprise restructuring, and building new institutions, among others. During the first years of transition, there were gains in female education, falls in fertility rates and in female labour participation, as well as sharp increases in unemployment [23].

The most recent enlargements of the EU have also brought about changes in the economic structure of the "old" countries (EU-15). In general, the integration process has brought benefits for all members. For example, "new" member states (EU-13) benefited from faster growth that enabled them to move from GDP per capita that was 40% of the EU-15 average prior to enlargement to 60% in 2016 [24]. "Old" member states gained from enlargement as well. First, they benefited from a larger export market and from a trade surplus with the new member states. Then, the private sector restructured production by relocating plants to maximize efficiency, which helped maintain global competitiveness and safeguard jobs in the old member states [25].

These developments make the EU a compelling case study for exploring the relationship between FLFP and economic development and for gaining a better understanding of the underlying factors behind this relationship in the region.

The rest of the paper is organized as follows. Section 2 reviews the theoretical considerations and the previous research. Section 3 explains the methodological framework and the data used. In Section 4, we present and interpret the main results, and the last section presents the conclusions.

2. Theoretical Considerations and Previous Research

The widespread hypothesis about the long-term relationship between economic development and FLFP is the feminization U-curve that suggests that FLFP declines in the first stages of development and then recovers as economic development proceeds. More specifically, research studies that have empirically tested the U-shaped hypothesis focusing on the long term argue that this shape is the result of the structural transformation of the economy of countries [5–8,10,11,26,27]. They claim that the downward portion of the U corresponds to the stage during which there is a structural change from an agricultural to an industrial society. The upward portion occurs in the advance economic development stages when women return to the labour market and begin working in the service industry.

The literature has also widely discussed the factors that affect FLFP. Women's decisions to participate in the labour market (in addition to the economic development opportunities) are also determined by current and future labour market conditions and the household and individual characteristics of women. One of the main driving factors behind FLFP is the level of education of women [28], which is closely related to economic development [6]. Fertility rate is another key factor for FLFP, which is also related to education, since women's progress in attaining higher levels of education is reflected in the delaying of marriage and pregnancy and the spacing of childbearing [10]. The impact of the unemployment rate on FLFP is, however, ambiguous. On the one hand, it is argued that the higher the unemployment rate, the lower the probability that women may be able to find a job, discouraging them from participating in the labour market [17,19,21,29,30]. On the other hand, when male unemployment increases, woman may decide to join the labour market in order to compensate the decline in household income [17]. There are other pertinent factors, albeit controversial ones such as culture, gender norms and identity that may also have an impact on FLFP [10,31,32]). In this regard, Goldin [10] stated that women were excluded from working in the industry due, precisely, to a social stigma. Finally, the degree of urbanization may have a positive effect on the FLFP. Urban areas offer more opportunities for employment than rural ones [17], and usually have more liberal socio-cultural attitudes [21].

The U-shape is, therefore, the result of a combination of factors whose theoretical fundamentals are as follows. In the first stages of economic development, when the country's income level is low and the dominant economic activity and income source is agriculture, female participation in the labour market is high. Women mainly work on farms and family businesses and they combine this work with childcare, which contributes to high fertility. As society develops and begins to shift to a more industrialized economy, women's opportunities for employment decrease. Family production aimed at self-consumption decreases and most consumed goods are produced outside the home, making it more difficult for women to reconcile childcare and work. Moreover, technical change requires employees with a higher level of education and the capacity to use machines, diminishing women's employment opportunities, and thus, their labour participation. This process is reinforced by the existence of social norms that dictate that women are responsible for domestic chores and stigmatize female participation in the workforce, making it difficult for women to work in the manufacturing industry. Manual labour in factories is considered inappropriate for women, particularly for those who are married. However, with the subsequent expansion of the service industry and the associated increase in female levels of education, new opportunities of employment for women are created. This, together with their higher wages, increases the opportunity cost of staying at home and reduces fertility rates. During this stage of economic development, women perform mainly administrative or clerical tasks, which contributes to reducing the social stigma. Higher wages and social acceptance lead to higher female labour participation.

During this process, both income and substitution effects take place [10]. With industrialization, the higher wages of men lead to an increase in household income, causing a decline in the labour participation of women who then dedicate themselves to childcare and domestic work.

As the process of economic development advances, girls' access to education improves, increasing the opportunity to earn higher relative wages and encouraging women to participate in the labour market (substitution effect). The downward portion of the U-shape suggests that a strong income effect is dominant over a small substitution effect. In the upward portion, the substitution effect of higher wages is dominant over the income effect.

So far, the U-shaped hypothesis has been the predominant hypothesis and has been supported by both cross-country studies and times-series studies. Prominent among the former is the study of Goldin [10] who confirmed the feminization hypothesis in a group of more than 100 countries during the period 1980–1985. Later, Mammen and Paxson [33] extended the analysis for the period 1970–1975 and reached the same findings. Other authors achieved similar results [12–14]. These studies analyse different groups of countries and suggest that the female labour participation rate tends to be high in low- and high-income countries, but relatively low in middle-income countries.

Research using time-series also supports the U-shaped hypothesis for developed economies. Goldin [10,31] and Olivetti [18] found evidence of this hypothesis for the United States. The same result was found by Tilly and Scott [20] for England and France, and by Suh [34] in South Korea. The feminization hypothesis has also been tested for developing countries with similar findings, such as Mammen and Paxson [33] for India and Thailand, Lahoti and Swaminathan [16] and Mehrotra and Parida [35] for India, Tansel [19] and Dildar [36] for Turkey, and Fatima and Sultana [17] for Pakistan.

Several studies have examined the U-shape hypothesis focusing on Middle Eastern and North African countries (MENA). Tsani et al. [21] examined South Mediterranean countries using data for the period 1960–2008 and by applying a two-stage approach of econometric and general equilibrium modelling. They concluded in favour of the U-curve. They also stated that the FLFP rate is determined mainly by education, fertility, religious norms and urbanization. Verme [22] tested the same hypothesis for MENA countries using parametric and non-parametric estimates during the period 1990–2010. Parametric tests showed that the countries of the MENA region are distributed over a U-shaped curve. However, non-parametric tests suggest, in general, an inverted U-shape and high heterogeneity both across countries and age cohorts. Thus, the author refuted the existence of a relationship between economic development and female labour participation rate.

Unlike previous authors, Gaddis and Klasen [15] found no evidence for the U-shaped relationship among non-OECD countries (Organisation for Economic Co-operation and Development). They tested the U-shape hypothesis for both a static (OLS and FE) model and a dynamic model using cross-country data from 1980–2005. They found that the results were very sensitive to the data source and the estimation methods used. The results depended on the Gross Domestic Product (GDP) data and were also affected by the version of the International Labour Organization's database on female labour participation They used GDP data from Penn World Table (PWT) in two versions (PWT 6.3 and PWT 7.1) [37,38]). They found that the static-fixed effects regression using PW6.3 provided little support for the U-shaped hypothesis, but the U-shape did emerge under the new PWT 7.1. Nevertheless, for both sets of data, the U-shaped relationship tended to disappear when dynamic methods were used.

Our study builds on this literature and extends it by empirically examining the U-shape hypothesis in the EU-28 countries, distinguishing between the "old" member states and the "newest" countries.

3. Data and Methodological Framework

3.1. Data

Our data comes from different data sources. First, FLFP is defined as the women's (aged 15 and above) share in the country's total labour force (LFP). Labour force participation (LFP) is defined as employed plus unemployed (actively seeking work). Second, to approximate the level of economic development, we used gross domestic product per capita based on purchasing power parity (PPP) at constant 2011 international $ (*GDPpcPPP*). The meaning of *GDPpc* is the gross domestic product divided by the mid-year population of the country. All these data come from World Bank open data repository. Third, we also studied how some variables affect FLFP, including fertility rate, life expectancy, female unemployment rate and female education.

Total fertility rate represents the number of children that would be born to a woman if she were to live to the end of her childbearing years and bear children in accordance with age-specific fertility rates of the specified year. Life expectancy at birth indicates the number of years a new-born infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life. Unemployment rate refers to the share of the labour force that is without work but available for and seeking employment. These variables were also taken from the World Bank open data repository. Education-related variables included secondary and tertiary education. These were measured as the percentage of females (from 15 to 64 years) who have upper secondary and post-secondary non-tertiary education and tertiary education, respectively. These data were taken from Eurostat.

Finally, some authors have referred to additional factors affecting FLFP, such as the sectoral structure [22], wages, social and cultural norms [10,31,32,35,36], or the urbanization level [17,21]). Nevertheless, these factors were not examined in this study.

The basic data were annual observations for a cross-country panel covering the 28 European member estates over the period 1990–2016. The dataset was an unbalanced panel, with several observations missing over different variables, countries and years. Table 1 shows some basic statistics of the whole sample.

Table 1. Basic statistics of the whole sample, 1990–2016.

	Mean	SD	Min	Max
FLFP	50.0	7.2	27.9	64.6
GDPpc	30,236.6	14,379.0	8001.7	97,864.2
Life expectancy	80.0	2.9	72.6	86.3
Fertility rate	1.6	0.2	1.1	2.4
Tertiary education	22.3	9.4	3.9	43.2
Secondary education	43.8	13.0	11.6	70.4
Female unemployment rate	9.6	4.9	1.5	31.4

FLFP: Female Labour Force Participation; *GDPpc:* Gross Domestic Product per capita.

3.2. Model Specifications and Estimation Techniques

We estimated different models to test the U-hypothesis. First, we followed the initial studies that were made about the feminization hypothesis and used OLS estimations, pooling the data in a unique cross-section [8,9]) as in Equation (1).

$$FLFP_{it} = \alpha + \beta lnGDPpc_{it} + (lnGDPpc_{it})^2 + \varphi X_{it} + \varepsilon_{it} \quad (1)$$

where $lnGDPpc_{it}$ is the natural log of the national GDP per capita PPP (constant 2011 international $), $FLFP_{it}$ is the female labour force participation rate, Xit is a vector of control variables which includes life expectancy, fertility rate, secondary education, tertiary education and unemployment rate, i denotes countries and t denotes time. The U-shaped hypothesis holds if: $\hat{\beta} < 0$ and $\hat{\gamma} > 0$.

However, although there is some value in using an OLS estimator as it is a transparent way to describe the data, it is well known that it can be biased in the presence of time-invariant unobserved heterogeneity. When this is the case, it is more appropriate to exploit the panel structure of the data and use the fixed effects estimator. Therefore, we also estimated Equation (2) which includes country-specific intercepts α_i and time-specific fixed effects γ_i to capture common trends.

$$FLFP_{it} = \alpha_i + \beta lnGDPpc_{it} + (lnGDPpc_{it})^2 + \varphi X_{it} + \delta_t + \varepsilon_{it} \tag{2}$$

The use of the fixed- effects model controls for the potential endogeneity problems emerging from the correlation between the set of independent variables and the time-invariant country-specific unobserved heterogeneity. However, they do not account for other sources of endogeneity. For example, first, if FLFP varies little, lagged FLFP is correlated with the error term and the repressors become endogenous [22]. Second, there could be a potential reversed causality between the dependent and independent variable. To overcome these potential endogeneity problems, we propose a dynamic model using Equation (3):

$$FLFP_{it} = \alpha_i + \varphi FLF_{it-1} + \beta lnGDPpc_{it} + (lnGDPpc_{it})^2 + \varphi X_{it} + \ \delta_t + \varepsilon_{it} \tag{3}$$

This model, however, if estimated with fixed effects accounts for endogeneity but does not correct for autocorrelation. Arellano and Bover [39] and Blundell and Bond [40] estimators can account for autocorrelation. Both estimators are well suited for panel data where the number of periods is relatively smaller than the number of countries. However, the Blundell and Bond [40] types of estimators assume that the instruments (lagged dependent variable) are uncorrelated with the individual effects (country/year). As in Gaddis and Klasen [15] and Verme [22], we find this assumption too restrictive and opt to use the difference model for the panel equations. This is also the preferred choice in the recent literature.

Since we are not interested in short-term cyclical effects and want to follow in the tradition of the feminization literature, we used 5-year windows.

Furthermore, the shape of the FLFP–GDP per capita relation may be different across groups of countries (as well as across individual countries) in the European Union. This is because different groups of countries may be transiting on different parts of the U curve during the period considered. Hence, we could expect if $\hat{\beta} < 0$ and $\hat{\gamma} > 0$ for U-shape transitions, $\hat{\beta} > 0$ and $\hat{\gamma} > 0$ for positive transitions and $\hat{\beta} < 0$ and $\hat{\gamma} < 0$ for negative transitions. It is also possible, of course, to find inverted U-shaped transitions with $\hat{\beta} > 0$ and $\hat{\gamma} < 0$.

As control variables, we included fertility rate, education levels, unemployment rate and life expectancy. We expected a negative relationship between fertility rate and FLFP because when socio-cultural attitudes change and the productive activity of women is more valued than their reproductive role, more women enter the labour market [10]. The fertility rate controls for population growth and it also indicates the extent to which women are occupied with raising children, and thus will have less time to work or attend school [41].

We also expected a positive effect of education on the FLFP as education increases the potential earnings of women as well as the opportunity costs of not working [10,19,21,30,33,42].

The unemployment rate is one of the variables that best describes the conditions of the labour market. However, the relationship between the unemployment rate and FLFP is ambiguous. The former variable affects the likelihood that a woman will find a job. The higher the unemployment rate, the less likely it is for a woman to find a job. For this reason, women can be discouraged in the search for employment, becoming part of the "group of discouraged" (inactive). Therefore, unemployment would have a negative impact on FLFP [17,19,21,29,30]. However, when the unemployment rate of men increases, women may decide to enter the labour market in order to compensate for the loss of family income ("added worker effect"). In this case, the FLFP is expected to rise with the increase in the male unemployment rate [17,43–45].

Finally, the impact of life expectancy at birth is uncertain [33]. This variable may be seen as a proxy for sufficient health care, that is, it captures aspects of the physical quality of life [41,46]. However, if retirement age does not increase as life expectancy increases the effect would be the opposite.

4. Results

Before presenting our estimation results, it is worth first focusing on the visual representation of the data. In Figures 1–3 we show the scatter plots of the association between $FLFP_{it}$ and $GDPpc_{it}$ for the EU-28, EU-15 and EU-13 countries, respectively.

Figure 1 confirms that the EU-28 countries follow a slight U pattern over the period 1990–2016. This is stable for individual survey time periods (not presented here). It was observed that both for relatively low and high levels of $GDPpc_{it}$, $FLFP_{it}$ was around 50%, while for average per capita incomes, $FLFP_{it}$ was highly variable. In countries where $lnGDPpc_{it}$ ranged from approximately 9.5–10.5, women's participation in the labour market was observed both at relatively high (over 60%) and low (below 30%) levels. Over the years under study, several countries have experienced significant increases in female labour force participation. However, despite positive changes, there are still economies lagging behind, not reaching the EU average $FLFP_{it.}$ Countries situated below the curve turning point are older member countries of the EU (except Denmark, Finland, Sweden and the UK) and some new member states (Malta, Cyprus, Bulgaria or Romania). However, most Eastern countries exhibited above average female labour participation rates. These economies of Eastern Europe represent cases of highly feminized labour forces because of the socialist commitment to and imperative for women's economic mobilization [11].

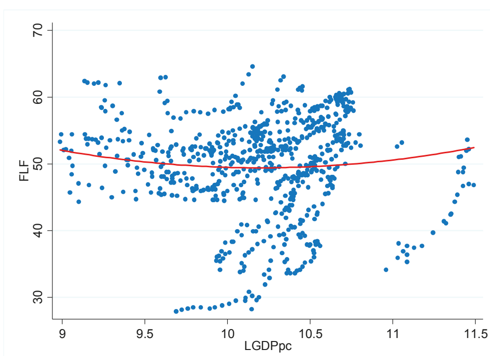

Figure 1. Female labour force participation versus *GDPpc*. 28 EU countries. 1990–2016.

When we move to the distinction between the EU-15 countries (Figure 2) and the newest European countries (Figure 3), we find mixed results, indicating the relevance of contextual factors in determining the $FLFP_{it}$-$GDPpc_{it}$ relationship. In the former group of countries, an inverted U-shape is found whereas in the latter one, a slight U-shape relationship is identified.

Given this, and in order to gain a better understanding of the relationship between $FLFP_{it}$ and $GDPpc_{it}$, we report the estimation results for our sample.

We first present the results for the static models (OLS and FE) for all EU countries in Table 2. We report for each regression the coefficients for GDP per capita (in logs), GDP per capita squared (in logs), the control variables as well as the turning point (time-fixed effects are included). It shows that there was a statistically significant U relationship in both OLS and FE estimations when control variables were not included.

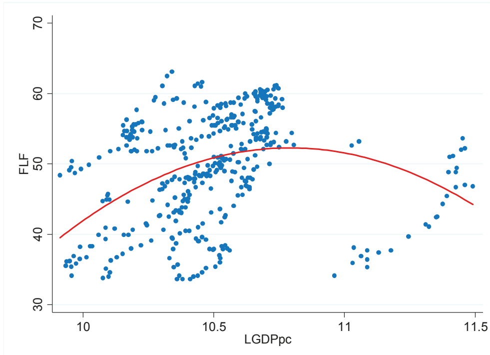

Figure 2. Female Labour Force participation vs. *GDPpc* (EU-15 countries, 1990–2016).

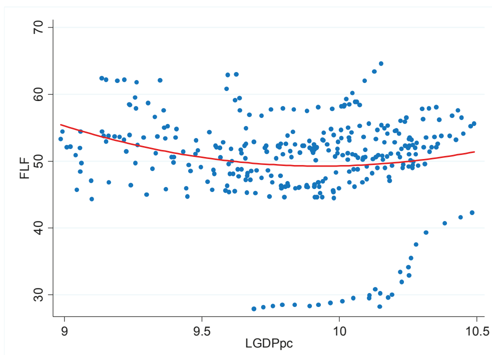

Figure 3. Female labour force participation versus *GDPpc* (EU-13 countries, 1990–2016).

There was a variability in turning points between the estimations, being lower in the FE estimator than in the OLS one, similar to the findings in Gaddis and Klasen [15]. The turning point occurs at $34,417 per capita (in 2011 constant prices) in OLS estimation without control variables and at $22,608 per capita (in 2011 constant prices) in the FE estimation without control variables.

When we included control variables, the U-shaped relationship remained significant only in the fixed-effect estimation. We are aware that many studies have noted that female education and fertility rates are strongly inversely correlated, creating a collinearity problem in the equations. For this reason, we have run the models with and without the fertility rate variable, and results remain largely unchanged. The coefficients of education variables were positive and statistically significant meaning that an increase in the education level leads to higher female labour participation. The tertiary education had greater value than the secondary education. The unemployment rate held a negative and significant coefficient. Unemployment rates had a statistically negative effect. This is an indication of the existence of a discouraged worker effect, which occurs during recessions when workers do not search for work *because* they view their chances of finding a suitable job as being too low. This result was also found by Ozerker [29]. Finally, life expectancy and fertility rates were not statistically significant. In Appendix A, we present a robust test for the U-shaped relationship.

The static models for the entire group of EU countries suggest that, in general terms, the FLFP and economic development relationship followed a U-shaped pattern over the period analysed. The downward slope of the curve exhibited the de-feminization process of the labour force that is associated with economic development. Countries in the early stages of development are exposed to structural changes that encourage women in low-paid jobs to join the education system [14]. The upward slope suggests the empowerment process in women is growing due to further economic development.

Table 2. Static models (EU-28).

	Model 1 OLS		**Model 2 OLS**		**Model 3 Fixed Effects**		**Model 4 Fixed Effects**	
lnGDP_pc	–52.148 (30.49)	*	51.258 (29.79)		–221.917 (26.39)	***	–124.02 (29.78)	***
lnGDP_pc2	2.496 (1.49)	*	–2.477 (1.40)		11.067 (1.36)	***	6.187 (1.52)	***
Life expectancy			–.450 (0.37)				–.258 (0.49)	
Fertility rate			–1.548 (2.20)				–1.298 (2.27)	
Secondary education			0.154 (0.06)	***			0.212 (0.06)	***
Tertiary education			0.455 (0.07)	***			0.353 (0.09)	****
Unemployment rate			–0.378 (0.11)	***			–0.072 (0.08)	
Constant	318.991 (318.99)	**	–190.145 (114.23)		1158.14 (128.16)	***	676.20 (148.56)	****
N	163		148		163		148	
F (7,155); F (12,135) F (7,128); F (12,108)	1.71		13.37		20.70		16.30	
Prob > chi2	0.090		0.000		0.000		0.000	
Rho					0.886		0.848	
N groups					28		28	
R-sq	0.074		0.499					
R-sq: within					0.530		0.644	
R-sq: between					0.006		0.294	
R-sq: overall					0.024		0.339	
Turning point	34,417.3		31,156.9		22,608.2		22,530.6	

Cluster standard errors (country-level) in brackets. Time dummies included, but not reported. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$. *lnGDPpc: Gross Domestic Product per capita (in logs); lnGDPpc2: Squared of Gross Domestic Product per capita (in logs): OLS: Ordinary Least Squares*

Moving to the estimations of the two groups of EU countries included in the study (Table 3), we find that the U-shaped relationship between FLFP and GDP*pc* only holds for new member states. We observed that in both estimators (OLS and FE), the coefficient of GDP*pc* was much larger than the one of the squared GDP*pc*, which might suggest that the "negative" relationship between FLFP and GDP*pc* was dominant.

For the EU-15 group of countries, there was no evidence of a U relationship since the corresponding coefficients were not statistically significant (except in the OLS estimation without controls where an inverse U-shaped relationship was found).

For the two groups of countries, the coefficients for education variables were positive and statistically significant. The unemployment rate was statistically non-significant (except for UE-15 in OLS estimations with controls) although it had a negative sign, as do the estimations for the whole of Europe. The remaining variables were not statistically significant (except for the life expectancy in EU-13, which was significant and negative in OLS estimations with controls). In Appendix A, we present a robust test for the U-shape relationship.

Table 3. Static models (EU-15 and EU-13).

	EU-15				EU-13			
	Model 5 OLS	**Model 6 OLS**	**Model 7 Fixed Effects**	**Model 8 Fixed Effects**	**Model 9 OLS**	**Model 10 OLS**	**Model 11 Fixed Effects**	**Model 12 Fixed Effects**
lnGDPpc	283.26 *** (105.26)	−45.42 (99.82)	−91.04 (76.03)	−35.87 (66.20)	−114.92 (125.87)	−159.12 * (92.34)	−264.18 *** (58.20)	−141.46 * (79.23)
lnGDPpc2	−13.17 *** (4.91)	1.72 (4.58)	4.78 (3.58)	2.12 (3.10)	5.67 (6.40)	8.94 * (4.73)	13.38 *** (3.05)	7.51 * (4.13)
Life expectancy		−1.01 (.63)		0.71 (0.90)		−2.38 *** (0.51)		−0.314 (0.83)
Fertility rate		−4.68 (3.19)		3.26 (4.51)		−6.97 (4.25)		−4.17 (3.75)
Secondary education		0.13 ** (0.06)		0.19 ** (0.07)		0.24 *** (0.051)		0.30 * (0.15)
Tertiary education		0.59 *** (0.11)		0.31 ** (0.12)		0.39 *** (0.061)		0.48 *** (0.19)
Unemployment rate		−0.63 *** (0.14)		0.03 (0.10)		−0.08 (0.17)		0.04 (0.21)
Constant	−1473.61 ** (562.31)	410.86 (522.84)	475.93 (403.66)	116.24 (363.50)	631.14 (615.82)	929.39 ** (459.28)	1353.04 *** (278.06)	0.722.76 * (407.84)
N	90	86	90	86	73	62	73	62
F(7,82); F(12,73) F(7,68) F(12,59) F(7,65) F(11,50); F(7,53) F(11,38)	3.37	17.31	17.91	15.53	0.61	10.07	5.47	2.79
Prob > chi2	0.003	0.000	0.000	0.000	0.7479	0.000	0.000	0.009
Rho			0.896	0.906			0.845	0.709
N groups			15	15			13	13
R-sq	0.223	0.638			0.06	0.689		
R-sq: within			0.648	0.7595			0.419	0.446
R-sq: between			0.002	0.1335			0.017	0.509
R-sq: overall			0.068	0.2376			0.042	0.523
Turning point	46,663.7	542,253.2	13,732.50	4703.90	25,185.90	7327.1	19,298.3	12,239.7

Cluster standard errors (country-level) in brackets. Time dummies included, but not reported. *** $p < 0.01$; ** $p < 0.05$; * $p < 0$.

Besides the signs and significance levels of the GDP variables, the fixed-effect regressions also provide useful information on country-specific differences in FLFP, which cannot be explained by the level of GDP or over time changes. Figure 4 shows the estimated fixed effects using the regression without controls revealing the countries with the largest positive and negative fixed effects. The figures unveil striking regional patterns in female labour force participation, which are conditioned on the level of GDP.

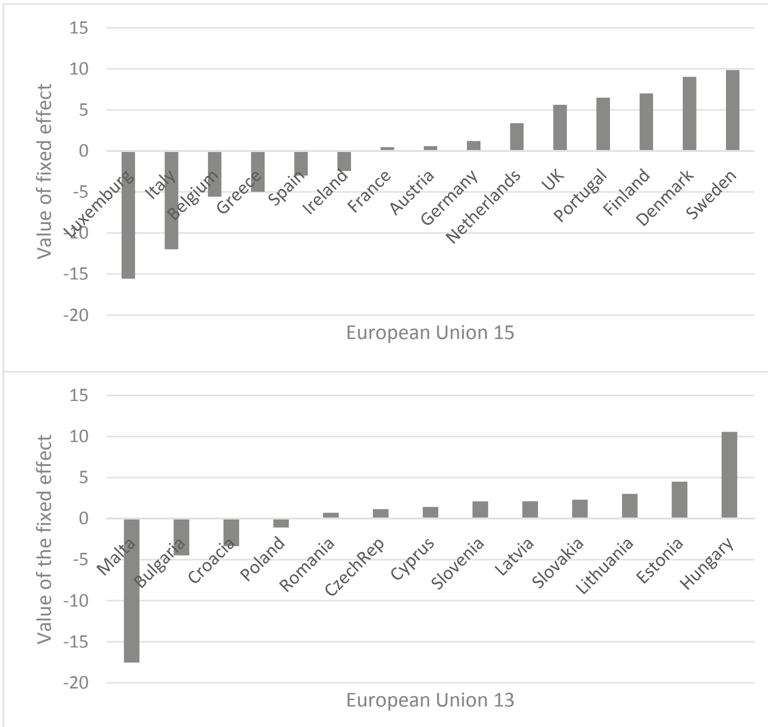

Figure 4. Country-specific fixed effects by country group. Fixed-effect regression based on the OLS without controls.

Most Eastern transition countries (Hungary, Estonia, Slovenia, Lithuania, Czech Republic and Latvia) had large positive effects confirming the idea that the region has above average rates of FLFP because of the legacy of socialism, which promoted female labour force participation [15,47].

Figure 4 also shows the pattern of FLFP for EU-15 countries, with negative fixed effects in Southern European countries (Italy, Spain and Greece) along with other countries such as Luxemburg or Belgium. The largest positive fixed effects are associated with Northern countries (Finland, Denmark and Sweden). These results reveal, as stated by Gaddis and Klasen [15] the strong influence of the history of the countries in determining the evolution of the labour force participation.

The use of dynamic models (i.e., GMM) allows us to capture, at least partially, the influence of past values of FLFP, that is, the power of history. Table 4 displays the results of the difference of the GMM estimator for the EU-28 and the two subgroups of European countries. We report the turning points, sample sizes and regression diagnostics.

Table 4. Dynamic models: GMM estimator (EU-28, EU-15 and EU-13).

	EU-28				EU-15				EU-13			
	Model 13		**Model 14**		**Model 15**		**Model 16**		**Model 17**		**Model 18**	
Female Labour Force Participation ($t-1$)	0.77 (0.14)	***	0.70 (0.19)	***	0.76 (0.08)	***	0.84 (0.13)	***	0.61 (0.22)	***	0.24 (0.13)	*
lnGDPpc	–98.38 (42.39)	**	–264.10 (124.50)	***	–104.54 (71.80)		–129.05 (82.78)		–211.04 (94.35)	**	–230.19 (140.39)	*
lnGDPpc2	5.51 (2.25)	**	14.23 (6.48)	**	5.03 (3.31)		6.21 (3.95)		11.049 (4.86)	**	11.98 (7.26)	*
Life expectancy			0.92 (0.97)				0.45 (0.35)				0.415 (0.66)	
Fertility rate			19.13 (15.62)				1.72 (2.48)				–0.545 (3.77)	
Secondary education			0.12 (12.56)				0.01 (0.06)				0.203 (0.15)	
Tertiary education			–0.06 (15.25)				–0.04 (0.12)				0.162 (0.17)	
Unemployment rate			0.07 (0.24)				–0.06 (0.05)				–0.057 (0.13)	
N	112		119		60		60		52		49	
Wald Chi2(9)(14)(9)(14)(9)(14)	153.0		307.4		469.8		5167.7		57.43		1330.48	
Prob > chi^2	0.000		0.0000		0.000		0.000		0.000		0.000	
N groups	28		28		15		15		13		13	
Number of instruments	13		18		13		14		10		11	
2^{nd} order autocorrelation	0.610		0.675		0.105		0.174		0.510		0.324	
Hansen test of over identifying. restrictions	0.177		0.136		0.408		0.335		0.244		0.313	
Turning point	7472.9		10,682.9		32,328.1		32,660.7		14,047.3		14,899.4	

Standard errors in brackets. Time dummies included, but not reported. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$.

We observed the persistent behaviour of FLFP, as the coefficient of the first lag of the dependent variable was positive and highly significant in all cases. There are significant differences in the intensity of the persistence since in the EU-15 countries, the coefficient for this variable was 0.84 (significant at the 1% level) while in the EU-13 countries this coefficient was 0.24 and marginally statistically significant at the 10% level. This finding suggests that, for the latter group of European countries, past values of the FLFP do not contribute to forecasting future values of FLFP as much as in the EU-15 subgroup of countries. In other words, the resilience to recover from a shock was lower.

The FLFP and economic development relationship follows a U-shaped pattern when all European countries were considered. However, when the EU-28 was split into the two groups, we found that there was evidence for the feminization U hypothesis only in the newest European countries (EU-13). The coefficient, however, was only significant at the 10% level. We did not find such evidence for the old countries (EU-15), since the coefficients for GDP per capita (*lnGDPpc*) and the squared GDP per capita (*lnGDPpc2*) were statistically non-significant. The turning point for the former group of countries occurred at around $14,000 (at 2011 constant prices). Again, the negative relationship between female labour force engagement and level of per capita income was strong (*lnGDPpc*), compared to the positive one (*lnGDPpc2*). In the dynamic models, control variables were not statistically significant due to the high persistence of the female labour participation variable. In Appendix A, we present a robust test for the U-shape relationship.

5. Conclusions and Discussion

This paper studies the relationship between female labour force participation and economic development in the European Union countries over the period 1990–2016, distinguishing between the long-standing EU member countries (EU-15) and the new member states (EU-13) incorporated into the European Union in the extensions, which have taken place since 2004.

We have estimated static (OLS and fixed-effect estimators) and dynamic models (GMM estimator) with and without control variables. We control for life expectancy, fertility rate, secondary and tertiary education and unemployment rate. The most robust estimates, those based on GMM estimations with control variables, support the U-hypothesis for the EU-28, which suggests that in the early stages of economic development, female labour force engagement tends to fall, then as countries increase their development and become more serviced-based, the female labour force starts to grow.

Nevertheless, when the feminization hypothesis was tested in the two country clubs (old and new member states) separately, the results changed. For the EU-15 countries, the existence of the U-shaped relationship was not verified. Most of these countries were already high-income economies in the 90s, and female labour participation had almost reached its full potential. For the group of new member states, the U-shaped relationship was confirmed. However, the coefficients for this group of countries were only statistically significant at the 10% level, suggesting that evidence in favour of the feminization hypothesis is weak in this group of countries.

In all of the groups of countries, the results also show that female education had a positive effect on female labour force participation (although they were not statistically significant). Although the fertility rate had negative correlation with female labour force participation (in EU-13 countries), it was not statistically significant.

The differences between “old” and “new” member states regarding the relationship between FLFP and economic development suggest the desirability of achieving further progress in the deepening of the integration process as a solution to the possible dissimilarities in the level of resilience to cyclical and structural forces.

These findings regarding the relationship between female labour force participation and economic development in the European Union, however, should be interpreted with certain caution since the period analysed was not very long. Moreover, besides the traditional control variables considered in our analysis, there may be other factors affecting women’s labour participation such as legal and tax regulation, level of competition and liberalization or the *openness* of the country as claimed by Lechman and Kaur [14].

Thus, this work has extended the current empirical state of the art by providing additional evidence on the relationship between FLFP and economic development in the European context, which had not been examined to date.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Given a model of the form $FLFP_i = lnGDPpc_i\alpha + lnGDPpc_i^2\beta + \ Z_i\gamma + u_i$

Lind and Mehlum (2010) [48] show that a test for the presence of *U* relationship needs to be based on the following joint null hypotheses:

H0: $(\alpha + 2\beta lnGDPpc_{\min} \leq 0) \cup (\alpha + 2\beta lnGDPpc_{\max} \geq 0)$, (1)

against the alternative:

H1: $(\alpha + 2\beta lnGDPpc_{\min} > 0) \cap (\alpha + 2\beta lnGDPpc_{\max} < 0)$, (2)

where, $lnGDPpc_{\min}$ and $lnGDPpc_{\max}$ are the minimum and maximum values of *lnGDPpc*, respectively. Lind and Mehlum [48] use Sasabuchi's (1980) likelihood ratio approach to build a test for the joint hypothesis given by Equations (1) and (2). Tables A1–A5 report the results of the Sasabuchi–Lind–Mehlum (SLM) test based on the results of Tables 2–4, respectively.

The top panel of Table A1 shows that the marginal effect of *lnGDPpc* is negative and statistically significant at $lnGDPpc_{\min}$ and positive and statistically significant at $lnGDPpc_{\max}$ for models 1, 3 and 4. The bottom panel of the table shows that the SLM test rejects H_0 (presence of inverse U-shape) for the aforementioned models and indicates that these results are consistent with the presence of a U relationship between *lnGDPpc* and FLFP.

Table A1. Tests for a U-shape: EU-28.

	Test for Model 1 OLS	Test for Model 2 OLS with Controls	Test for Model 3 FE	Test for Model 4 FE with Controls
Slope at *GDPpc* min	–50.65 **	49.77 **	–215.27 ***	–120.31 ***
Slope at *GDPpc* max	5.05 *	–5.50 **	31.67 ***	17.75 ***
SLM test for inverse U shape	1.25	1.72 (a)	5.97	3.22
p value	0.10	0.04	0.00	0.00
Fieller 90% confidence interval	(10.01; 52.82)	(5.75; 11.12)	(9.87; 10.21)	(9.73; 10.40)

This table reports the results of the Sasabuchi–Lind–Mehlum test for a U-shaped relationship. Robust standard errors *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. (a) Sasa- buchi-Lind-Mehlum (SLM) test for U-shape. The test rejects the H0 (presence of U-shape).

Table A2 shows results of the U-shape test for the EU-15 countries. Results for these regressions do not strongly support the presence of the U-shape. The marginal effect of *lnGDPpc* is positive and statistically significant at $lnGDPpc_{\min}$ (Model 5). The SLM tests rejects the null of existence of inverse U-shape against the alternative of U-shape or monotonic. For estimations 6–8, the marginal effect of *lnGDPpc* is negative but statistically non-significant at $lnGDPpc_{\min}$.

Table A2. Tests for a U-shape: EU-15.

	Test for Model 5 OLS	Test for Model 6 OLS with Controls	Test for Model 7 FE	Test for Model 8 FE with Controls
Slope at *GDPpc* min	275.35 ***	–44.39	–88.18	–34.59
Slope at *GDPpc* max	–18.6024 ***	–5.93	18.43 ***	12.73 **
SLM test for U shape	3.19 (a)	(b)	1.19	0.54
p value	0.0012	-	0.118	0.296
Fieller 90% confidence interval	(10.55–10.91)	(–Inf; +Inf) U (10.25; +Inf)	(–Inf; 14.67) U (10.30; +Inf)	(–Inf; 11.88) U (10.26; +Inf)

This table reports the results of the Sasabuchi–Lind–Mehlum test for a U-shaped relationship. Robust standard errors *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. (a) SLM test for inverse U-shape. The test rejects the null of existence of a U-shape. (b) Extremum outside interval—trivial failure to reject Ho (H0: monotone or U shape).

In Table A3, the top panel shows that the marginal effect of *lnGDPpc* is negative and statistically significant at $\text{lnGDPpc}_{\text{min}}$ and positive and statistically significant at $lnGDPpc_{\text{max}}$ for all models. The bottom panel shows that the SLM test rejects H_0 (presence of U-shape) for model 9–11 suggesting that the results are consistent with the presence of a U relationship between *lnGDPpc* and FLFP.

Table A3. Tests for a U-shape: EU-13.

	Test for Model 9 OLS	Test for Model 10 OLS with Controls	Test for Model 11 FE	Test for Model 12 FE with Controls
Slope at *GDPpc* min	–111.51	–153.75 **	–256.14 ***	–136.96 **
Slope at *GDPpc* max	15.062	45.73 ***	42.53 ***	30.74 **
SLM test for U shape	0.71	1.72	3.43	1.78
p value	0.239	0.046	0.000	0.0412
Fieller 90% confidence interval	(–Inf; +Inf)	(2.12; 9.38)	(9.64; 10.22)	(6.57; 10.43)

This table reports the results of the Sasabuchi–Lind–Mehlum test for a U-shaped relationship. Robust standard errors *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A4 shows that the marginal effect of *lnGDPpc* is negative and statistically significant at $lnGDPpc_{\text{min}}$ and positive and statistically significant at $lnGDPpc_{\text{max}}$, for both models. The SLM test rejects H_0 (presence of U-shape) for models 13–14 suggesting that the results are in line with the feminization hypothesis.

Table A4. Tests for a U-shape for dynamic panels: EU-28.

	Test for Model 13 GMM	Test for Model 14 GMM with Controls
Slope at *GDPpc* min	–95.06 **	–255.55 **
Slope at *GDPpc* max	27.98 ***	62.07 ***
SLM test for U shape	2.32	2.12
p value	0.0112	0.0182
Fieller 90% confidence interval	(7.69; 9.37)	(8.15; 9.56)

This table reports the results of the Sasabuchi–Lind–Mehlum test for a U-shaped relationship. Robust standard errors *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Finally, Table A5 shows that the marginal effect of *lnGDPpc* is negative and statistically significant at $lnGDPpc_{\text{min}}$ and positive and statistically significant at $lnGDPpc_{\text{max}}$ for all models. The SLM test rejects H_0 (presence of U-shape) suggesting that the results are consistent with the presence of the U relationship between *lnGDPpc* and FLFP for estimations 17–18. However, this hypothesis is not confirmed for estimations 15 and 16.

Table A5. Tests for a U-shape for dynamic panels: EU-15 and EU-13.

	EU-15		EU-13	
	Test for Model 15 GMM	**Test for Model 16 GMM with Controls**	**Test for Model 17 GMM**	**Test for Model 18 GMM with Controls**
Slope at *GDPpc* min	–101.52*	–125.32 *	–204.41 **	–223.01 *
Slope at *GDPpc* max	10.82**	13.20 *	42.14 **	44.26 *
		SLM test for U shape	SLM test for U shape	SLM test for U shape
SLM test for U shape	1.45	1.41	2.24	1.64
p value	0.0755	0.0814	0.0148	0.0538
Fieller 90% confidence interval	(–Inf; 14.58) U (11.01; +Inf)	(–Inf; +Inf)	(8.95; 9.82)	(6.57; 10.43)

This table reports the results of the Sasabuchi–Lind–Mehlum test for a U-shaped relationship. Robust standard errors *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

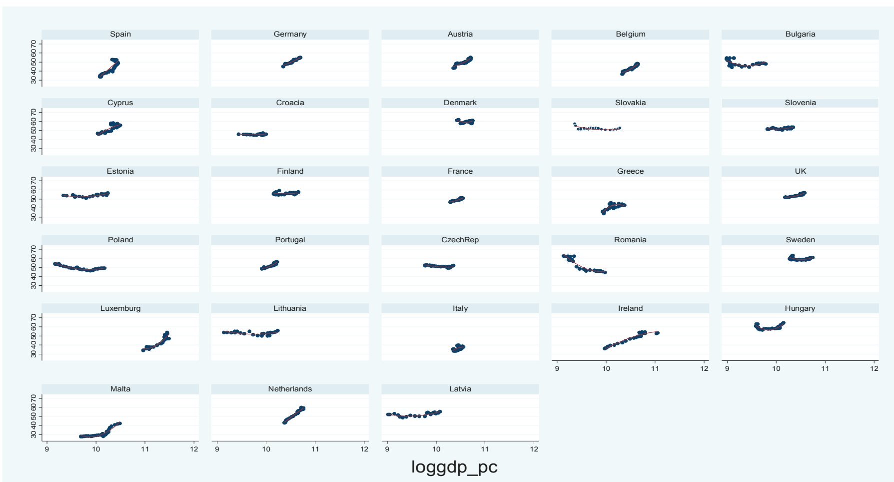

Figure A1. Countries.

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Article

Analyzing Determining Factors of Young Graduates' Decision to Stay in Lagged Regions

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Abstract: This study identifies what factors have effects on college graduates' decisions to stay for jobs in lagged regions using a bivariate probit model with sample selection. The results show that strong preferences for a home village and a university region contribute to the decision about job location concerning the regions. In addition, low living costs have much significant impact on spatial choice compared with economic factors, such as the levels of wage and job security. The long-term economic growth of lagged regions could be affected by a preference of high-school graduates to attend local universities.

Keywords: young college graduates; location decision; hometown effect; university region

1. Introduction

In 2019, The New York Times reported that, from 2000 to 2010, knowledgeable workers moved to rural regions in Minnesota, US with ample socioeconomic assets due to the government loan forgiveness program and financial incentives across generations. Many lagged regions attempted to induce well-educated people to return from economically developed regions in order to strengthen regional competitiveness [1,2]. It would be worthwhile finding out what makes young educated people work in lagged regions because workers so rarely return home to lagged regions [3,4]. Several studies have shown that people tend to stay in lagged regions where they have lived due to familiarity with their hometown or their university [5–7]. However, there are few studies to examine why young graduates stay in lagged regions without leaving for the high expected wages of large cities.

The purpose of this study is to analyze the determining factors of young college graduates' decision to stay for a job after graduation in lagged regions. By using a bivariate probit model with sample selection, this study explores the spatial mobility of Korea's young graduates born in lagged regions in terms of individual background and regional components. One innovative element that distinguishes this paper from previous works is that it empirically identifies non-economic factors that influence young graduates' decisions to stay for a job in the lagged regions after university graduation. The remainder of this study is organized as follows. Section 2 reviews the previous studies on the determinants that retain human capital in lagged regions. Section 3 discusses the result of the bivariate probit model with sample selection. The final section discusses conclusions and future research.

2. Literature Reviews

Many studies on urban agglomeration have shown what makes well-educated people move to regions, which helps to fortify the absorptive capacity of regions [2,8,9]. However, attracting well-educated people could be challenging to lagged regions [10]. Young graduates' behavior in returning to lagged regions has been noted in a growing number of inter-regional migration studies [3,11]. Few studies have analyzed the determining factors of young graduates staying in lagged regions. There have been a few studies on why people continue to stay in their communities [7,12]. Young workers are expected to be highly mobile because they can minimize their concerns regarding lifecycle and family [13]. They have many opportunities for transition from unemployment to employment because of their ability to adapt to new technology skills and fast-changing jobs [14]. Their decision as to where to stay is closely relevant to job opportunities, which was different from the older generation's choice to stay in their current place of residence.

We would like to review the literature on (1) the migration patterns of people staying in lagged regions and (2) the behavior of young graduates returning to lagged regions. One of the primary issues in the previewed works was why people stay in their current residence despite fewer opportunities to obtain high wages. Of course, economic incentives positively influenced the decision to stay in, as well as to return to, lagged areas. Large opportunities for employment were expected to influence people's decisions to stay. Local public education satisfied the needs people have for their regional communities due to a high rate of return to education regardless of whether by in-migrants or natives of the local area [15]. Graduates with a teacher's degree or a degree in applied science had a strong tendency to remain in their university region [5,16]. They could easily enter the regional labor market because of high consistency between their field and the regional labor market. These subjects might be more oriented toward the practical use of knowledge and skills than natural sciences, social science, or the humanities [17].

However, even without direct monetary rewards, social networks accounted for the likelihood of graduates staying in their university region in terms of the maximization of graduates' contacts with regional companies as well [6]. Particularly, self-employed graduates were more likely to stay in their university region due to a large demand for a business network. In addition to economic incentives, non-economic benefits have been known to explain people staying. A feeling of belonging or being similar to those living in a neighborhood has been known to reduce the probability of people leaving current areas [7,12]. Similarly, the effect of place-based factors, such as the ability to meet people and make friends, explained people staying in their current place of residence [18]. On the other hand, the propensity to be immobile varied depending on time and the level of regional urbanization. For example, many graduates did not leave their university regions within 10 years after graduation. In addition, this propensity decreased when they had a partner, children, or strong family ties, owing to the high costs of out-migration. [5,10,19].

Another finding is that young graduates have been widely known to return due to economic benefits [3,10,20]. Ample opportunities for labor performance and high wages were expected to be the main reasons for graduates to return [1,2,21]. They were likely to go back to regions for job security and opportunities to be hired by top research institutes [22], while low unemployment rates did not seem to be an attractive condition. A conditional effect with respect to the relative unemployment rate between the origin and destination was significant for the return of young graduates. Specifically, earlier findings provided empirical evidence that when the unemployment rate of a destination region was less than 12.7% of the unemployment rate of their region of origin, graduates did not go back to those regions [20]. Sometimes, even with many economic incentives, such as high wages, job opportunities, and huge investments in higher education, graduates did not return to regions unless the economy was developed in those regions. Individual experience affected young graduates' return to lagged regions. Young graduates were likely to go back when they attended a college near to their hometown or they had job experience outside the region [21]. Lots of young graduates returned to their hometown as self-employed workers [11]. People from rural areas were more likely than those from large cities to return to lagged regions. Ties with family, friends, and comfort from familiarity were positively associated with graduates deciding on their mobility pattern [23–25].

In sum, wages, job security, and ties to family and friends are known as three major factors to induce young graduates to move to lagged regions. Additionally, these factors have the same impacts on keeping people living in their current place of residence, even in lagged regions. However, previous work has not been concerned with the determining factors of young college graduates' decisions to stay in lagged regions. This paper is mainly concerned with the analysis of the impact of the familiarity of the hometowns or the university regions of young graduates on their decisions to stay in lagged regions after graduation.

3. Analysis

3.1. Methodology

Korea consists of 226 cities and counties, 65 of which are included in the Seoul Metropolitan Area (SMA), and the rest are in the non-Seoul Metropolitan Area (non-SMA). The SMA is the developed region and the non-SMA is the lagged region in terms of economy and population density. We had eight types of high-school graduates' decisions concerning university and jobs within the leading regions and the lagged regions, as illustrated in Figure 1. In this study, we analyzed only type 8—high-school graduates from lagged regions who go to colleges within lagged regions and get a job within lagged regions after graduation.

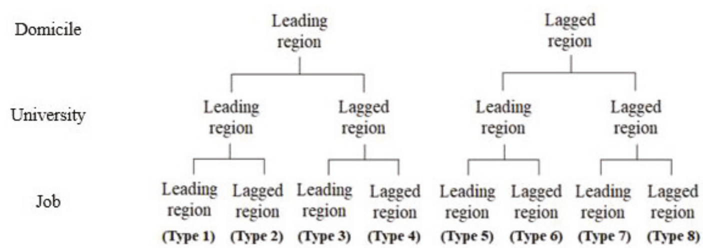

Figure 1. Eight types of graduate migration.

We used a bivariate probit model with sample selection, which allowed for control over self-selection bias when individuals were making two-stage decisions regarding the location of their universities and jobs. Applying a bivariate probit model with sample selection yielded consistent estimates of the explanatory variables when a young graduate's location decision regarding a job was conditional on the decision they had made regarding their university's location [26]. Whether graduates studied in leading regions or in lagged regions affected their location choice for a job. In this respect, this method identified the migration patterns of the graduates who studied at the colleges in lagged regions compared to those in leading ones. While university students stayed in lagged regions for education, they built their own social networks in the lagged regions. After graduation, they might have found jobs in the university regions in order to maintain emotional comfort and to rely on social contacts.

This study classified the independent variables into two types of individual background and regional components and was particularly interested in the spatial variables for hometown and university regions We took into account that young graduates are less likely to move to lagged regions even though employment and high-income potential are high in the regions as noted in previous research [3,4,20]. Thus, this study was mainly concerned with the non-economic factors of regional components, such as family or friend ties and affection toward student colleges. Our model was derived from the literature on young graduates' return migration. High-school graduates' location choice of university was assumed to be affected by education and R&D investment, the existence of a state-owned university within a lagged region, and their interactions [20,27], as shown in Equation (1). An increase in R&D expenditure could affect the economies of scale of outputs, so it is possible to examine whether there are economies of scale with respect to university students using the interaction effect of R&D investment and state-owned universities. In addition, the decision regarding job location of graduates who studied at colleges in lagged regions depended on employment opportunities and high wages [1,2], job security [22], the location of job experience, living cost and self-employment [5,21], and ties with family and the emotional comfort gained from familiarity [7], as shown in Equation (2). A brief description of the variables is summarized in the Appendix A.

$$\begin{aligned} LUNIV_i = \alpha_0 + \alpha_1 GEND_i + \alpha_{2ki} FEDU_{ki} + \alpha_3 lnFINC_i + \alpha_4 KAT_i + \alpha_5 lnRINC_{ir} + \alpha_6 lnPOP_{ir} \\ + \alpha_7 lnRDU_{ir} + \alpha_8 (lnRDU_{ir})^2 + \alpha_9 SOU_{ir} + \alpha_{10}(lnRDU_{ir} \times SOU_{ir}) \\ + \alpha_{11} RTMA_{ir} + \alpha_{12}(lnRINC_{ir} * RTMA_{ir}) + \alpha_{13}(lnPOP_{ir} * RTMA_{ir}) + \varepsilon_{1i} \end{aligned} \quad (1)$$

$$\begin{aligned} LJOB_{(i|LUNIV=1)} = \beta_0 + \beta_1 GEND_i + \beta_{2mi} MJR_{mi} + \beta_3 GRADE_i + \beta_4 GRDLATE_i + \beta_5 EXPRGW_i \\ + \beta_6 EXPSL_i + \beta_7 RGW_i + \beta_8 lnWAGE_i + \beta_9 lnLCOST_i + \beta_{10} HIND_i \\ + \beta_{11}(HIND_i \times MJR_{(i|m=3)}) + \beta_{12} lnRINC_{ir} + \beta_{13} lnPOP_{ir} + \beta_{14} DR + \beta_{15} UR_i \\ + \varepsilon_{2i} \end{aligned} \quad (2)$$

where subscripts i and r refer to the individual and region at the state level, respectively.

The Korean Graduate Occupational Mobility Survey was performed for each graduate during the year following college graduation in winter 2010 and two years later. The number of data samples was 18,078 graduates, representing four percent of all graduates in Korea in the year 2010. It provides information on each subject's attributes in the transition from school to the labor market including gender, age, college major, parental income, work experience, and occupational category (employee or self-employed). These individual data were combined with regional information provided by Statistics Korea. This survey showed that 84.2% of the graduates from lagged regions studied at the college in those regions, and 81.3% of these graduates chose a job in the lagged regions. Table 1 shows descriptive statistics of the explanatory variables. The correlation coefficients of the variables are shown in the Appendix A.

Table 1. The description statistics of the explanatory variables.

Variables	Mean	S.D.	Min	Max
GEND	0.583	0.493	-	-
$FEDU_h$	0.435	0.496	-	-
FEDUu	0.216	0.412	-	-
FEDUg	0.062	0.241	-	-
ln(FINC)	1.302	0.491	0.000	2.303
KAT	0.159	0.366	-	-
ln(RINC) +	0.302	0.742	−2.190	3.512
ln(POP) +	0.246	0.626	−1.913	2.954
ln(RDU)	12.834	1.859	7.659	15.993
SOU	0.722	0.448	-	-
RTMA	0.237	0.425	-	-
MJR1	0.078	0.268	-	-
MJR2	0.280	0.449	-	-
MJR3	0.259	0.438	-	-
MJR4	0.118	0.322	-	-
MJR5	0.096	0.295	-	-
MJR6	0.087	0.282	-	-
GRADE	3.738	0.412	1.000	4.500
GRDLATE	0.114	0.317	-	-
EXPRGW	0.042	0.202	-	-
EXPSL	0.017	0.130	-	-
RGW	0.303	0.460	-	-
ln(WAGE)	5.374	0.593	0.000	7.419
ln(LCOST)	0.275	0.875	−2.384	3.512
HIND	0.052	0.222	-	-
ln(RINC) ++	0.144	0.614	−2.415	2.331
ln(POP) ++	0.219	0.735	−2.286	2.919
DR	0.474	0.499	-	-
UR	0.486	0.500	-	-

Note: Unit is one thousand US dollars in father's income when an individual entered university (FINC) and education R&D investment per research manpower (RDU), regional income of destination region compared to origin region (RINC), population of destination region compared to origin region (POP), present monthly wage of the present job compared to reservation wage (WAGE), and the level of living cost of destination region compared to origin region (LCOST). + indicates the variables of university region compared to domicile region and ++ means the variables of job location compared to university region.

3.2. Result

Table 2 shows the results of the bivariate probit model with sample selection. The rho value (ρ) was −0.359, which was estimated to be significantly different from zero, determining the presence of sample selection; a univariate decision model would have been inefficient. The negative sign of the rho value explained that the probability that an individual who studied in a lagged region decided to stay for a job in the region was higher than the probability that an individual who studied in a leading region decided to return for a job to a lagged region. The result of the first step decision was as shown in the left panel of Table 2. The male dummy had a positive and statistically significant coefficient (0.545), which suggested that with all else being equal, males had a stronger tendency to stay to study in lagged regions than females. The students whose fathers were highly educated tended not to choose a university in a lagged region, showing negative values and being statistically significant at the 1% level. Highly educated fathers would want them to study in the leading regions, where a high quality of educational institutions is densely distributed. The variable of the Korean scholastic aptitude test (KAT) was used to control one of the Korean university attributes—that scores are significantly higher in leading regions. With an increase in educational investment in lagged regions, the probability that a student leaves the areas was expected to decrease with a convex shape, showing a negative linear term (−15.060) and a positive square term (0.600) (significant at the 1% level). The presence of state-owned universities (SOU) and the product term between educational investment and the presence of a state-owned university (see RDU×SOU) showed a positive (3.329) and negative sign (−0.291) with statistical significance, respectively. The investment made in universities in lagged regions failed to encourage students to choose regional universities. However, in the case that a state-owned university was available in their hometown area, high-school graduates were likely to go to the university. These universities emphasize teaching and learning rather than research, which has positive effects on high-school students' decisions to be willing to work in these regions. Analysis of a variable of distance from Seoul (central city) showed that the students in a lagged region far from Seoul were less likely to go to a local university, showing the coefficient of −2.045 (significant at the 1%-level). The signs of regional income and population were negative (−9.027) and positive (5.828), which were statistically significant at the 1% level, respectively. This means that the students considered urban benefits when making the decision to attend college in lagged regions, rather than the regional economic level. The higher the income gap between the hometown and the aspiring university region was, the higher the number of students who went to the leading region, in particular if a lagged region was located far from Seoul. Meanwhile, students were less likely to move to a leading region even when the population of the university region was large, even more so for students from a region far from Seoul. This means, however, that some regions with relatively lower income had locational advantages in terms of inducing university students (see RINC×RTMA and POP×RTMA).

The result of the second step decision was as shown in the right panel of Table 2. For the major variables of this study, the values of the consistencies between domicile and job location (see DR) and between university and job location (see UR) were positive values, and these variables were statistically significant at the 1% level. This implied that family or friend ties and affection toward home villages and student colleges were associated with deciding on jobs or residential areas not only for retirees and the middle-aged but also for young graduates. This result is consistent with earlier findings [7,12] that people were likely to stay in their current place of residence due to a strong preference for their hometown. In addition, the coefficient of the spatial consistency between university and job location (2.017) was higher than that between domicile and job location (0.462). Namely, young graduates were willing to find jobs in the region of their university rather than their hometown: staying in a university region could provide young graduates with the opportunities to maintain their social network and to maximize their contacts within local companies [6,21].

Table 2. Estimation of bivariate probit model with sample selection.

Study in the Lagged Regions				Stay for Job in the Lagged Regions			
Variables	**Coefficient**		**Standard Error**	**Variables**	**Coefficient**		**Standard Error**
Intercept	94.755	***	12.289	Intercept	1.233	**	0.505
GEND	0.545	***	0.113	GEND	−0.018		0.077
$FEDU_h$	−0.350	***	0.098	MJR1	−0.254		0.166
FEDUu	−0.605	***	0.118	MJR2	−0.026		0.133
FEDUg	−0.636	***	0.190	MJR3	−0.255	*	0.136
ln(FINC)	−0.134		0.086	MJR4	−0.111		0.149
KAT	0.372		0.307	MJR5	−0.111		0.151
ln(RINC)	−9.027	***	0.571	MJR6	−0.188		0.160
ln(POP)	5.828	***	0.601	GRADE	−0.033		0.085
ln(RDU)	−15.060	***	1.878	GRDLATE	−0.174		0.108
$(\ln RDU)^2$	0.600	***	0.072	EXPRGW	0.586	***	0.191
SOU	3.329	***	0.534	EXPSL	−1.240	***	0.262
ln(RDU)×SOU	−0.291	***	0.103	RGW	−0.206	***	0.072
RTMA	−2.045	***	0.296	ln(WAGE)	−0.050		0.068
ln(RINC)×RTMA	−6.773	***	2.029	ln(LCOST)	−0.860	***	0.226
ln(POP)×RTMA	7.241	***	1.776	HIND	0.258		0.255
Rho(ρ)	−0.359	***	0.117	HIND×MJR3	0.671	*	0.352
				ln(RINC)	−0.021		0.057
				ln(POP)	−0.041		0.256
				DR	0.462	***	0.082
				UR	2.017	***	0.137
Number of observations			5232				1294
Log likelihood				−1551.044			
Wald chi2 (20)				1045.57			
Prob > chi2				0.000			

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10 % level.

Young graduates who majored in engineering had a higher tendency to migrate to leading regions than those who majored in humanities, social science, natural science, medicine, and art and physical education, having a negative coefficient (−0.255) with statistical significance. Young graduates who majored in engineering might have had the advantage of getting a job in a leading region, despite graduating from a college in a lagged region, due to the large demand for high technology. The variable of graduating more than one year late showed a negative coefficient, explained by the fact that the young graduates had prepared to get a proper job (i.e., a stable or permanent high-paying job) in leading regions, but this did not have a statistically significant effect on the mobility pattern. The coefficients of prior experience in a stable job and in the central city of Korea, Seoul, were 0.586 and −1.240 (significant at the 1%-level), respectively. Students who graduated from a university in a lagged region were more likely to land a job in a lagged region if they were experienced in taking a full-time job and less likely to do so if they had worked in the central city before. Young graduates would not have chosen to transit from a full-time job to a part-time job, and were likely to stay in a lagged region for job security because it is less competitive to take a full-time job in lagged regions. Additionally, graduates who have worked in the central city would have wanted to enjoy the urban benefits more, such as urban public services. In addition, they were more likely to work as a part-timer compared to students who were hired in a leading region, showing a negative sign (−0.206). This result is in line with the analysis result that the living cost variable had a negative value (−). Meanwhile, the value for wage was positive with statistical insignificance. The value of the product term between a major in engineering and regions with heavy industry was positive (statistically significant at the 10% level), showing locational advantages of regions agglomerated with heavy industries (HIND×MJR3).

4. Conclusions

This study identifies the factors that have effects on college graduates' decisions to stay for a job in lagged regions by using a bivariate probit model with sample selection. The results show that a strong preference for a graduate's home village contributes to decisions regarding job location for the regions. In addition, low living costs have a great significant impact on the spatial choice compared with economic factors such as levels of wage and job security. Consequently, the long-term economic growth of lagged regions depends on the preference of high-school graduates to attend local universities.

Our results of the second step decision model concerning the preference for graduates to stay in the region of their university reveals that the university-related variables, such as a state-own university and the educational investment of the first step decision model are important in shedding light on the strategies of regional educational investment. Once a high-school graduate has been attracted to a local university, he/she is expected to remain in the local community for a long time. Educational investment has been emphasized as a driving force to pursue a balanced development of regions in endogenous economic growth theory. However, this result shows that the highest priority should be placed on enhancing the competitiveness of the universities in terms of the size and the status of the universities with expanded investment in lagged regions. In addition, living expense is one of the significant factors for graduates deciding on job location. That is, young graduates who studied at colleges in lagged regions could search a few places among the regions when they decide to stay for a job in lagged ones to maximize their net income (wage minus living cost). Additionally, they tend to consider expenses more than revenues because ties with family, emotional comfort from the familiarity of their hometown, and opportunities to maintain their social network are significant to them rather than maximizing their economic utility, such as income and job security. However, in terms of implementing regional policies, this is not significant in affecting their locational choices because housing and basic living necessities are priced low in most regions in Korea except for Seoul.

Concerning issues for further research, it would be interesting to examine the effects of each type of university on the migration of young graduates. Universities could be classified into three categories, such as (1) public universities or private schools, (2) research-intensive universities or teaching-focused colleges, and (3) national universities or regionally accredited institutions. In addition, financial aids, including scholarships, could affect high-school graduates' mobility patterns. We could analyze the impact of each type of university on young talented students' choices to stay for jobs in lagged regions. The results of this work are expected to influence the implementation of regional policies to facilitate population inflow into lagged regions through education investment in local universities.

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Appendix A

Table A1. Description of the variables

Variables	Name	Definition
Dependent	LUNIV LJOB	University within the non-SMA (=1) Job within the non-SMA (=1)
Individual background	GEND	Male (=1)
	FEDUk	Father received a middle-school education (reference) k = H if father received a high-school education (=1) k = U if father received a university education (=1) k = G if father received a graduate-school education (=1)
	FINC	Father's income when an individual entered university
	KAT	Korean scholastic aptitude test level, high score (=1)
	MJRm	m = 1 if humanities (=1) m = 2 if social science (=1) m = 3 if engineering (=1) m = 4 if natural science (=1) m = 5 if medicine (=1) m = 6 if art and physical education (=1) m = 7 if education (reference)
	GRADE	College grade
	GRDLATE	Graduation more than one year late (=1)
	EXPRGW	Job experience of regular work condition (=1)
	EXPSL	Job experience in Seoul (capital city of Korea) (=1)
Regional components	WAGE	Present monthly wage of the present job compared to reservation wage
	RGW	Regular worker (=1)
	LCOST	The level of living cost of destination region compared to origin region
	HIND	Heavy industry or resource-oriented industry of the present job (=1)
	RTMA	When his/her domicile is a metropolitan area remote from the capital city, over 300 km (e.g. Gwangju, Ulsan and Pusan)
	RINC	Regional income of destination region compared to origin region
	POP	Population of destination region compared to origin region
	RDU	Education R&D investment per research manpower
	SOU	State-owned university existing within domicile region (with twenty thousand students)
	DR	Consistency between domicile and job location (=1)
	UR	Consistency between university and job location (=1)

Table A2 shows Pearson's correlation coefficients of the explanatory variables used in the job location choice model. The correlation coefficients between ln(POP) and ln(LCOST), ln(RINC) and ln(LCOST), and ln(POP) and ln(RINC) are measured as 0.983, 0.539, and 0.451, respectively, and are relatively higher than the other coefficients that were denoted in superscript +.

Table A2. The correlation coefficients of the explanatory variables.

	GEND	**MJR1**	**MJR2**	**MJR3**	**MJR4**	**MJR5**	**MJR6**	**GRADE**	**GRDLATE**	**EXPRGW**
GEND	1.000									
MJR1	−0.067	1.000								
MJR2	−0.025	−0.182	1.000							
MJR3	0.351	−0.173	−0.371	1.000						
MJR4	−0.034	−0.107	−0.229	−0.218	1.000					
MJR5	−0.148	−0.094	−0.202	−0.192	−0.119	1.000				
MJR6	−0.079	−0.089	−0.191	−0.182	−0.112	−0.099	1.000			
GRADE	−0.205	−0.018	0.070	−0.109	−0.066	0.026	0.043	1.000		
GRDLATE	0.064	0.064	−0.040	0.074	0.023	−0.033	−0.060	−0.187	1.000	
EXPRGW	−0.041	0.016	−0.005	−0.031	0.016	0.020	0.025	−0.039	−0.027	1.000
EXPSL	−0.061	0.022	−0.010	−0.038	−0.007	0.022	0.046	−0.028	0.008	0.426
RGW	−0.069	0.030	−0.027	−0.028	0.034	0.045	0.015	−0.031	−0.058	0.241
ln(WAGE)	0.261	−0.039	−0.045	0.177	−0.043	0.028	−0.112	−0.080	0.120	−0.082
ln(LCOST)	0.008	−0.011	−0.036	0.039	−0.018	0.056	0.002	0.020	0.025	0.009
HIND	0.124	−0.016	−0.024	0.169	−0.024	−0.068	−0.050	−0.023	0.004	−0.049
ln(RINC)	0.021	−0.011	−0.011	0.022	−0.001	0.013	0.016	0.025	0.011	−0.009
ln(POP)	0.014	−0.016	−0.041	0.051	−0.016	0.054	−0.005	0.015	0.029	0.005
DR	−0.101	0.005	0.055	−0.103	0.013	−0.009	0.022	0.044	−0.164	0.044
UR	−0.038	0.011	0.085	−0.082	−0.001	−0.038	−0.005	0.014	−0.019	−0.001
	EXPSL	RGW	ln(WAGE)	ln(LCOST)	HIND	ln(RINC)	ln(POP)	DR	UR	-
EXPSL	1.000									-
RGW	0.135	1.000								-
ln(WAGE)	−0.020	−0.075	1.000							-
ln(LCOST)	0.058	0.044	0.024	1.000						-
HIND	−0.031	−0.155	0.121	−0.061	1.000					-
ln(RINC)	0.057	0.035	0.029	0.539+	−0.016	1.000				-
ln(POP)	0.052	0.035	0.030	0.983+	−0.055	0.451+	1.000			-
DR	−0.071	0.023	−0.187	−0.371	−0.016	−0.253	−0.363	1.000		-
UR	−0.047	−0.054	−0.070	−0.268	−0.009	−0.216	−0.250	0.340	1.000	-

Note: Pearson correlation coefficient ranges from −1 to +1, where +1 is positive linear relation, 0 is no linear relation, and −1 is negative linear relation.

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Which Sectors Really Matter for a Resilient Chinese Economy? A Structural Decomposition Analysis

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Abstract: This study explores the structural effect of economic resilience with a case of China by examining the extent to which the major economic sectors contribute to the relative resilience of China's overall economy. By applying a time series analysis, we use the Hodrick–Prescott filter to delineate China's national economy on a quarterly basis and reveal different performances in responding to two recent economic crises in 1997 and 2008. Using quarterly data pertaining to eight economic sectors (including agriculture, industry, and major service sectors) and the national GDP from 1993Q1 to 2017Q2, we examine their effects on China's economic resilience by simulating the responses of the national economy to a unit shock from each sector. Results show that the construction, real estate, and financial services have the greatest potential to "disturb" the national economy whereas the industrial sector has the greatest potential to "stabilize" it. The findings correspond with the understanding that extensive infrastructure development and the real estate boom have driven China's rapid urban development and created economic prosperity, whereas the sectoral decomposition of economic resilience compels a critical reflection on the risks of this growth model.

Keywords: economic resilience; sectoral effect; time-series analysis; urbanization; China

1. Introduction

An article in The New York Times published in November 2012 [1] advocated for a paradigm shift from an emphasis on sustainability to an emphasis on resilience based on the idea that the latter is a better fit for an imbalanced world. The world is subject to pronounced disruptions and disturbances, and it is contended that the success with which individual countries and international trading bodies negotiate this unpredictable and rugged terrain depends on how resilient they are [2]. The global financial crisis of 2008 and its aftermath had a profound impact on the economies of Western Europe and North America, stimulating extensive studies on the responses to and consequences of recessions [3–7]. The post-crisis economic recovery at multiple geographical scales has given rise to an increasing research attention to the significance, definition, and spatial heterogeneity of resilience, as well as the factors that contribute to achieving and maintaining this state. At the national level, the European countries differed significantly from each other in terms of their responses to the financial crisis of 2008 [8]. Within a specific country, i.e., Canada, resilience literature assessed the importance of industry-mix and regions within the country to account for differences in regional resilience to economic shock [9]. Study about the relationship between regional policies and resilient outcomes examined the ways in which regional policies intersect with exogenous and endogenous factors to explain the relative resilience of various regions with a case of Turkey [10]. To explain resilient performances of urban and regional development, literature has examined the relationship between economic resilience and a wide range of factors such as economic structure, labor market conditions, export orientation, innovation, entrepreneurial culture, and institutional arrangements [11]. Among these complex factors, economic structure has been hypothesized as being particularly significant for regional resilience given that economic sectors differ in their reactions to economic shock [12] whereas the relationship between economic structure and resilience remains varied across space.

Compared with the growing body of resilience research in the context of the industrial West, economic resilience has become prominent in both China's official parlance and its popular media. Chinese leaders have openly claimed that China's economy is "highly resilient". For example, at the 2015 Boao Asian Forum, China's President Xi Jinping commented that "the Chinese economy is highly resilient and has much potential, which gives enough room to leverage a host of policy tools". Existing studies of economic resilience have been mainly focused on some specific regions in China such as a study of economic resilience in the Pearl River Delta region [13] and economic resilience of resource-based cities in Northeast China [14]. However, the question of to what extent the Chinese economy as a whole is resilient and what factors contribute to its resilience is still under-researched in the literature. Far from being immune to the global crisis of 2008, China saw the growth of its GDP drop from 14.7% in 2007 to 8.5% in 2009, followed by a decelerated national economy in recent years. Official statements notwithstanding, we know little about how to measure economic resilience in China and the key factors implicated in determining the relative resilience or lack of resilience of the Chinese economy have yet to be identified.

In the present paper, we focus on a structural analysis of economic resilience and examine different roles played by major economic sectors in shaping the national economic resilience. The national economy constitutes an aggregation of multiple sectors such as agriculture, manufacturing, construction, and services. From a structural perspective, economic resilience of this aggregate system is determined by the "system effects", i.e., the effects of interactions among the system's components and the synthetic effects thereby generated [15]. The main objective of this research is to shed light on the endogenous mechanism through which the system's "components" each affect aggregate performances, i.e., the role of major economic sectors in China's resilience to recent global recessions since the establishment of the socialist market economy in 1992. In the present paper, using the quarterly data of China's GDP growth rate and that of eight sectors from 1993Q1 to 2017Q2, we apply vector-auto regression (VAR) modeling and the impulse response function (IRF) to simulate the reaction of the national economy to a sector-specific shock. The national perspective is adopted given that consistent data on the national economy and its sector components are available on a quarterly basis. Equivalent data at the urban or regional level were recorded only on an annual basis, which is not sufficient for time series modeling.

The rest of this paper is organized as follows. First, we present a succinct review of the literature on the determinants of economic resilience in general and the debate about economic structure and resilience in specific. Then, we introduce our research methods including time series modeling and a detrending approach of the Hodrick–Prescott (HP) filter to clean the data. We present our empirical results in the next section and discuss their implications. A summary of major findings and potential areas for future research are given in the closing section.

2. Economic Resilience and Related Structural Debates

2.1. Determinants of Economic Resilience

These exists a growing number of studies pertaining to the spatial heterogeneity in the impacts of the global financial crisis of 2008 as well as their post-crisis recovery in the industrial West [8,16–20]. The developing literature on economic resilience has indicated that it is a highly complex and multi-dimensional concept and explored the determinants of economic resilience at varied scales [20]. It is argued the extent to which countries are integrated in the global economy, differences in the institutional framework, and differences in sectoral composition are three explanatory factors to the variation in the consequences of the global recession on European countries and regions [21]. Factors including economic diversity, trade openness, human and social capital, as well as financial constraints have been considered to explain the geographical asymmetries in economic resilience [22]. At the city level, both individual and place-specific factors account for cities' variation in adaptation and adaptability. Specifically, individual factors accounting for economic resilience include the characteristics of local labor markets, such as gender, age, education, and skill profile of local labor force [18,23–25]. In addition, geographers emphasized "region-specific" or "competitiveness" effects on economic resilience [26]. In this vein of research, literature emphasized the role of place-bound, invisible factors in shaping local economic resilience, such as social values [27], innovation [28], creative small-and-medium sized enterprises (SMEs) [29], entrepreneurship [30,31], as well as the variety of local economic cultures [32]. A recent study identified there exists an inverted U-shaped relationship between local economic embeddedness and resilience [33]. Beyond the socio-economic characteristics, the role of human agency has been found under-explored in understanding the variation in local economic resilience [34]. Taking an agency perspective, insights from this vein of research further emphasized the significance of place and context in resilience studies [34].

2.2. Economic Structure and Resilience

Economic structure is considered to be a crucial determinant of economic resilience [9,26,35]. To date, studies that address the causal relationship between economic structure and resilience focus on identifying the relative vulnerability of different industries or sectors and sectoral composition in accounting for a given region's ability to withstand a recession. Manufacturing is typically assumed to be a vulnerable sector whereas services are shown to be comparatively more resilient in the Western literature [21,36]. In an empirical study of job losses as a consequence of severe recession from 1987 to 2012 in Canada, it is argued that compared with the business services the manufacturing sector is less resilient to economic shock [9]. Pursuing a finer-scale approach to the subject of resilience to recession, transport equipment was found as the most recession-sensitive of 14 sectors in the EU-wide business cycle [21]. Furthermore, their results confirmed the general view that in comparison with the services sector, manufacturing is more sensitive to economic turbulences. An implication of this sectoral resilience effects for regional development is that regions where manufacturing is dominant are generally expected to be less resilient than regions that rely to a greater extent on service sectors [12]. However, a contradictory finding revealed that the presence of manufacturing activities account for the high resilience of some Italian regions during their recessions and recoveries [37].

In addition, another strand of literature has paid increasing attention on industry portfolios, i.e., how the specific mix of economic activities and the relationships and interdependency between and among them might influence regional reactions to economic shocks [26,35,38,39]. In fact, the role of sectoral composition in economic stability has been studied in economic research [40,41] while the focus was placed on exploring whether a diversified economic structure is favorable for regional resilience. However, there is no consensus among economists in regard to the relationship between regional economic diversity and economic stability [42]: Some economists have pointed to industrial diversity as a defining element in explaining a large proportion of regional variation in economic stability [38,43] whereas based on an alternative measurement of regional industrial diversification other scholars have found little evidence to suggest that diversity supports stability [44,45]. In more recent years, urban and regional scholars have argued that a diversified structure helps local economies to absorb sector-specific shocks and thus contributes to overall economic stability. This argument has been supported by empirical studies from Munich and the US according to which a diversified economic structure conditioned the success of each of these countries in riding out the deep recession of 2008 [46,47]. Drawing on the hotly debated relationship between diversity and stability of regional economies, commentators suggested that diversity should not be understood as entailing simply the absence of specialization, especially so among regions or metropolitan areas of sufficient size of their economy [48]. It is further argued that diversification per se may be neutral in its effects on economic stability. The relative vulnerability of a region's economy derives from the extent to which it specializes in cyclically sensitive activities. Given the mixed results pertaining to the structural debates of economic resilience, it is essential, therefore, to understand the specific roles played by major sectors in responding to external shocks.

The debate on the divergent roles of different sectors in economic resilience reminds us the relationship between local economic structure and economic resilience may depend on the type of economic shock, as well as how each sector plays its role in responding to the shock, i.e., the endogenous mechanism of how each sector interacts with the aggregate economy for a given region/country and how that composite effect generates resilient outcomes. In this paper, drawing on ideas from the Modern Portfolio Theory (MPT) [49], we argue the existing structural debate on the relative vulnerability of manufacturing or services sector in economic resilience focuses on the unique risk or unsystematic risk which is sector-specific while overlooking the systematic risk that may not be alleviated simply through the diversification strategy. The systematic risk may affect all sectors and thus it is important to understand how different sectors play their role in the aggregate system.

In terms of methodology, a geographical reading of regional economic resilience has typically been done by looking into the spatial heterogeneity in the resistance to and recovery from economic crisis with a spatial econometric model. However, there is no single agreed approach to study economic resilience [26]. A simple way of looking into the relationship between sectoral composition and economic resilience is estimating the crisis sensitivity of different sectors by ordinary least squares (OLS) regression with the observations from different countries [21]. A more advanced method for spatial resilience research is the vector error correction model (VECM), which is used to address permanent effects of employment shocks and the interregional linkages [12,22]. We recognize the significance of spatial dynamics in resilience research while this study focuses on the temporal dimension of economic resilience with a case of China after 1992. With consistent quarterly series data of GDP and that of eight major sectors during the study period, the selected VAR model is used for simulating how the aggregate economy would respond to sector-specific shock, which fits well to the purpose of this study.

This paper contributes to resilience research in two principal aspects. First, given insights from the MPT, we shed light on the relationship between economic structure and regional economic resilience in China by emphasizing that the overall stability of the portfolio depends on the nature of each of its components and the ways in which they interact with the whole system. This perspective is novel in resilience literature and it is more relevant under the Chinese context given that different economic sectors and regions in China have shown uneven extents of integration to the global economy. Therefore, it is imperative for understanding resilience to unravel all aspects of the endogenous mechanism through which an entire system is affected by the distinct components of which it is comprised. Second, the time series analysis adopted in this study followed the evolutionary paradigm of interpreting economic resilience based on its historical information since each variable is regressed on the historical values of its own. This evolutionary thinking is not new in social science research. In studies of urban and regional economic resilience, researchers have long advocated for adopting an evolutionary view in seeking to understand resilience as a process rather than as an outcome [50,51]. However, rigorously interrogating the ways in which historical information has informed resilience remains a challenge. Grounded in evolutionary thinking, this research offers a quantitative method, i.e., the VAR model and IRF simulation from time series analysis, to explain the endogenous mechanism of economic resilience. Though this study is conducted at the national level, the methods applied in this study are applicable to different geographical scales given the availability of data.

Nevertheless, economic structure provides only a partial explanation for regional economic resilience. It is found that regional-specific effects appear to have played a significant role on a par with that of economic structure in shaping the resistance and recoverability of major UK regions to four significant recessions over the last 40 years [26]. However, a full explanation of China's economic resilience is far beyond the scope of this paper. Instead, we focus on the structural aspect and aim to open the black box of how the national economy reacts to turbulence from each of its major components. Yet, our research goes beyond the conventional structural debate of diversity and resilience given that a national economy is necessarily diversified. Rather than arguing which sector is more vulnerable to economic shock, we contend that it is critical to understand the specific roles of major sectors in shaping the aggregate economic resilience, which necessities explicating the endogenous mechanism whereby major economic sectors interact with the overall economy.

3. Research Methods

3.1. Measurement Issues

Measuring economic resilience in China has to address a few specific concerns. First, the study period of economic resilience in China is shorter than that of the West. China's annual GDP growth rate from 1953 to 2015 shows a salient trend of increasing stability (Figure 1). Absolute declines in the GDP can be seen pre-1976 only, i.e., during the Maoist era when resource allocation in China and thus economic growth were strictly under the control of the state. The discussion of economic resilience is invalid during the period of a command economy. Therefore, we examined China's economic resilience after 1992 since it was not until 1992 that China's socialist market economy was formally established. Since then, the hybrid effects of the state and the market have complicated the forces behind economic fluctuations. Second, a finer-scale approach of investigation on China's economic growth is in order since the annual data indicate that neither the Asian financial crisis of 1997 nor the global financial crisis of 2008 had more than a very weak negative impact on the Chinese economy as shown in Figure 1. Given a shorter period of observation, a closer look at economic fluctuations in China on a quarterly basis is necessary to reveal the processes through which the country responded to any economic shocks identified. Third, compared with the Western literature about investigating the absolute decline and recovery of employment, exploring economic resilience in China has to be considered in reference to the fluctuation of the growth rate in relative terms. We used data of economic output (measured by GDP) rather than employment to conduct a longitudinal study of economic resilience in China. Employment used to be the preferred indicator for studying economic resilience in Western literature [18,20,22,35,37] whereas China's official statistical records of employment is not sensitive to economic fluctuations. More accurately, China's urban unemployment has been highly underestimated in official data given the problematic definition, data collection system, and calculation of "registered urban unemployment" from the Chinese National Bureau of Statistics (hereafter NBS) (see detailed discussion from prior research [52]). The exclusion of laid-off (xiagang) workers and unemployed persons without urban resident status (hukou), i.e., rural migrants, seriously reduced the data credibility of Chinese unemployment rate. Under the urban-rural dual economy, a large number of migrant workers from rural to urban areas are not fully counted in official statistics. When the economy declines, they are in the most vulnerable position to lose jobs, although this is hardly reflected in statistical data. In addition, the Chinese state-owned enterprises (SOEs) used to maintain life tenure with their employees in the past. The soft-budget constraints enable the SOEs to achieve that commitment, and even under difficult times, the SOEs would not lay off their workers. Despite the continuous restructuring of the Chinese SOEs, the institutional inertia still takes effect. As a result, official data of employment (or unemployment) is hardly reliable for assessing resilience. Comparatively, output data is consistently available over time, which is deemed an appropriate variable to study economic resilience under the Chinese context.

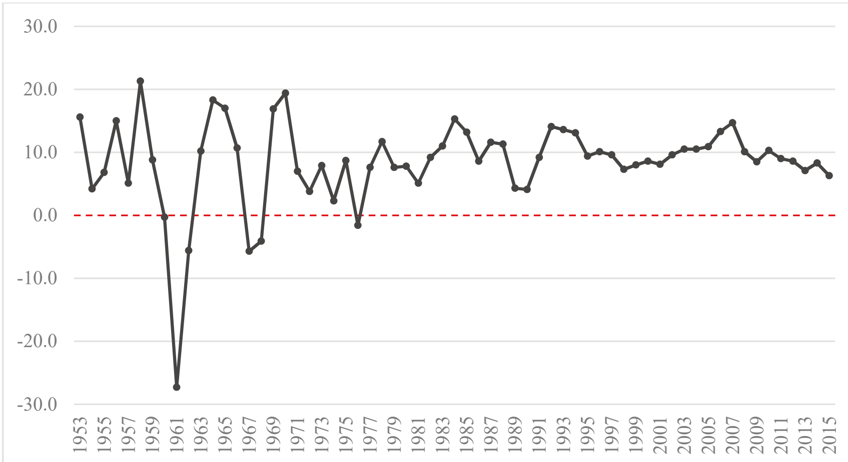

Figure 1. China's annual GDP growth rate from 1953 to 2015. (Source: Data from *China Statistical Yearbook (2016)*.)

3.2. Seasonal Adjustment and Hodrick–Prescott Filter

For the present paper, a longitudinal observation of economic resilience in China was undertaken in reference to the post-reform period with quarterly data of GDP growth rate from 1993Q1 to 2017Q2. Using quarterly data, we used the standard U.S. Census Bureau's X12 seasonal adjustment program from EViews 10 to adjust for the potential seasonal trends in our series. The seasonally adjusted data were saved as *_sa. We de-trended the quarterly GDP growth rate of China and that of eight major economic sectors with the HP filter to separate fluctuations in economic growth from its long-term trend [53]. The HP filter is a frequently used tool in Real Business Cycle (RBC) theory to decompose a time series into its growth and cyclical components [54]. According to the rationale of HP filter [55], a given time series the growth rate of GDP_t is the sum of a growth component g_t and a cyclical component c_t expressed as

$$GDP_t = g_t + c_t \quad (t = 1,\ 2,\ \ldots,\ T). \tag{1}$$

The growth component measures the long-term trend or the potential output, and the cyclical component indicates the output gap between the real and potential output. The logarithm of the HP filter is given by

$$\text{Min}\left\{\sum_{t=1}^{T}(GDP_t - g_t)^2 + \lambda\sum_{t=1}^{T}[(g_t - g_{t-1}) - (g_{t-1} - g_{t-2})]^2\right\}, \tag{2}$$

where GDP_t is the raw data of the growth rate of GDP, and g_t represents the trend component. The first part of the equation is the sum of the squared cyclical component. The second part of the equation is λ multiplied by the sum of squares of the growth component's second differences. The smoothing parameter λ penalizes the variability in the growth component series [55]. The standard practice in the econometrics is to set λ as 1600 for quarterly data as we applied in this study.

Economic resilience is assessed by observing the change of cyclical component of quarterly GDP growth rate. The filtering approach extracted the long-term trend component of the GDP growth rate, leaving the cyclical component which centers on zero. A negative cyclical component indicates that the real output is smaller than the potential output, implying production resources have not been fully utilized in the society. When the economy was shocked, the gap between real and potential output would normally enlarge. Economic resilience is revealed if the cyclical component could quickly bounce back to or even beyond zero. In that case, idle factory buildings, equipment, and labor force are reused to realize the full potential of social production capabilities, meaning that the economy has recovered from the shock.

Besides the national GDP, we selected the quarterly growth rate of eight sectors during the same study period to investigate their interactions with the national economy. The eight sectors included in this study are (1) agriculture (2) industry (industry sector includes mining, manufacturing, and the production and supply of electronic power and heat power according to the "Industry Classification of the National Economy (GB/T 4754-2011)", manufacturing is the dominant sector); (3) construction; (4) retailing; (5) transport, storage, and post (referred to as transport); (6) hotel and catering services (referred to as hotel and catering); (7) financial services and (8) real estate. The sources of the annual GDP growth rate since 1953 are *China Statistical Yearbook 2016, 60 Years of New China* [56], and the *China Compendium of Statistics 1949–2008* [57], all published by NBS of China. We retrieved time series data for the sectoral GDP growth rate for 1993Q1 to 2017Q2 from the official NBS database. All the data are calculated at constant prices.

3.3. Stationarity Test and the VAR Model

Our data set contains the cyclical component of quarterly GDP growth rate and that of eight major sectors during the study period. The stationarity of the data series should be tested before developing the VAR model. The Augmented Dickey–Fuller (ADF) test, being one of the unit root tests used in statistics and econometrics, was adopted to test the stationarity of all those time series data. The principle of the unit root test is to testify whether the latent roots fall within a unit cycle. If all of the latent roots are within a unit cycle, it means the time series data are stationary; otherwise, any latent root falls on or outside of the unit cycle indicates that the series is non-stationary. The ADF tests were conducted by EViews 10.

Then, we developed a VAR model via a time series analysis—an approach based on the evolutionary thinking that past data pertaining to a variable can be used to forecast its development. There are only endogenous variables in a VAR model, each of which are predicted evolutionarily based on its own lagged values and the lags of the other variables. For a time series data GDP growth rate $\{gdpR_t\}$, the value of variable $gdpR$ at the time t can be regressed on the historical values of its own, which is given by the auto-regression model (AR). The standard p-order AR model is given as

$$AR\ (p) : gdpR_t = \phi_1 gdpR_{t-1} + \phi_2 gdpR_{t-2} + \ldots + \phi_p gdpR_{t-p} + \varepsilon_t, \tag{3}$$

where $gdpR_{t-p}$ denotes p-periods lagged $gdpR_t$. Multiple time series analysis extends the idea of evolution to a set of time series variables. The primary model in multivariate time-series analysis is the VAR model, which studies the linear inter-dependencies among multiple time series. A stable VAR model of p-order is given as [58]

$$gdpR_t = \upsilon + \mathrm{A}_1 gdpR_{t-1} + \mathrm{A}_2 gdpR_{t-2} + \ldots + \mathrm{A}_p gdpR_{t-p} + \mu_t, \quad (t = 1, \ldots, T), \tag{4}$$

where $gdpR_t = \left(gdpR_{\mathrm{N}t}, gdpR_{\mathrm{Agr}_t}, \ldots, gdpR_{RE_t}\right)'$ denote a $(n \times 1)$ vector of the cyclical component of GDP growth rate of the nation and each sector. A_i are $(n \times n)$ coefficient matrices and $\nu = (\nu_1, \ldots, \nu_n)'$ is a fixed $(n \times 1)$ vector of intercept terms. $\mu_t = (\mu_{1t}, \ldots, \mu_{nt})'$ is a $(n \times 1)$ white noise vector process satisfying the conditions of $E(\mu_t) = 0$, $E\left(\mu_t \mu_t'\right) = \sum_\mu$ and $E\left(\mu_t \mu_t'\right) = 0$ for $s \neq t$.

Based on the above VAR model, we applied an IRF simulation and variance decomposition (VD) to identify the sectors that contribute most to China's economic resilience. The IRF can simulate the impacts of unexpected shocks to a specified variable on the variables in the model, which is useful in capturing the model's dynamic properties. The rationale behind the IRF is that for multiple time series, a shock to one series generates an immediate effect on that same series, and it can also affect other variables in a system, which can, in turn, affect the original variable. The results of the IRF simulation delineate the national economy's responses to a unit shock from each sector, thus unfolding the endogenous mechanism of national economic turbulence.

4. Empirical Results

4.1. A Holistic Observation of China's Relative Economic Resilience in Response to Two Recent Shocks

At the aggregate level, filtering result of the seasonal adjusted GDP growth rate of China from 1993Q1 to 2017Q2 is shown in Figure 2. The trend curve shows a significant decrease in the late 1990s and after 2008. However, the cycle curve shows a minor decline in the late 1990s compared with a sharp decline in 2008. We used the cyclical component of the GDP growth rate to measure China's economic resilience and the result reveals different resilience of China's national economy in responding to two recent economic crises in 1997 and 2008.

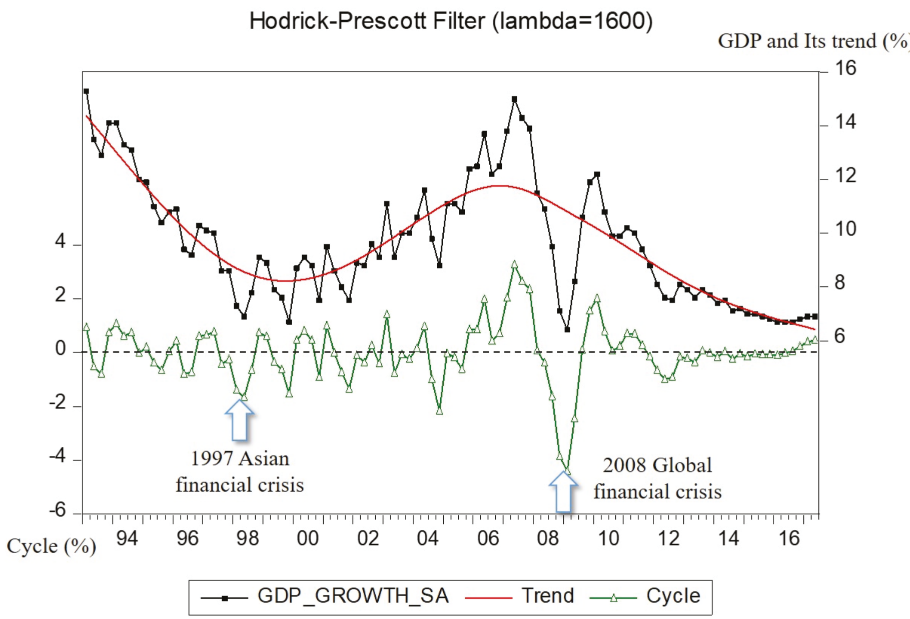

Figure 2. Hodrick–Prescott (HP) filter of China's quarterly GDP growth rate (1993Q1–2017Q2).

The financial crises of 1997 and 2008 each had a direct negative impact on China's economy by decreasing external demand. However, the circumstances in which that impact occurred differed significantly between these two crisis events. Ushered in by its formal endorsement of a socialist market economy in 1992, China experienced a rapid economic expansion, with an average growth rate of 13.6% from 1992 to 1994. However, there was also a high rate of inflation in China during the same period, reaching an unprecedented level of 24.1% in 1994 [59]. To cool down the overheated economy, Zhu Rongji, China's prime minister at the time, implemented an austerity program before the crisis of 1997, leading to a downward trend in potential output (Figure 2). The cycle curve did not show a prominent deviation from zero in 1997, revealing that the consequence of the 1997 Asian financial crisis was not severe in comparison with the crisis of 2008. After 1997, China experienced economic expansion over about 10 years as illustrated by the upward trend curve. China's national economic growth rate reached its peak level of 14.7% in 2007, just before the global financial crisis of 2008. Shocked by the 2008 crisis, the cyclical component of the country's quarterly GDP growth rate underwent a sharp decline, implying that the real output of the Chinese economy fell far short of the level that would have been projected otherwise.

4.2. Sectoral Decomposition of China's Economic Resilience

Having the data set of the cyclical component of each sector from 1993Q1 to 2017Q2, the Pearson correlations of each pairwise variable were calculated via SPSS (Table 1). The results show that the industry (coefficient of 0.897) and real estate (coefficient of 0.588) sectors are strongly correlated with the cyclical movement of the Chinese economy. Industry, with manufacturing as its major component, shows the highest correlation coefficient with the national economy. Next, transport and retailing show moderate correlations with the national economy, with coefficients of 0.433 and 0.406, respectively. The inter-sectoral correlations reveal that the real estate sector has statistically significant correlations with five of the other eight variables: aggregate GDP (0.588), financial services (0.448), construction (0.386), industry (0.383), and retailing (0.305). The financial services sector is also closely related with the aggregate GDP, real estate, retailing, and construction sectors. Given that both the transport and real estate sectors are major consumers of manufacturing products, the second most relevant sector for industry is transport (the coefficient for this latter sector is 0.396 in the third column), followed by industry and real estate with a coefficient of 0.383. Findings on the relevance of the cyclical component of each sector and that of the national economy reveal that the significance of different sectors to the aggregate resilience is not just a matter of the sectoral proportion in the national economy. Though industry accounted for 33.3% of the national economy in 2016, the proportion of real estate sector in the national economy was only 6.5% in 2016 [60]. Nevertheless, these two sectors have shown the highest correlations with the national economic fluctuations. Given this, we further developed a VAR model to explore the endogenous mechanism of the sectoral effects.

Table 1. Pearson correlations between the pairwise cyclical components of the major sectors.

	Cycle GDP	**Cycle AGR.**	**Cycle IND.**	**Cycle CON.**	**Cycle RET.**	**Cycle TRA.**	**Cycle HOT.**	**Cycle FIN.**	**Cycle R.E.**
Cycle GDP	1								
Cycle Agriculture	−0.222 *	1							
Cycle Industry	0.897 **	−0.286 **	1						
Cycle Construction	0.189	−0.125	0.010	1					
Cycle Retailing	0.406 **	−0.124	0.253 *	0.138	1				
Cycle Transport	0.433 **	0.116	0.396 **	−0.179	−0.031	1			
Cycle Hotel and catering	0.129	−0.124	0.209 *	−0.133	0.177	−0.086	1		
Cycle Financial Services	0.400 **	−0.142	0.150	0.344 **	0.370 **	−0.183	−0.141	1	
Cycle Real Estate	0.588 **	−0.424 **	0.383 **	0.386 **	0.305 **	0.119	0.002	0.448 **	1

*. Correlation is significant at the 0.05 level (two-tailed). **. Correlation is significant at the 0.01 level (two-tailed).

The stationarity of each time series was tested via ADF tests (Table 2). Each data series passed the stationary test, as the cyclical component of each sector's growth rate had already been filtered without trend or seasonal impact. Therefore, the raw data for each variable were used to develop the VAR model.

Table 2. Stationarity results of the Augmented Dickey–Fuller (ADF) tests for each time series.

	Test Format	*t*-Statistic	*p* Value	Result
GDP	N, N, 1	−5.237903	0.0000 *	Stationary
Agriculture	N, N, 0	−5.233866	0.0000 *	Stationary
Industry	N, N, 2	−6.158719	0.0000 *	Stationary
Construction	N, N, 0	−5.630373	0.0000 *	Stationary
Retailing	N, N, 0	−5.738462	0.0000 *	Stationary
Transport	N, N, 0	−5.585702	0.0000 *	Stationary
Hotel and catering	N, N, 0	−5.056096	0.0000 *	Stationary
Financial services	N, N, 0	−3.936282	0.0001*	Stationary
Real Estate	N, N, 2	−6.683200	0.0000 *	Stationary

Note: * indicates a significance level of 1%.

The results of the IRF simulation are graphically presented in Figure 3. Within the observation of 15 periods, the responses of the cyclical component of the GDP growth rate to the sectoral shocks finally approached zero. The cyclical component of the GDP growth rate is highly sensitive to a unit shock from each of the construction, real estate, and financial services sectors. Despite a short lag, the response to the shock from the construction sector was the most significant and persistent of all the sectors considered herein. It increased to the highest level of 0.29 in the fourth period and remained positive in the first six periods. The national economy responded to the real estate and financial services sectors more promptly whereas the extent of the reaction was not as strong as that of the construction sector. As shown in the bottom two graphs of Figure 3, response of the national economy to a unit shock from the financial services sector reached its peak level of 0.21 in the secondary period, and then decreased steadily and became negative in the seventh period. In comparison, the reaction of the national economy to real estate disturbances was 0.18 in the secondary period and increased further to 0.23 in the third period. It dropped below zero in the sixth period and finally faded out after the tenth period.

Findings from the variance decomposition (VD) reveal similar sectoral effects to those shown by the IRF simulation (as shown in Table 3). After 15 periods, the fluctuation of the GDP growth rate itself explained only 44.14% of its total variance, whereas the construction and real estate sectors accounted for 16.33% and 9.63%, respectively. These sectors are followed by the agriculture and financial services sectors, which explain 7.15% and 7.12%, respectively, of the total variation. The industry sector accounted for only 6.94% of the total variance. The result of VD confirmed that construction and real estate sectors have contributed the most to the variance of China's national economy despite their relative small size in the overall "portfolio".

The IRF simulation and VD unfolded the endogenous structure of China's relative economic resilience. According to the response patterns (Figure 3), the effects of each of eight sectors on China's economic resilience can be understood as follows: first, the results of the IRF simulation verify the potential role of the construction, real estate, and financial services sectors in "disturbing" the national economy. A unit shock, i.e., an impulse from one of these sectors would generate significant impact on the national economy. Second, the response pattern is almost reversed in the cases of agriculture and industry, which have served as "stabilizers" for the overall economy. There is a negative deviation of the national economy followed by positive responses to a unit shock from the agriculture and industry sectors, as the first two graphics of Figure 3 show. Finally, we observe that the shocks from retailing, transport, as well as hotel and catering do not have a strong impact on the national economy.

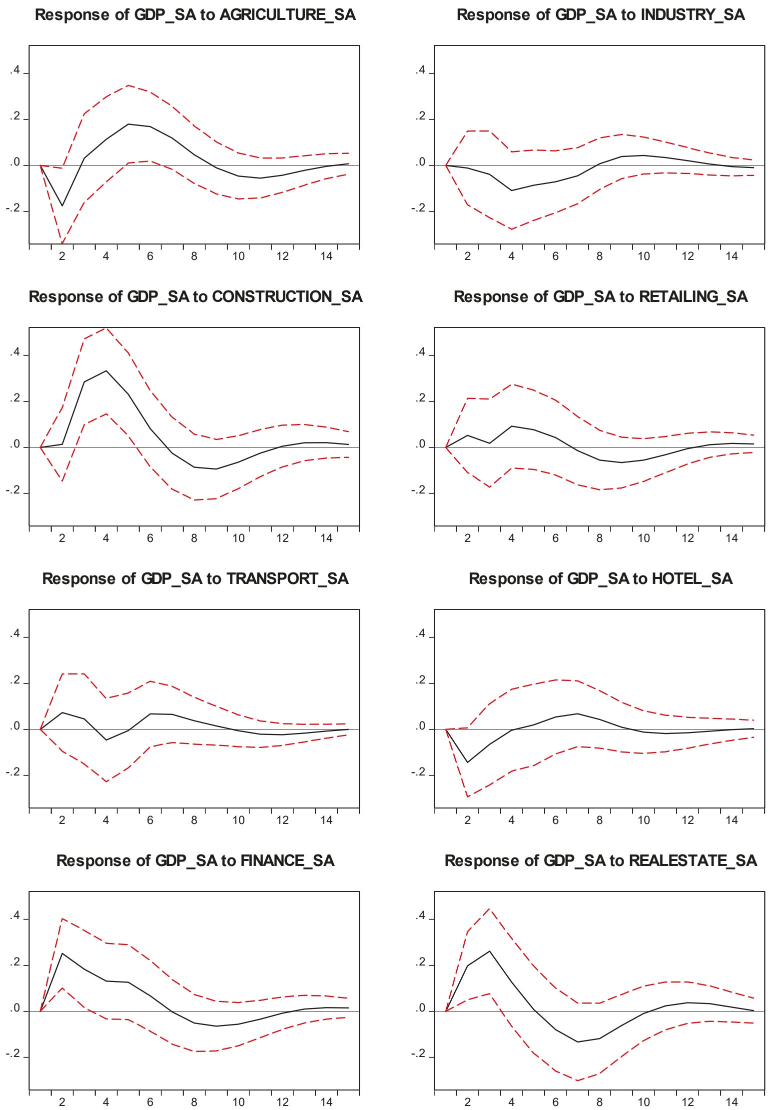

Figure 3. Results of the impulse response function (IRF) simulation.

Table 3. Variance decomposition of the cyclical component of China's GDP growth rate.

Period	S.E.	GDP	AGR.	IND.	CON.	RET.	TRA.	HOT.	FIN.	R.E.
1	0.59	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.82	79.81	1.55	5.02	0.50	0.05	0.00	1.58	6.61	4.88
3	0.95	64.46	1.73	6.03	8.95	0.13	0.11	1.94	6.47	9.14
4	1.03	55.29	1.47	7.01	15.35	0.53	0.64	1.78	6.97	9.01
5	1.08	51.46	2.00	7.13	17.70	1.17	0.59	1.64	7.55	8.40
6	1.11	50.09	3.40	6.87	17.66	1.44	0.92	1.60	7.27	8.31
7	1.14	48.62	5.19	6.50	16.72	1.39	1.40	1.73	6.91	9.20
8	1.17	47.08	6.23	6.39	16.40	1.39	1.90	1.82	6.86	9.67
9	1.18	45.95	6.37	6.57	16.53	1.65	2.13	1.83	7.05	9.64
10	1.19	45.29	6.28	6.83	16.65	2.00	2.13	1.82	7.19	9.51
11	1.20	44.89	6.41	6.97	16.58	2.21	2.12	1.80	7.19	9.51
12	1.20	44.57	6.74	6.99	16.45	2.26	2.18	1.78	7.13	9.60
13	1.21	44.34	7.01	6.96	16.36	2.25	2.27	1.77	7.10	9.65
14	1.21	44.20	7.13	6.93	16.33	2.25	2.32	1.77	7.11	9.64
15	1.21	44.14	7.15	6.94	16.33	2.27	2.34	1.77	7.12	9.63

Note. AGR. = Agriculture, IND. = Industry, CON. = Construction, RET. = Retailing, TRA. = Transport, HOT. = Hotel and catering, FIN. = Financial services, R.E. = Real Estate.

Results of the time series analysis indicate that a heavy reliance on the construction, real estate, and financial services sectors may increase the endogenous vulnerability of the national economy from a resilience perspective. China's economic "miracle," in large measure, has been achieved by enormous investment in the production and reproduction of urban space over the last 40 years. Urbanization, in terms of "fixing" capital in the urban space, is of paramount importance to China's economic growth. China's industrial and urban development was characterized by development zone fever and real estate fever over the last four decades. In more recent years, the bidding war over hosting mega-events and a feverish implementation of mega-projects among Chinese cities and regions are strong evidence of local governments' interest in reproducing space and marketing place in order to sustain resilient economic growth [61]. However, the simulation results of the sectoral effects on China's economic resilience indicate that the national economy would be highly sensitive to unpredicted shock from construction, real estate, and financial services sectors. Though the identified critical sectors remain the major sectors receiving enormous investments in contemporary China (such as the four-trillion-yuan (equivalent to $585.5 billion) stimulus package fueled by the Chinese governments in 2009), this study raises a serious concern that any considerable reduction of investment in these sectors would challenge the stability of the national economy to a greater extent than would be the case for a reduction in any of the other sectors. Therefore, our analysis calls for a critical reflection on the potential risk of "fixing" capital in the built environment as a way to counterbalance the adverse effects of an economic slowdown. Given uncertainty for the continuity of large-scaled investment in these three critical sectors, it is imperative to ask what the other source of national economic resilience in the future would be.

5. Conclusions

This research addresses the structural discourse of economic resilience from a novel perspective with insights from the portfolio theory. The relationship between economic structure and resilience has long been recognized while the scholarship to date focuses on the vulnerability of specific sectors. In the Western literature, manufacturing has been deemed the most vulnerable sector in terms of failing to withstand economic turbulence whereas the services have generally been considered capable of absorbing recessionary shocks [9,36]. However, we contend the vulnerability of manufacturing or services sector is subject to specific shock which can be understood as responses to a unique risk or unsystematic risk. In addition to sector-specific shock, there exists systematic risk which may generate impacts on all components of the system, and such impacts could hardly be mitigated simply through diversifying the structure of the given system. Thus, insights from the MPT reminds us diversification may not be helpful in cushioning systematic risk. Rather than seeking the most "safe" portfolio composed of selected "ideal" types of economic sectors, it may be more helpful to understand what are the roles played by each sector under different local contexts so as to generate targeted policies. Resilience study should not replicate the common mistake made in the previous study of competitiveness, that is, identifying determinants of urban competitiveness as being insensitive to contingencies of place [5]. It may never be taken for granted that the same drivers of change are at work everywhere and once the right levers have been pulled, the appropriate drivers will respond and deliver required outcomes.

In this paper, we argue that study of economic resilience should pay more attention on the ways in which different sectors intersect with each other and how that internal interactions generate resilient outcomes of a given country's economy overall. Our analysis extended the structural discourse of economic resilience research beyond the proportional distribution of the components of China's economy, such as the debate over diversification versus specialization. Instead, we demonstrated that insights of greater significance can be gained by identifying the role of each sector in determining the extent of a country's, in this case, China's, aggregate resilience. As stated, our goal in this paper was to open the black box of the national economy's responses to turbulence experienced by each of its principal components by applying a VAR model and IRF simulation based on quarterly data of China's GDP growth rate and that of eight major sectors for the 1993Q1–2017Q2 period. The adopted method of IRF simulates the reactions of the cyclical fluctuation of the GDP growth rate to a unit shock, i.e., an impulse from one specific sector. The simulation results showed that if subjected to an economic shock that construction, real estate, and financial services sectors have the greatest potential to disturb the national economy. However, we also showed that the industry sector (dominated by manufacturing) is capable of absorbing external shocks and, therefore, served as a stabilizing factor in the national economy. Investment in the built environment, as we witnessed an unprecedented speed of infrastructure development and urbanization in China, has made a considerable contribution to the prosperity and resilience of the Chinese economy. However, findings of this study call for a critical reflection on the risk of this growth model.

This study has a number of limitations. First, though we examined China's responses to the two major external shocks from the crises of 1997 and 2008, the structural decomposition analysis of China's economic resilience was based on a long-term observation since 1993. Impacts of these economic crises on China's economy have been embedded in the evolution of the cyclical fluctuation of the national economy and its sectoral components. Second, this study did not take China's spatial inequality at the sub-national level into consideration. The ways in which major sectors take effect may differ significantly across the space. Future study may address the limitation at the regional level with available data. As stated, the structural discourse of economic resilience should go beyond asking which sector is the most resilient one, if it exists. More insights would be gained through a deeper understanding of how different sectors played their role in the aggregate economy, which is highly contingent on region and place.

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Measuring Energy Performance for Regional Sustainable Development in China: A New Framework based on a Dynamic Two-Stage SBM Approach

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Abstract: Sustainable development has always been an important issue for all policy makers, even more so now, as global warming has seriously threatened the whole world. To understand the efficacy of regional sustainable policies, we proposed a dynamic, two-stage, slacks-based measure (SBM) model with carry-over and intermediate variables, highlighting the importance of an electricity portfolio, to measure overall energy performance for the purpose of regional sustainable development. In this unified linear programming framework with intertemporal evaluation, we estimated the effects of a clean electricity supply by the abatement of CO_2 emissions and the gain of economic growth. The results can be used as a reference for decision makers to shape regional sustainable development policies. Using data of 30 provincial administration regions in China for the period of 2012–2017, we postulate that the lower energy performance of the Chinese regional economic system for sustainable development may be attributed to a lower electricity portfolio performance. We then postulate that investment in low-carbon energy infrastructure can combat CO_2 emissions, and is also a major driving force in the regional economic growth.

Keywords: energy performance; regional sustainable development; China; two-stage evaluation framework; dynamic two-stage SBM model

1. Introduction

Over the last decade, global warming has become aggravated, and extreme weather conditions have threatened the living environment of all species. The culprit is believed to be the greenhouse gas (GHG) emissions, mainly from the burning of fossil fuels [1–3]. However, because energy is always indispensable among the many resources required to support economic development, the overdependence on fossil fuels had gone unchallenged for a long time, especially in developing countries [4]. As China experienced unprecedented economic growth after the nation's markets were opened up to the world, it has also become the world's largest GHG emitter [2]. In order to fight climate change, the consensus is for the world to abate CO_2 emissions, so that the Earth's temperature rises by no more than 1.5 °C. Sustainable development has thus become a priority on every government's policy plate. Electrification and decarbonizing the production of electricity have become major directives in long-term sustainable development [5]. China is no exception.

The Chinese government has laid out a set of energy policies in its strategic planning on national development, i.e., the 11th–13th Five-Year Plans (from 2006 to 2020), and also participates in the Nationally Determined Contribution (NDC) that spells out the CO_2 abatement goal by 2030.

Nonetheless, the real challenge is to improve the efficiency and productivity of energy, without sacrificing potential economic growth. China has long been involved in renewable energy investment and has made structural changes in its electricity mix by raising the renewable energy share—which had maintained decade-long rising trend over 2006–2015 [6]. However, to remain economically competitive while fulfilling international climate responsibility, it is important for the government to evaluate the consumption of primary energy and electricity mix, the current state of CO_2 emissions, and economic performance as a whole. Policy makers can thus optimize the allocation of limited resources in order to achieve sustainable development goals (SDGs). In general, one could imagine that making low-carbon electricity infrastructure investment would be a win-win strategy for both the economy and the environment. Therefore, when it comes to regional sustainable development, authorities should evaluate energy performance, not only from the traditional economic standpoint, but also from an environmental one.

Zhou et al. [7] had reviewed the literature on data envelopment analysis (DEA) application for regional energy and/or environmental performance evaluation. The number of studies applying a DEA model in China's provincial administration regions has since increased (e.g. [8–12]). However, some crucial but often neglected ingredients in modelling energy and/or environmental performance in Chinese provincial regions are intermediate and intertemporal structures, which incorporate (but are not limited to) energy consumption, gross regional product, and CO_2 emissions. There were a handful of studies working on that aspect: when evaluating the generation performance of China's provincial power systems, Xie et al. [13] treated power capacity as an intertemporal factor in their model specification; Guo et al. [14] incorporated energy stock in their study, and treated it as a carry-over input/output from one period to another. As the previous literature had pointed out, the electricity generated from power infrastructure is idle before it is used to support economic or household activities. In that sense, we argue that a two-stage model, with electricity playing the intermediate role, would reflect more correctly on the energy performance in the real world. Moreover, in line with the progress of renewable energy in China, we also consider different types of energy, i.e., thermal power and clean power, as the intermediate variables, and model their corresponding installed capacity as the intertemporal elements, in order to evaluate the regional energy performance in China more effectively.

DEA is commonly used to estimate the performance score among homogenous decision-making units (DMUs). In a traditional DEA model, as proposed by Tone and Tsusti [15], there is no intertemporal dependency of the inputs and outputs for each DMU. There are some other approaches, such as windows analysis and the Malmquist index with dynamic DEA structure, that have been used to handle the specific characteristics of time effect under a DEA-based framework. However, these previous models failed to consider the effect of carry-over activities between two consecutive periods. In a real business environment, however, for long-term strategic planning, it is important to consider intertemporal effects in order to comprehensively assess a DMU's efficiency.

Dynamic DEA models with inter-connected activities have been proposed to evaluate the relative performance behavior of DMUs in an intertemporal setting for long-term optimization. The subsequent development was proposed by Guo et al. [14] for further applications. Tone and Tsutsui [16] also expanded dynamic DEA in terms of slacks-based measure (SBM), and introduced the dynamic network SBM model to evaluate performance. Furthermore, traditional DEA treats the operational structure of each DMU as a black box, in which the information on internal inefficiency cannot be deciphered. It overlooks valuable managerial information on how to improve efficiency in the value-creation chain. Using a two-stage framework, we are able to open the DMU black box and decompose it into different stages, under a divisional structure with network connections. This method is commonly used to depict the operational structure in many industries [17–22]. In this paper, we adopt the basic assumptions of Tone and Tsutsui [16]. Details of the model are presented in the following section.

The purpose of this paper is to evaluate the energy performance of provincial administration regions in China and to see how cleaner (i.e., with lower CO_2 emissions) electricity had helped regional sustainable development. To do so, we employ a two-stage dynamic slacks-based measure model, in which we introduced a carry-over variable in the electricity portfolio stage. By considering the overall effort to supply clean electricity, to abate CO_2 emissions, and to stimulate economic growth in a unified framework, we hope to shed some light on regional sustainable development policy. In this paper, we use a sample of 30 provinces in China to estimate their energy performance over the period 2012–2017 in terms of performance in electricity portfolio and energy productivity. In particular, we evaluate the regional sustainable development based on the proposed energy performance model with an intertemporal effect, where we put the emphasis on installed capacity used as the carried-over activity linking two consecutive periods in the electricity portfolio stage. Our model not only makes measuring the overall and stage performance and observing dynamic changes possible, but could identify variables that contribute to improvement in each performance stage. In this regard, our model contains more information to be translated into policy planning strategies.

The contributions of this paper are as follows. First, using installed clean power capacity as the carry-over variable and clean electricity as the intermediate variable, we have improved the discriminatory power of the DEA-based model, highlighting the importance of an electricity portfolio in energy performance for sustainable development. Second, we showed that capital investment in electricity infrastructure, especially in clean power capacity, is closely related to the effectiveness of massive electrification and the decarbonizing of electricity production, as the benefits of these investments will be carried forward into the future.

The reminder of this paper is organized as follows. In Section 2, we develop the evaluation model and introduce our research methodology. Data collection and the model validity test are presented in Section 3. An overview of the empirical results based on the model are discussed in Section 4. A summary of the main findings and remarks are presented in the final section.

2. Model Framework and Methodology

2.1. Conceptual Framework

Guo et al. [14], used the dynamic DEA model to evaluate China's energy performance. They also considered energy stock, i.e., the difference between energy supply and its usage at national level, to be a carry-over variable from one period to another. Undertaking massive electrification and decarbonizing the production of electricity are important actions to promote an economic system for sustainable development [5]. Obviously, investment in electricity infrastructure plays a crucial role on planning for low-carbon future by increasing reliance on clean electricity and adopting clean fuels on thermal electricity. Extending Guo et al. [14], we constructed a two-stage network structure, composing of an electricity portfolio stage and an energy productivity stage, to evaluate the overall energy performance and sustainable development of provincial administration regions in China. Installed thermal and clean power capacity were treated as two carry-over variables in the electricity portfolio stage, and electricity generation, and were employed as two intermediate variables to link the electricity portfolio stage and the energy productivity stage. In addition, we also added the importance of outside electricity from other regions through national grid as an exogenous input in the energy productivity stage. The modified dynamic two-stage network DEA model with SBM approach developed in this paper is illustrated in Figure 1.

In the electricity portfolio stage, we assumed DMUs (e.g., provincial administration regions) invested in modern electricity infrastructure to decarbonize the production of electricity for a visible future. Installed thermal and clean power capacity built in the past were carry-over inputs for electricity generation in the present period, which would satisfy regional electricity demand. In the energy productivity stage, the aims were regional economic growth and its environmental protection. Thermal and clean electricity from the electricity portfolio stage would be considered as intermediate inputs. The exogenous input, primary energy consumption, was used to produce gross region product and to mitigate as much undesirable CO_2 emissions as possible. Meanwhile, the regional economic system may also need to import extra electricity from other regions. These imports were treated as another exogenous input to support the regional economic system.

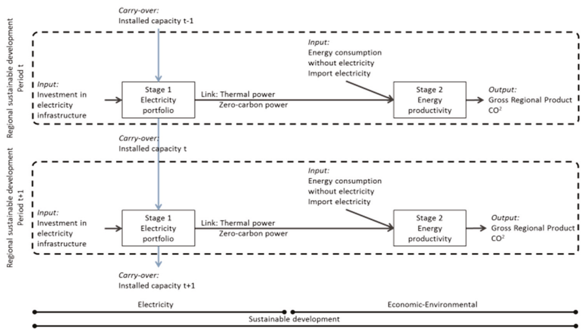

Figure 1. Two-stage dynamic network structure for regional sustainable development.

2.2. Variable Selection

As shown in Figure 1, the variables we selected to build the evaluation framework for regional sustainable development were based on both the previous literatures [14,22–26] and the role of low-carbon electricity in energy consumption. Note that the pursuit of low-carbon economy transition should also involve energy consumption, and, in this regard, we took a value-added approach to our model. In the electricity portfolio stage (stage 1), we considered three variables, namely, investment in electricity infrastructure (Investment) (input), thermal power installed capacity (ThermalPIC) (carry-over), and clean power installed capacity (CleanPIC) (carry-over). Here, "Investment" referred to the expenditure used for electricity infrastructure in any given provincial region. Thermal power installed capacity was the electricity infrastructure using fossil fuels to generate electricity. Clean power installed capacity referred to infrastructure using hydro, nuclear, and renewable energies for electricity generation. Two intermediate variables, thermal electricity (ThermalE) (intermediate) and clean electricity (CleanE) (intermediate), were used to link the electricity portfolio stage (stage 1) and the energy productivity stage (stage 2). Compared with previous studies, we used thermal power installed capacity (ThermalPIC) and clean power installed capacity (CleanPIC) as indicators for performance analysis in the electricity portfolio stage. Accordingly, in the energy productivity stage (stage 2), there were four inputs and two outputs. The four inputs consisted of two dedicated inputs and two intermediate inputs, ThermalE and CleanE, from the preceding stage. One of the two dedicated inputs was the primary energy consumption (PEC) (input), referring to the consumption of coal, gas, fuel oil, etc., excluding electricity used for regional economic system; and the other was the import of outside region electricity (IOE) (input), the extra electricity from other region(s) through national grid. The electricity imported from outside regions was measured by the difference between the production and consumption of electicity at the given provincial administration region. The two final outptuts of the energy productivity stage were gross regional product (GRP) and CO_2 emissions (CO_2). Gross regional product was used to measure regional economic performance as the corresponding desirable final output in the energy productivity stage, while CO_2 emissions was the undesirable output.

2.3. The Dynamic Two-Stage Energy Perforamnce Model for Regional Sustainable Development

In this paper, we proposed a dynamic two-stage energy perforamce model, based on the DNSBM approach, to rate the energy perforamnce of provincial regions in China in terms of their sustainable development, as shown in Figure 1. We took the DNSBM approach in order to integrate the productions of DMUs with multiple inputs, intermediate outputs/inputs, carry-over variables, and outputs into a unified mathamtic programming framework [16,27]. The advantage was that we were able to observe overall energy perfroamnce in separate stages: electricity portfolio stage and energy productivity stage.

The energy performance score of an efficient DMU in any period would be equal to 1 in both stages. This also suggested that there was no room for improvement, and vice versa.

The non-oriented dynamic two-stage SBM model under the assumption of variable returns to scale (VRS) is illustrated in Figure 1. Notations of variables in this paper are definied as follows. Consider that there were n $(j = 1, 2, 3, \ldots, n)$ provincial adminstration regions in China, as separate DMUs, and that each DMU was involved in two stages, the electricity portfolio stage (k) and the energy productivity stage (h), during T terms $(t = 1, 2, 3, \ldots, T)$. There were L_{hk} serial connection link between the electricity portfolio stage and the energy productivity stage in period t, as donated by $(k, h)_{\mathrm{l}}^{\mathrm{t}}$ $(l = 1, \ldots, L_{hk})$, and L_k carry-over activities between two consecutive periods in the electricity portfolio stage (k), denoted as $c_{jkl}^{(t,t+1)}$ $(j = 1, \ldots, n; \quad l = 1, \ldots, L_k; \quad t = 1, \ldots, T)$. In the electricity portfolio stage, a regional economic system consumed m_k^t inputs at time t, which was denoted x_{ijk}^t $(i = 1, \ldots, m_k^t; \quad j = 1, \ldots, n; \quad t = 1, \ldots, T)$, and $c_{jkl}^{(t,t+1)}$ carry-over variables from the previous time $t - 1$, while the number of intermediate outputs generated from the electricity portfolio stage, as donated $z_{i(h,k)l}^t$ $(j = 1, \ldots, n; \quad l = 1, \ldots, L_{hk}; \quad t = 1, \ldots, T)$. In addition, at the energy productivity stage, the imtermediate outputs, $z_{i(h,k)l}^t$, to be the intermediate inputs as well as u_h^t inputs, as denoted x_{ijh}^t $(i = 1, \ldots, u_h^t; \quad j = 1, \ldots, n; \quad t = 1, \ldots, T)$, were consumed to create r_h^t desirable output, as denoted y_{rjh}^t $(r = 1, \ldots, r_h^t; \quad j = 1, \ldots, n; \quad t = 1, \ldots, T)$ and b_h^t undesirable output, as denoted y_{bjh}^t $(b = 1, \ldots, b_h^t; \quad j = 1, \ldots, n; \quad t = 1, \ldots, T)$ at time t, respectively. The input and output constraints of oberved $DMU_o (o = 1, \ldots, n)$ are listed in Euation (1) below.

$$\begin{aligned} x_{iok}^t &= \sum_{j=1}^{n} x_{ijk}^t \lambda_{jk}^t + s_{iok}^{t-} \\ x_{ioh}^t &= \sum_{j=1}^{n} x_{ijh}^t \lambda_{jh}^t + s_{ioh}^{t-} \\ y_{boh}^t &= \sum_{j=1}^{n} y_{bjh}^t \lambda_{h}^t + s_{boh}^{t-} \\ y_{roh}^t &= \sum_{j=1}^{n} y_{rjh}^t \lambda_{jh}^t - s_{roh}^{t+} \\ \sum_{j=1}^{n} \lambda_{jk}^t &= 1; \quad \sum_{j=1}^{n} \lambda_{jh}^t = 1 \end{aligned} \tag{1}$$

where x_{iok}^t (Investment) and x_{ioh}^t (PEC and IOE) were inputs used into the electricity portfolio stage (k) and the energy productivity stage (h) of observed $DMU_0 (0 = 1, \ldots, n)$, respectively. y_{boh}^t (CO_2 emission) was the undesirable output generated by the energy productivity stage (h), which was also fed as the input of that in the mathmatic programming. y_{roh}^t (GRP) was the desirable output produced by the energy productivity stage (h), s_{iok}^{t-}, s_{ioh}^{t-}, and s_{boh}^{t-} were slacks calculated as the difference between the input of DMU_o and its optimal level, and s_{roh}^{t+} was the slacks demonstrated as the improvement of the given output of DMU_o into its optimal level, respectively. λ_{ijk}^t and λ_{ijh}^t were the intensity vectors of DMU_j corresponding to the electricity portfolio stage and the energy productivity stage at the specific time t.

There were four kinds of links: free, fix, bad, and good, with respect to the intermediate linking constraints [28]. ThermalE and CleanE were outputs from the preceding stage (i.e., the electricity portfolio), and were carried over to the subsequent stage (i.e., energy productivity) as inputs. ThermalE and CleanE played crucial roles in regional sustainability evaluations, as Fay et al. [5] argued that massive electrification and decarbonizing the production of electricity were two major actions promoting sustainable development. ThermalE was given a free link, which may increase or decrease in the optimal problem of Equation (4); CleanE had a good link, as it was the desirable output from the electricity portfolio stage due to zero CO_2 emissions. Any shortages of ThermalE and CleanE of observed DMU were counted as inefficient performance, as demonstrared in Eqution (2).

$$\begin{aligned} \sum_{j=1}^{n} z^{t}_{(k,h)_l free}\lambda^{t}_{jh} &= \sum_{j=1}^{n} z^{t}_{(k,h)_l free}\lambda^{t}_{jk} \\ \sum_{j=1}^{n} z^{t}_{(k,h)_l out}\lambda^{t}_{jh} &= \sum_{j=1}^{n} z^{t}_{(k,h)_l out}\lambda^{t}_{jk} \\ z^{t}_{o(k,h)_l free} &= \sum_{j=1}^{n} z^{t}_{(k,h)_l free}\lambda^{t}_{jk} + s^{t-}_{o(k,h)_l free} \\ z^{t}_{o(k,h)_l out} &= \sum_{j=1}^{n} z^{t}_{(k,h)_l out}\lambda^{t}_{jk} - s^{t+}_{o(k,h)_l out} \end{aligned} \tag{2}$$

where $s^{t-}_{o(k,h)_l out}$ and $s^{t+}_{o(k,h)_l out}$ were slacks to the two intermediate outputs we introduced.

Regarding to the carry-over constraints, there were also four options: free, fix, bad, and good. ThermalPIC and CleanPIC were assigned free and good carry-over activities in the electricity portfolio stage between two consecutive periods, as shown in Equation (3).

$$\begin{aligned} \sum_{j=1}^{n} c^{(t,t+1)}_{jk,good}\lambda^{t}_{jk} &= \sum_{j=1}^{n} c^{(t,t+1)}_{jk,good}\lambda^{t+1}_{jk} \\ \sum_{j=1}^{n} c^{(t,t+1)}_{jk,free}\lambda^{t}_{jk} &= \sum_{j=1}^{n} c^{(t,t+1)}_{jk,free}\lambda^{t+1}_{jk} \\ c^{(t,t+1)}_{oh,good} &= \sum_{j=1}^{n} c^{(t,t+1)}_{jh,good}\lambda^{t}_{jh} - s^{(t,t+1)}_{oh,good} \\ c^{(t,t+1)}_{oh,good} &= \sum_{j=1}^{n} c^{(t,t+1)}_{jh,free}\lambda^{t}_{jh} + s^{(t,t+1)}_{oh,free} \end{aligned} \tag{3}$$

where $s^{(t,t+1)}_{oh,good}$ and $s^{(t,t+1)}_{oh,free}$ were slacks to the two carry-over variables (See Tone and Tsustui [15] for more details on the definition of links).

The overall energy performance of observed $DMU_o(o = 1, \ldots, n)$, θ^*_o, was evaluated by Equation (4):

$$\theta^*_0 = \min \frac{\sum_{t=1}^{T} W^t\left[w^k\left[1-\frac{s^{t-}_{iok}}{x^t_{iok}}\right] + w^h\left[1-\frac{1}{u^t_h+b^t_h}\left(\sum_{i=1}^{u^t_h}\frac{s^{t-}_{ioh}}{x^t_{ioh}} + \frac{s^{t-}_{boh}}{y^t_{boh}}\right)\right]\right]}{\sum_{t=1}^{T} W^t\left[w^k\left[1+\frac{1}{linkout^t_k+ngood^t_k}\left(\sum_{(k,h)_l=1}^{linkout^t_k}\frac{s^t_{o(kh)_l out}}{z^t_{o(kh)_l out}} + \sum_{k_l=1}^{ngood^t_k}\frac{s^{(t,t+1)}_{ok_l good}}{c^{(t,t+1)}_{ok_l good}}\right)\right] + w^h\left[1+\frac{1}{r^t_h}\left(\sum_{t=1}^{r^t_{th}}\frac{s^{t+}_{roh}}{y^t_{roh}}\right)\right]\right]} \tag{4}$$

subjected to Equations (1)–(3) for the selected variables.

The numerator included elements related to relative slacks of inputs in the electricity portfolio stage and the energy productivity stage, respectively, whereas the denominator contained relative slacks of good intermediate link and good carry-over from the electricity portfolio stage, and that of desirable output from the energy productivity stage. They were weighted by the stage weights w^k and w^h, as well as the period weight W^t, and the ovrall energy performance θ^*_o of observed DMU_o could be estimated in Equation (4). $\theta^*_o = 1$ if and only if all slacks of that were zero, and the DMU would be treated as an efficient one.

The weights to stage and time were exogenous and satisfied the constraint of Equation (5). w^k and w^h were the weights assigned to stages k and h, respectively, and the sum of the weights was in unity. W^t was the weight assigned to time t, and the sum of that was also in unity.

$$\begin{aligned} w^k + w^h &= 1 \\ \sum_{t=1}^{T} W^t &= 1 \end{aligned} \tag{5}$$

In addition, the performance of observed DMU_o in each period was τ_o^{t*}, period-R&D stage was ρ_{ok}^{t*}, and period-commercialization stage was ρ_{oh}^{t*}. They were calculated by Equations (6)–(8), respectively.

$$\tau_0^* = \frac{w^k\left[1-\frac{s_{iok}^{t-}}{x_{iok}^t}\right]+w^h\left[1-\frac{1}{u_h^t+b_h^t}\left(\sum_{i=1}^{u_h^t}\frac{s_{ioh}^{t-}}{x_{ioh}^t}+\frac{s_h^{t-}}{y_{boh}^t}\right)\right]}{w^k\left[1+\frac{1}{linkout_k^t+ngood_k^t}\left(\sum_{(k,h)_l=1}^{linkout_k^t}\frac{s_{o(kh)_l out}^t}{z_{o(kh)_l out}^t}+\sum_{k_l=1}^{ngood_k^t}\frac{s_{ok_l good}^{(t,t+1)}}{c_{ok_l good}^{(t,t+1)}}\right)\right]+w^h\left[1+\frac{1}{r_h^t}\left(\sum_{t=1}^{r_{th}^t}\frac{s_{roh}^{t+}}{y_{roh}^t}\right)\right]} \tag{6}$$

$$\rho_{0k}^* = \frac{w^k\left[1-\frac{s_{iok}^{t-}}{x_{iok}^t}\right]}{w^k\left[1+\frac{1}{linkout_k^t+ngood_k^t}\left(\sum_{(k,h)_l=1}^{linkout_k^t}\frac{s_{o(kh)_l out}^t}{z_{o(kh)_l out}^t}+\sum_{k_l=1}^{ngood_k^t}\frac{s_{ok_l good}^{(t,t+1)}}{c_{ok_l good}^{(t,t+1)}}\right)\right]} \tag{7}$$

$$\rho_{0h}^* = \frac{w^h\left[1-\frac{1}{u_h^t+b_h^t}\left(\sum_{i=1}^{u_h^t}\frac{s_{ioh}^{t-}}{x_{ioh}^t}+\frac{s_h^{t-}}{y_{boh}^t}\right)\right]}{w^h\left[1+\frac{1}{r_h^t}\left(\sum_{t=1}^{r_{th}^t}\frac{s_{roh}^{t+}}{y_{roh}^t}\right)\right]} \tag{8}$$

3. Data Collection, Descriptive Statistics, and Model Validity

3.1. Data Collection and Descriptive Statistics

We used data from thirty provincial administration regions in China, covering the six years from 2012 to 2017. The data of all selected variables were obtained from *China Energy Statistics Yearbook* and *China Electric Power Yearbook* (2013–2018), except for CO_2 emissions. The data on regional CO_2 emissions was calculated by the amount of regional consumption of coal, oil, natural, and electricity, times their corresponding coefficients of calorific value, carbon emission factor, and carbon oxidation factor, according to the Intergovernmental Panel on Climate Change (IPCC) Guideline for National Greenhouse Gas Inventories [29], as shown in Equation (9):

$$\sum_{i=1}^{E} CO_{2ijt} = E_{ijt} \times NCV_i \times CEF_i \times COF_i \times (44/12) \tag{9}$$

where CO_{2ijt} denoted the CO_2 emissions from energy type $i(i = 1, \ldots, E)$, such as coal, crude oil, natural gas, and electricity in region j at year t; E_{ijt} denoted the total consumption of each type of energy in region j at year t; NCV_i was the net calorific value of each type of energy; CEF_i denotes the carbon emission factor of each type of energy; and COF_i denotes the carbon oxidation factor of each type of energy. The constant value of 44 and 12 are the molecular weights of CO_2 and carbon, respectively. The descriptive statistics of variables are summarized in Table 2. It should be noted that all monetary variables used in this paper were in 2012 RMB, which have been deflated with the consumer price index (CPI index 2012 = 100). Table 1 summarizes the descriptive statistics of all selected variables to the proposed model.

Table 1. Descriptive statistics.

Variables	Mean	Std. Dev.	Max	Min
Inputs-Electricity portfolio				
Inv (100 million RMB)	567.83	376.92	2214.23	73.10
Intermediate outputs				
ThermalE (100 million kWh)	1420.17	1131.58	4671.00	120.00
CleanE (100 million kWh)	479.61	606.89	3215.00	4.90
Carry-over				
ThermalPIC (MW)	3217.33	2312.75	10,335.00	230.00
CleanPIC (MW)	1629.91	1572.94	8059.00	23.70
Inputs- Energy productivity				
PEC (MTOE)	143.97	99.04	482.90	15.85
IOE (100 million kWh)	1394.81	607.65	3144.00	1.00
Final outputs-Energy productivity				
CO_2 (Million ton)	526.79	346.09	1757.02	75.62
RGP (100 million RMB)	22,282.84	16,804.72	81,571.96	1893.54

Note: Inv refers to the expenditure on the energy industry for electricity infrastructure; ThermalE is the electricity generated from the thermal power installed capacities; CleanE is the electricity produced by the clean power installed capacities; ThermalPIC denotes the thermal power installed capacities operation at a specific period; CleanPIC denotes the clean power installed capacities operation at specific period; PEC denotes the total consumption of primary energies without electricity; IOE is the import of outside region electricity, as measured the difference between the production and consumption of electricity at given provincial administration region; CO_2 is assumed to be the product of energy consumption, which calculated by the emission factors related to energy consumption; GRP denotes the real value of gross regional product.

3.2. Model Vadility

According to Tone et al. [27], there were four criteria to test DEA-based model validity: homogeneity, minimum number of DMUs, isotonicity, and relevance variables selection. We adopted these four criteria to verify the feasibility of the proposed dynamic two-stage SBM model. First in our model, we selected 30 provincial administration regions in China to be DMUs. Because these regions are all second-tier administrative bodies under the central government, and all have equally political statutes, it was safe to assume our model satisfied the homogeneity criterion. However, we considered that there are geographical differences in China, which brought us to comparisons among different areas, in Section 4.4.

Second, as Li et al. [30] had explained, for a DEA-based evaluation model to have acceptable discriminatory ability, the number of DMUs should be at least three times as many as the number of total input and output variables. Similarly, Golany and Roll [25] proposed that the minimum required ratio related to the number of DMUs and model variables was two. As we used data from 30 DMUs across 6 research years (from 2012 to 2017), we had a total of 180 province-year DMUs, which was more than three times that of the nine variables we employed, providing acceptable validity for analysis propose (Tibet was not included in this paper due to the lack of data).

Third, we conducted the Spearman's correlation analysis for the selected variables in the electricity portfolio and the energy productivity stages, and presented the results in Tables 2 and 3. The coefficients were mostly significantly positive, indicating that the variables were suitable for the proposed dynamic two-stage network SBM model. It is worth noting that the coefficient between two inputs in the energy productivity stage, zero-carbon power and the import of electricity, was −0.260, indicating the higher the electricity generation of zero-carbon capacity, as a supplement to thermal power capacity, the further it could reduce the need for imported electricity from outside regions. In summary, the variables have also satisfied the assumption of isotonicity proposed by Golany and Roll [31].

Lastly, we used regression to show that our variables selection was relevant. We were able to show that that the outputs in the electricity portfolio and energy productivity stages, could significantly explained by the input variables in each stage. The results are shown in Table 4. This also confirmed our model satisfied the validity criterion.

Table 2. Correlation coefficients for the selected variables in the electricity portfolio stage.

	Inv	CleanPIC	ThermalPIC	CleanE	ThermalE
Inv	1.000				
CleanPIC	0.606 ***	1.000			
ThermalPIC	0.641 ***	0.235 ***	1.000		
CleanE	0.497 ***	0.947 ***	0.153 **	1.000	
ThermalE	0.576 ***	0.124 *	0.968 ***	0.042	1.000

Note: Inv refers to the expenditure on the energy industry for electricity infrastructure; CleanPIC denotes the clean power installed capacities operation at specific period; ThermalPIC denotes the thermal power installed capacities operation at a specific period; CleanE is the electricity produced by the clean power installed capacities; ThermalE is the electricity generated from the thermal power installed capacities. *, **, *** represent significant at 0.10, 0.05, and 0.01 levels, respectively.

Table 3. Correlation coefficients for the selected variables in the energy productivity stage.

	CleanE	ThermalE	PEC	IOE	CO_2	GRP
CleanE	1.000					
ThermalE	0.042	1.000				
PEC	0.108	0.895 ***	1.000			
IOE	−0.260 ***	0.144 *	0.071	1.000		
CO_2	0.191 **	0.888 ***	0.981 ***	0.127 *	1.000	
GRP	0.148 **	0.543 ***	0.576 ***	0.518 ***	0.867 ***	1.000

Note: CleanE is the electricity produced by the clean power installed capacities; ThermalE is the electricity generated from the thermal power installed capacities; PEC denotes the total consumption of primary energies without electricity; IOE is the import of outside region electricity, as measured the difference between the production and consumption of electricity at given provincial administration region. CO_2 is assumed to be the product of energy consumption, which calculated by the emission factors related to energy consumption; GRP denotes the real value of gross regional product. *, **, *** represent significant at 0.10, 0.05 and 0.01 levels, respectively.

Table 4. Regression results on the relevance of variables.

	Electricity Portfolio Stage		Energy Productivity Stage
Inputs/Outputs	log(ThermalE)	log(CleanE)	log(GRP)
Constant	0.633	1.263 ***	6.754 ***
	(0.916)	(2.735)	(10.505)
log(Inv)	0.096 ***	0.038	
	(3.329)	(0.830)	
log(ThermalPIC)	0.738 ***		
	(8.551)		
log(CleanPIC)		0.583 ***	
		(9.961)	
log(ThermalE)			0.150 **
			(2.541)
log(CleanE)			0.050 *
			(1.950)
log(PEC)			0.650 ***
			(5.048)
log(IOE)			0.001
			(0.067)
log(CO_2)			1.212 ***
			(5.949)
Adj. R^2	0.987	0.989	0.995
F-statistic	390.211 ***	451.616 ***	976.811 ***

Note: *** denoted the 1% significance level, ** represented the 5% significance level, and * indicated the 10% significance level. Inv refers to the expenditure on the energy industry for electricity infrastructure; ThermalPIC denotes the thermal power installed capacities operation at specific period; CleanPIC denotes the clean power installed capacities operation at specific period; ThermalE is the electricity generated from the thermal power installed capacities; CleanE is the electricity produced by the clean power installed capacities; PEC denotes the total consumption of primary energies without electricity; IOE is the import of outside region electricity, as measured the difference between the production and consumption of electricity at given provincial administration region; CO_2 is assumed to be the product of energy consumption, which calculated by the emission factors related to energy consumption; GRP denotes the real value of gross regional product. *, **, *** represent significant at 0.10, 0.05, and 0.01 levels, respectively.

4. Empirical Results

4.1. Parameters Setting on the Proposed Dynamic Two-Stage SBM Model

In our dynamic two-stage SBM evaluation model, it should be noted that the choice of preferred weights for time periods and stages were important parameters in Equation (1). The last period *T* could be treated as having the largest contribution to the dynamic evaluation framework [16,32]. Therefore, we considered the possibility that the weight of time periods in the proposed model should increase yearly. We then used the sum-of-the-year's digits method to set the preferred weight of each period. As we had 6 years' research period (2012–2017), with 2012 being 1, 2013 being 2, and so on, we got a total sum of 21 as the denominator. So, the preferred weight in 2012 was 1 divided by 21, which equaled to 0.048. Following this calculation, the preferred weights assigned to the year during 2013 to 2017 were as followed: 2013 = 0.095, 2014 = 0.143, 2015 = 0.19, 2016 = 0.238, and 2017 = 0.286. It would also be reasonable to assume the overall performance of two-stage SBM framework with serial connection as the weighted sum of the performance behavior of the individual stages [7]. Thus, in this paper, we assumed that both the electricity portfolio stage and the energy productivity stage had the same contribution to the overall energy performance for regional sustainable development, and assigned each stage with the same weight of 0.5. Similarly, the preferred weights of periods and stages mentioned above were also employed under the dynamic SBM model, two-stage SBM model, and SBM model to obtain the overall energy performance for Chinese provincial administration regions.

The overall energy performance of provincial regions in China could be estimated by the Equations (1) and (2). To understand the applicability of our model, we also compared our evaluation results to those using other SBM models, including two-stage SBM models without carry-over activities, and regular single-stage SBM models; further details are discussed in the following section.

4.2. Comparsion among Dynamic Two-Stage SBM, Dynamic SBM, Two-Stage SBM and SBM Performormance Scores

To see the effectiveness of our model in evaluating performance, we have chosen three other SBM-related models to be compared with. The evaluation results of all four models were presented in Table 5. From Table 5, we observed that, if we ignored the two-stage structure (as the proposed model in this paper, namely Model 1) and used only a single-stage structure with dynamic component (Model 2), the average overall energy performance of these 30 DMUs almost doubled (0.3487 vs. 0.6118). This suggested that neglecting the internal structure within community, as the importance of electricity portfolio stage to regional sustainable development, might lead to overestimating the overall energy performance in China.

In Model 3, we removed the carry-over linkage, i.e., thermal and clean power installed capacity. the average overall energy performance of this static two-stage SBM model was also higher than that of Model 1. Ignoring the power installed capacity built from the past that could be carried over to the next periods, which could create a discrepancy in estimation of investment in electricity infrastructure, and this might consequently lead to overestimate the overall energy performance as well.

Model 4 was where a simple SBM model, with neither a two-stage structure nor a carry-over linage between two consecutives. The average overall energy performance of Model 1 was still lower than that of Model 4. Obviously, the black-box model might overestimate the overall energy performance and lack meaningful information to identify inefficient DMU.

Note that the number of efficient DMUs in the proposed dynamic two-stage model was two, which was significantly less than other three models, ranging from 6 to 10. We used the non-parametric Krukal-Waillis rank sum test to see whether the average overall energy performance obtained from four models (e.g., the proposed model was an experimental group and other three models were a control group) originated from the same distribution, i.e., if there were significant difference of performance scores among four models or on a pairwise comparison. Table 6 summarized the p-value of Krukal-Waillis rank sum test under the four model comparison or on a pairwise comparison. Most of the p-values were on the fare significant between 1% to 5% level under four model comparison scenario and three pairwise comparison scenarios. Based on the statistical test, we argued that the proposed dynamic two-stage SBM model had more discriminative power than the other three SBM-related models had to empirical applications.

Table 5. Overall performance score rank under the proposed dynamic two-stage SBM model.

		Dynamic Two-Stage SBM (Model 1)		Dynamic SBM (Model 2)		Two-Stage SBM (Model 3)		SBM (Model 4)	
No.	DMU	Performance Score	Rank	Performance Score	Rank	Performance Score	Rank	Performance Score	Rank
1	Beijing	0.0591	28	1.0000	1	1.0000	1	1.0000	1
2	Tianjin	0.0223	29	0.0886	30	1.0000	1	0.9999	7
3	Hebei	0.0988	21	0.1353	26	0.5816	29	0.3354	21
4	Shanxi	0.0823	24	0.0938	29	0.9928	12	0.1307	27
5	Inner Mongolia	0.3020	13	0.1896	22	1.0000	1	0.1228	28
6	Liaoning	0.2962	15	0.4579	18	0.5880	28	0.3805	18
7	Jilin	0.1943	17	1.0000	1	0.8540	16	0.4689	16
8	Heilongjiang	0.1820	18	0.2572	21	0.7703	22	0.3553	20
9	Shanghai	0.0817	25	1.0000	1	1.0000	1	1.0000	1
10	Jiangsu	0.2047	16	0.9996	11	1.0000	1	1.0000	1
11	Zhejiang	0.4200	11	0.5949	17	0.8140	19	0.6623	11
12	Anhui	0.0708	27	0.0991	28	0.9988	11	0.3000	23
13	Fujian	0.5013	7	0.6449	15	0.7534	24	0.4459	17
14	Jiangxi	0.3005	14	0.4193	19	0.7577	23	0.3761	19
15	Shandong	0.0824	23	0.9983	13	0.9509	13	1.0000	1
16	Henan	0.0894	22	0.1808	24	0.7769	21	0.6383	12
17	Hubei	0.8145	3	1.0000	1	0.9333	14	0.5567	14
18	Hunan	0.4668	8	0.9994	12	0.8312	18	0.8403	10
19	Guangdong	0.5503	5	1.0000	1	1.0000	1	1.0000	1
20	Guangxi	0.4606	9	0.6051	16	0.6671	27	0.3310	22
21	Hainan	1.0000	1	1.0000	1	1.0000	1	0.9998	8
22	Chongqing	0.4315	10	0.7029	14	0.7898	20	0.5514	15
23	Sichuan	1.0000	1	1.0000	1	1.0000	1	1.0000	1
24	Guizhou	0.5666	4	1.0000	1	0.9222	15	0.2142	25
25	Yunnan	0.9956	2	1.0000	1	1.0000	1	0.6274	13
26	Shaanxi	0.0812	26	0.1202	27	0.7157	25	0.2666	24
27	Gansu	0.3075	12	0.4086	20	0.6871	26	0.1561	26
28	Qinghai	0.5293	6	1.0000	1	1.0000	1	0.9995	9
29	Ningxia	0.1255	20	0.1721	25	0.8345	17	0.0723	30
30	Xinjiang	0.1424	19	0.1875	23	0.4020	30	0.0961	29
	Mean	0.3487		0.6118		0.8540		0.5643	
	Std.	0.2949		0.3808		0.1379		0.3333	
Number of efficient DMU		2		10		10		6	

Table 6. Krukal-Waillis rank sum test of the overall energy performance differences within/between the four models.

Performance Indicator	Group	Significant Sign	Significant Level
Overall energy performance	Independent sample	Y	1%
	Model1–Model2	Y	1%
	Model1–Model3	Y	1%
	Model1–Model4	Y	5%
	Model2–Model3	N	-
	Model2–Model4	N	-
	Model3–Model4	Y	5%

Note: The independent sample group denoted the Krukal-Waillis rank sum test was used to identify the performance difference within four independent samples as the overall results of the four models, as listed in Table 5; Y and N represented significant and insignificant sign, respectively; Model 1 was the proposed dynamic two-stage SBM model; Model 2 was the dynamic SBM model; Model 3 was the two-stage SBM model; Model 4 was the SBM model.

4.3. Energy Performance of Chinese Provincal Adminstration Regions

The results of the energy performance evaluation for provincial regions in China, including performance scores, overall energy performance ranking in both the electricity portfolio stage, and energy productivity stage were presented in Table 7. It can be seen, in Table 7, that only two DMUs (i.e., Hainan and Sichuan) were estimated as efficient with the overall energy performance score equal to 1 during 2012–2017; they were also efficient in both stages. Beijing and Tianjin had an overall energy performance score of 0.0591 and 0.0223, respectively, which were ranked the bottom two within the 30 DMUs we evaluated. As for stage evaluation results, we found that only Hainan and Sichuan were deemed efficient in the electricity portfolio stage, while there were another four DMUs (e.g., Beijing, Inner Mongolia, Jiangsu, and Guangdong), in addition to Hainan and Sichuan, were seen as efficient ones in the energy productivity stage. Beijing and Tianjin had the worst performance in the electricity portfolio stage, while Beijing was deemed efficient in the energy productivity stage. One possible explanation was that these two DMUs imported most of their electricity from other regions, rather than from their own installed power plants.

Table 7. Performance evaluation of the proposed dynamic two-stage SBM model.

No.	DMU	Electricity Portfolio	Rank	Energy Productivity	Rank	Overall Energy Performance	Rank
1	Beijing	0.0273	29	1.0000	1	0.0591	29
2	Tianjin	0.0123	30	0.7516	12	0.0223	30
3	Hebei	0.0696	22	0.3160	26	0.0988	22
4	Shanxi	0.0638	23	0.2389	28	0.0823	25
5	Inner Mongolia	0.1385	16	1.0000	1	0.3020	14
6	Liaoning	0.3195	13	0.3298	25	0.2962	16
7	Jilin	0.1255	19	0.6516	18	0.1943	18
8	Heilongjiang	0.1300	18	0.4682	22	0.1820	19
9	Shanghai	0.0518	26	0.6941	15	0.0817	26
10	Jiangsu	0.0937	21	1.0000	1	0.2047	17
11	Zhejiang	0.2936	14	0.7772	11	0.4200	12
12	Anhui	0.0447	27	0.5848	19	0.0708	28
13	Fujian	0.3699	9	0.7829	9	0.5013	8
14	Jiangxi	0.1851	15	0.6584	17	0.3005	15
15	Shandong	0.0345	28	0.7231	14	0.0824	24
16	Henan	0.0526	25	0.5665	20	0.0894	23
17	Hubei	0.8549	5	0.7776	10	0.8145	4
18	Hunan	0.3529	10	0.7483	13	0.4668	9
19	Guangdong	0.3475	11	1.0000	1	0.5503	6
20	Guangxi	0.3971	6	0.5604	21	0.4606	10
21	Hainan	1.0000	1	1.0000	1	1.0000	1
22	Chongqing	0.3209	12	0.6835	16	0.4315	11
23	Sichuan	1.0000	1	1.0000	1	1.0000	1
24	Guizhou	0.9152	4	0.4282	24	0.5666	5
25	Yunnan	0.9968	3	0.9948	7	0.9956	3
26	Shaanxi	0.0540	24	0.4443	23	0.0812	27
27	Gansu	0.3807	8	0.2817	27	0.3075	13
28	Qinghai	0.3907	7	0.9363	8	0.5293	7
29	Ningxia	0.1254	20	0.1414	30	0.1255	21
30	Xinjiang	0.1303	17	0.1823	29	0.1424	20
	Mean	0.3093		0.6574		0.3487	

Notably, we found that the most regions in China had relatively better performance in the energy productivity stage than in the electricity portfolio stage, as shown in Table 7. This could be due to the fact that economic growth was an important criterion for promotion of the administrative officials, which then prompted governors to focus on productivity more. In summary, the Chinese government should make more effort to decarbonize the energy/electricity supply mix to improve deficiency of electricity portfolio stage, while maintaining economic growth momentum at the same time. Moreover, there existed great disparities of performance scores between the electricity portfolio stage and energy productivity stage among certain DMUs. Beijing was an example of them. To improve the performance in portfolio stage, we suggested that the government could increase the clean electricity capacity (through capital investment), as clean power produces "desirable" output, which would in turn translated into both better economic and sustainable performance.

4.4. Efficiency Analysis on Regional Discrepancy

Based on the geographical location and economic regional blocks from the seventh Five Year plan in 1987, the 30 regions in the research sample could be grouped into three areas: the east, the central, and the west, as listed in Table 8. We examined whether the performance score differences of three large economic regional blocks in China. Overall energy performance and stage-wise performance of each regional block are presented in Table 9. The East Area ranked first in the energy productivity stage, which could be due to significant effort it had put on to promote economic growth. The West Area ranked first in the electricity portfolio stage, which could be attributed to the effort on the improvement of electricity mix with lower CO_2 emissions. In summary, because the economic performance was still a crucial criterion for the political ascension, it was natural for the regional administration to focus on economic performance more. However, since the performance of energy productivity also played an important role in regional economic development, China's central government should pay more attention to the performance of the electricity portfolio stage regardless, as it would translate into better regional sustainable development.

Table 8. All selected provinces classified into three economic regional blocks in China.

Regional Block	Provinces
East	Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan
Central	Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan
West	Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang

Table 9. Performance scores of three economic regional blocks.

Regional Block	Electricity Portfolio			Energy Productivity			Overall Energy Performance		
	Mean	Efficiency	Inefficiency	Mean	Efficiency	Inefficiency	Mean	Efficiency	Inefficiency
Eastern	0.2382	1 (9%)	10 (91%)	0.7613	4 (36%)	7 (64%)	0.3015	1 (9%)	10 (91%)
Central	0.2262	0 (0%)	8 (100%)	0.5868	0 (0%)	8 (100%)	0.2751	0 (0%)	8 (100%)
Western	0.4409	1 (9%)	10 (91%)	0.6048	2 (18%)	9 (82%)	0.4493	1 (9%)	10 (91%)

5. Conclusions

In this paper, we proposed a dynamic two-stage SBM model for evaluating regional sustainable development, in terms of energy performance in China. Installed capacity and electricity generation, were the carry-over and intermediate variables, which we further decomposed into thermal and clean power. Incorporating these variables brings new insights to the energy performance evaluation by DEA-based modeling, as they reflect the dynamic and internal structure crucial to regional economic and sustainable development from an inter-connected perspective. We built the two-stage evaluation model consisting of electricity portfolio and energy productivity stage, in order to capture more valuable information in the model. The proposed model was designed to highlight the contribution of the electricity portfolio stage to overall energy performance, where installed clean power capacity and clean electricity were seen as desirable carry-over and intermediate outputs in the electricity portfolio stage, and then the latter will continuously to be beneficial input into the energy productivity stage. The main conclusions are as follows.

First, our results demonstrated that by incorporating installed capacity and electricity generation as carry-over and intermediate variables of the electricity portfolio stage in a dynamic two-stage SBM model, we can improve the discriminatory power of energy performance evaluation. Second, from our model, it can be inferred that, while investing in low-carbon electricity infrastructure could alleviate the pressure of CO_2 emissions, it would later be translated into better regional sustainable economic performance over long-term planning periods. Third, the group analysis in Section 4.4 suggests that the efforts to purse the growth of the economic system could play an important role for the eastern region in achieving impressive economic performance, and we therefore could conclude that regional imbalance did exist in China, leading to income imbalance among people in different regional economic blocks in terms of industrial development.

In summary, with this model, governors and policy makers could better understand the contribution of decarbonizing the electricity portfolio and comprehensively improving electricity investment with economic incentives. All provinces should be encouraged to make more efforts to improve performance in the electricity portfolio stage. As we know, decarbonizing electricity consumption is an effective strategy to mitigate the demand of primary energy with lower CO_2 emissions.

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Socioeconomic Impacts of Forest Fires upon Portugal: An Analysis for the Agricultural and Forestry Sectors

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Abstract: Recent forest fire activity has resulted in several consequences across different geographic locations where both natural and socioeconomic conditions have promoted a favorable context for what has happened in recent years in a number of countries, including Portugal. As a result, it would be interesting to examine the implications of forest fire activity in terms of the socioeconomic dynamics and performance of the agroforestry sectors in the context of those verified in the Portuguese municipalities. For this purpose, data from Statistics on Portugal was considered for output and employment from the business sector related to agricultural and forestry activities, which were disaggregated at the municipality level, for the period 2008–2015. Data for the burnt area was also considered in order to assess the impact of forest fires. The data was analyzed using econometric models in panel data based on the Keynesian (Kaldor laws) and convergence (conditional approaches) theories. The results from the Keynesian approaches show that there are signs of increasing returns to scale in the Portuguese agroforestry sectors, where the burnt area increased employment growth in agricultural activities and decreased employment in the forestry sector. Forest fires seem to create favorable conditions for agricultural employment in Portuguese municipalities and the inverse occurs for forestry employment. Additionally, some signs of convergence were identified between Portuguese municipalities for agroforestry output and employment, as well for the burnt areas. However, signs of divergence (increasing returns to scale) from the Keynesian models seem to be stronger. On the other hand, the evidence of beta convergence for the burnt areas are stronger than those verified for other variables, showing that the impacts from forest fires are more transversal across the whole country (however not enough to have sigma convergence).

Keywords: panel data; Portuguese municipalities; Keynesian models; convergence theory; regional resilience

JEL Classification: C23; E12; O13; O47; Q10

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1. Introduction

Forest fires and their consequences came to be in several countries such as Portugal as a result of a set of factors related to the social, economic, environmental and natural contexts, which create favorable conditions or environments for these occurrences. They are realities towards which everyone may contribute, in some way, in order to mitigate them. In fact, damage caused by forest fires has increased over the last few decades across the globe [1].

In these frameworks, the scientific community may and should bring contributions, namely through new approaches and insights that allow for the prevention of the negative consequences from forest fires and allow us to understand the several impacts after their occurrence. Computational modelling, for example, brings new approaches for forest fire assessment, namely because it allows us to link several dimensions related with these multidisciplinary realities [2]. Good assessments of the impacts of forest fires are important contributions to the design of adjusted agroforestry policies, specifically in order to direct support to the most negatively affected activities. Policy instruments and related legislation are determinant tools for reducing the negative impacts of forest fires [3].

Indeed, in international terms, agroforestry land inside and outside of Europe continues to burn, in some cases with more severity and frequency, namely due to climate change and global warming. On the other hand, governments and related institutions create (and disclose) more regulations than in the past [4]. Maybe, new approaches are needed, where new technologies may play a determinant role. Multidisciplinary approaches could bring interesting contributions, for instance, economic analysis could transmit valuable insights.

These undesirable forest fires have always brought negative implications, however the impacts from these forest fires are not always equal across the several economic sectors [5]. These realities appeal for more highlights about the real consequences of forest fires across the different economic activities and across geographic levels/locations.

In this context, the main objective of this study is to analyze the impact of verified forest fires in Portugal over the period of 2008–2015 on the socioeconomic dynamics of the agricultural (agriculture, farming, hunting, and related service activities), forestry (forestry and forest exploration) and economic sectors. For this purpose, we considered data from Statistics Portugal [6] that was disaggregated at the municipality level for both output (gross value added) and employment (employed persons) from the business sector (all figures and tables are of one's own elaboration with data used from this database).

In other words, with this study, it is intended to investigate if forest fires reduce or increase agroforestry output and employment across Portuguese municipalities, over recent years, bringing insights for several stakeholders, namely for policymakers (both Portuguese and from the European Union), researchers and economic agents. The findings presented in this study will be another contribution for the policymakers to establish priorities in the design of forest fire regulations and for the perceptions of the economic agents about the socioeconomic implications from the wildfires. This analysis is fundamental for activities where profit margins are, often, lower and where it is crucial to create more employment and attract more people. The approaches and findings, here presented for Portugal, may be considered for other contexts around the world and, for example, promote the creation of a common forest policy in the European Union, putting together the several regulations created by the European institutions [4].

Considering these objectives, this analysis was based on Keynesian and convergence theories and the statistical information was analyzed through panel data. For the regressions, we considered the developments and the procedures proposed by Islam [7], Torres-Reyna [8] and Stata [9]. In each case, more adjusted methodologies were considered, taking into account the results for tests relating, namely, to heteroscedasticity and autocorrelation.

Keynesian and convergence approaches are developments from the economic growth theory and are useful to analyze performance and dynamics within economic sectors. Considering the objectives defined by this research, these approaches are adjusted towards the intended focus. In turn, the consideration of these theories in forest fire analysis may be explored further. Subsequent explanations about the Keynesian and convergence frameworks will be presented in Section 3.

The need for more socioeconomic research relating to forest fires, for Portugal, has been identified in previous studies (as in, for example, Navalho et al. [10]) and the work presented here aims to contribute towards filling this gap.

Considering the objectives and methodologies adopted for the research presented here, this study will be structured, after this introduction, in a further six parts. The next section is a literature review, the third section is for the explanation of methodology, the fourth for the data description, the fifth and sixth for the results obtained from the Keynesian and convergence approaches, respectively, and finally the last section is for the main conclusions.

2. Literature Insights

In countries like Portugal and Spain, recent years have shown that the consequences of forest fires may be dramatic, with an inclusive loss of human lives and firms. The implications of forest fire activity in the social and economic context in certain geographic regions is enormous [11,12] and some areas will require several years for normality to be restored. In fact, the occurrence and severity of forest fires, as well as their relevant impact on various levels of human life, has become a concern for several stakeholders and policymakers in a variety of global locations [13].

The negative consequences of forest fires are, indeed, relevant across different areas of human life, inclusively affecting the normal conditions for human health [14]. In some contexts, forest fires are the main agent of disturbances having a more random spatial spreading [15], making it more difficult to predict the consequences. One of the main challenges for national authorities in some countries is to predict the implications on human survival from forest fires in more isolated regions.

To mitigate the potentially devastating consequences of forest fires, prevention is especially important, in particular through the reduction of the available fuel load [16]. However, it is also crucial to ensure that resources are immediately available for firefighting [17], and because some natural elements, such as changing winds, may render other existing factors irrelevant [18]. Adjusted forest fire management with balanced prevention and suppression approaches are crucial to reduce the negative impacts of these agents on forest disturbance.

In some circumstances the resilience of certain plants may make all the difference in reducing the impacts of forest fires, namely in the new context of climate change [19,20]. This question should be considered by the several agroforestry stakeholders, namely by policymakers, to design adjusted plans for forest management. In any case, the relationships between climate change, global warming and forest fires seem to be, in some cases, correlated [21].

During the post-fire period, it is important to quickly assess the implications [22,23] as a means to readily promote adjusted policies that will reduce these negative impacts from fires and support a quick recovery of the socioeconomic contexts and affected ecosystems.

In any case, avoiding the occurrence of forest fires altogether seems to be the most important factor and prevention plays a fundamental role. Fuel load reduction is important, but it is also crucial to make an adjusted assessment of the risks and critical periods which contribute to forest fire occurrence [24].

3. Methodology Explanation

From the Keynesian theory, we drew from the Verdoorn [25] and Kaldor's [26,27] developments, primarily those related to the Kaldor coefficient. The Kaldor coefficient, which we obtained from running regressions with employment growth as a function of output growth, captures the dynamic effects of economies of scale where we expect a coefficient value between 0 and 1, where values closer to 0 indicate stronger, increasing returns to scale. In this study, this relationship was enlarged using a variable related to forest fire severity (i.e., burnt area) as a way of assessing the effect of forest fires on the socioeconomic dynamics of the Portuguese municipalities. The enlargement of this Kaldor equation and its application for use in several economic sectors, including agricultural activities, has already been implemented in other work, such as Martinho [28,29]. Indeed, the Verdoorn and Kaldor developments are increasingly relevant in the current global economic context and bring insight to both regional development [30–33], of labor contexts [34,35] and the relationship between manufacturing and economic development [36].

In relation to the convergence theory, we considered the approaches related to absolute (unconditional) and conditional convergence [37–43]. The idea behind absolute convergence is that all countries or regions tend to converge to the same steady-state of economic development (for example, gross domestic product per capita). In turn, the conditional convergence approach defends the notion that convergence is dependent on the condition/state of the countries or regions. In this case, countries with similar contexts (for example, similar capital human accumulation) can converge at the same steady-state, defending the existence of different steady-states and the concept of clubs of convergence, meaning groups of countries that converge to the same level of development. In general, the convergence trends in this theory are analyzed through determining the sigma convergence (measured through the coefficient of variationaverage standard deviation by the mean) and beta convergence (coefficient of regression, expected negative for convergence). In practice, the sigma convergence analyses, for a given variable, the tendency of convergence/divergence over a period of time and across the several municipalities (for the case presented in this study). If there is a decreasing/increasing trend, over the period considered, in the coefficient of variation there is convergence/divergence. The beta convergence reveals the annual rate of convergence. In this way, the convergence theory argues that the beta convergence (annual convergence) is necessary, but not sufficient to guarantee sigma convergence (convergence over the period). These concepts have several applications in current times [44]. The implementation of approaches related to convergence theory in the agroforestry sector has been performed in several studies, for example, in Martinho [45] and others [46,47].

4. Data Description

Figure 1 shows that after 2011, there was continual growth in the agricultural business output (averaged across the Portuguese municipalities) after a relatively stable trend from 2008. The average growth of the forestry business output reveals a decreasing trend until 2012 and a strong increase after 2013. It's important to stress that these values for the output from the Portuguese agroforestry sectors were deflated with the consumer prices index disaggregated at NUTS (Nomenclature of territorial units for statistics) 2 level (the finest disaggregation available). We used the consumer price index from unprocessed food to deflate the municipality agricultural output and the consumer price index without housing to deflate the municipality forestry output.

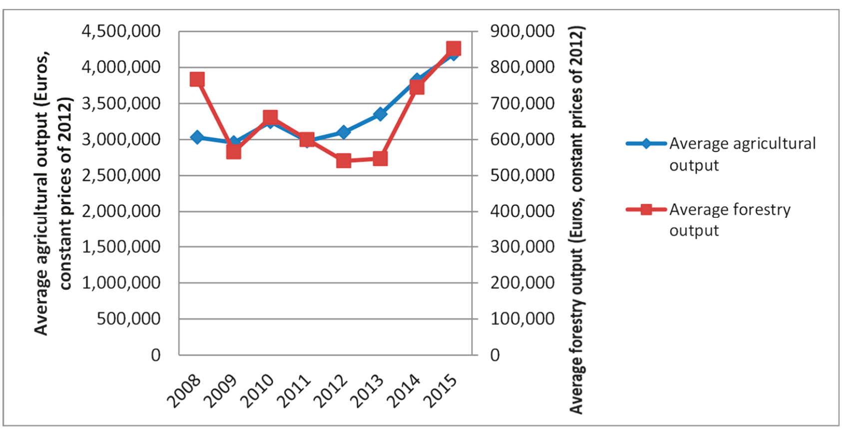


Figure 1. Average output for the agroforestry sectors across the Portuguese municipalities over the period 2008–2015.

Relative to agroforestry employment, Figure 2 shows that this variable increased strongly after 2012 following a stable tendency from 2008. It seems that the Portuguese economic crisis had a positive effect on the agroforestry municipal dynamics, both in terms of output and employment. In fact, the agroforestry sector in Portugal has a great potential for growth, however, due to several factors, some of which are historic, sometimes this sector is forgotten about along with its potential for a more sustainable social, economic and environmental development. The creation of a common forest policy in the European Union interconnected with common agricultural policy could potentially bring about more interesting contributions for agroforestry performance.

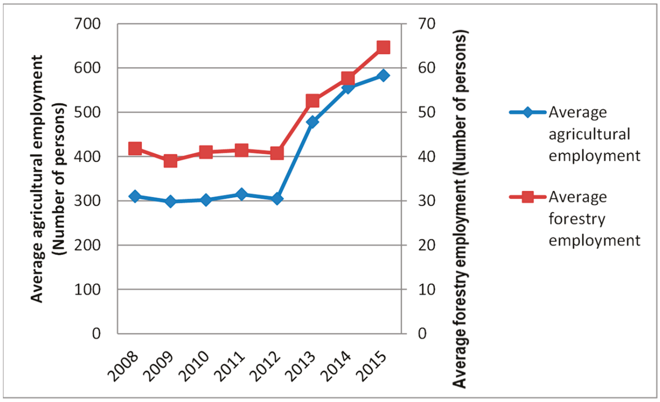


Figure 2. Average employment for the agroforestry sectors across the Portuguese municipalities over the period 2008–2015.

Figure 3 reveals that over the period 2008–2015, the years of 2010 and 2013 showed the greatest average burnt area. On the other hand, the years 2008 and 2014 showed the least severe average forest fire activity over the period in the Portuguese municipalities. As referred to before in the literature review, forest fire occurrences and severities have more of a time and spatial random distribution. This random behavior makes it more difficult to predict the forest fires' occurrences and consequences.

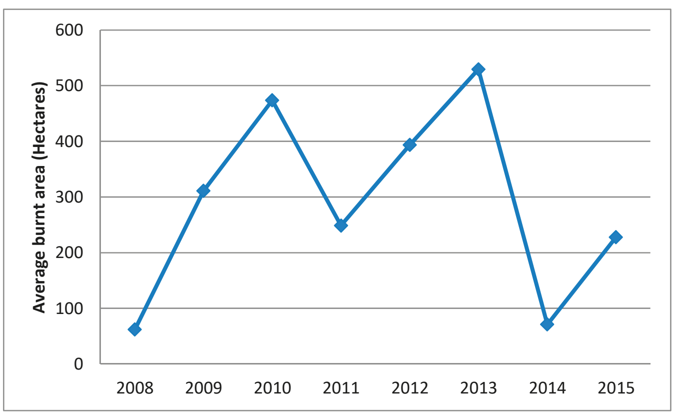


Figure 3. Average burnt area across the Portuguese municipalities over the period 2008–2015.

5. Results Obtained through the Keynesian Developments

The results presented in Table 1 which were obtained using the Kaldor equation through panel data methodologies for the agricultural sector, highlight the strong increasing returns to scale observed. In fact, the Kaldor coefficient (the coefficient for the output growth) is close to 0 (this could also be obtained by measuring the difference between 1 and the Verdoorn coefficient) which, as previously explained, is a sign of robust scale economies. On the other hand, this Table shows that the amount of burnt area may have had a favorable effect on employment growth within the agricultural sector. This is a curious result that needs further analysis in future research. In fact, it will be important to understand in future studies just how the burnt areas contribute towards increases in agricultural employment growth. In any case, some of the burnt areas may indeed be used for agricultural activities, thus improving the social contribution of the farming sector.

Table 1. Kaldor equation enlarged regression, for the agricultural sector, with the employment growth as a function of the output growth across the Portuguese municipalities.

	Period 2008–2015
Model	**Panels Corrected Standard Errors**
Constant	−0.147 * (−3.860) [0.000]
Output growth	0.038 * (3.330) [0.001]
Burnt area logarithm	0.069 * (5.520) [0.000]
Hausman test	1.990 [0.574]
Modified Wald test for group wise	Yes
Wooldridge test for autocorrelation	Yes

Note: * statistically significant at 1%.

The results from the forestry sector outlined in Table 2 reveal that although the economies of scale are slightly weaker in the forestry sector (coefficient around 0.041) than in the agricultural sector, they are, nevertheless, strong. In turn, this Table reports that, as expected, the burnt area has a negative impact on forestry employment growth (however, with a level of significance at 10%). Indeed, the main directly affected activities with forest fires are those related with the forestry sector. This reduction in forestry employment as a consequence of forest fires should be taken into account by the policymakers, namely because of the social and economic problems verified in the most affected areas (often located in rural and unfavorable Portuguese regions).

Table 2. Kaldor equation enlarged regression for the forestry sector, with the employment growth as a function of the output growth across the Portuguese municipalities.

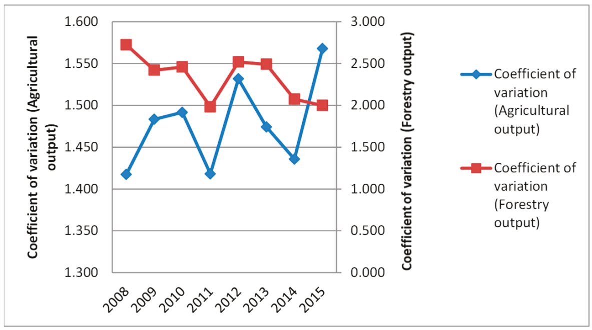
	Period 2008–2015
Model	**Robust Random Effects**
Constant	−0.033 (−0.920) [0.360]
Output growth	0.041 * (3.540) [0.000]
Burnt area logarithm	−0.015 ** (−1.910) [0.056]
Hausman test	2.230 [0.328]
Modified Wald test for group wise	Yes
Wooldridge test for autocorrelation	No

Note: * statistically significant at 1%; ** statistically significant at 10%.

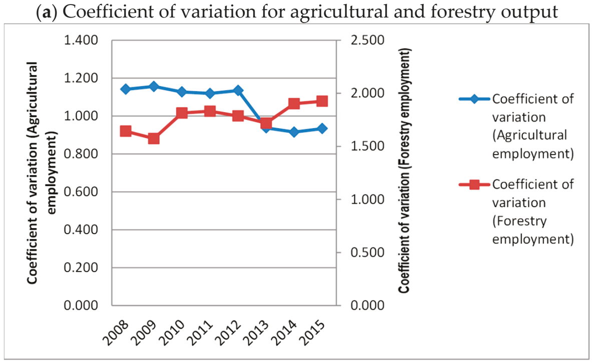
The strong increasing returns found for the agroforestry sectors are unexpected considering the Kaldor developments, however it is namely the way the agricultural sector has performed over recent years which has promoted an important increase in its dynamics and this explains in part these results obtained.

6. Results for the Absolute and Conditional Convergence

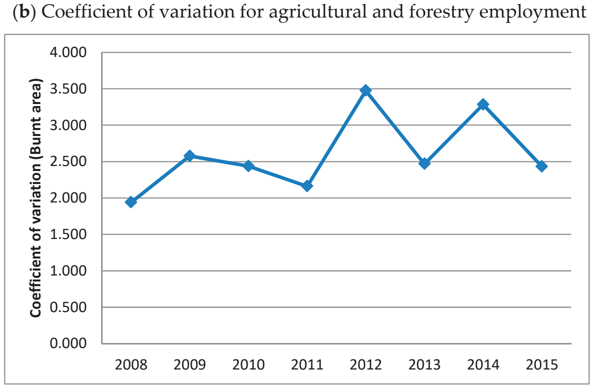
In regards to sigma convergence, Figure 4 shows that the agricultural output reveals a divergence tendency over the period considered and across the Portuguese municipalities, with signs of convergence in 2011, 2013, and 2014. This reveals that the agricultural output over the period taken into account agglomerated in some Portuguese municipalities. In turn, the forestry output shows a trend of convergence over 2008–2015, presenting that the output from forestry activities does not follow a trend of agglomeration in some municipalities (the spatial distribution is more homogeneous).



(**a**) Coefficient of variation for agricultural and forestry output



(**b**) Coefficient of variation for agricultural and forestry employment



(**c**) Coefficient of variation for burnt area

Figure 4. Sigma convergence across the Portuguese municipalities over the period 2008–2015.

Relative to agroforestry employment, the tendencies of divergence/convergence are the opposite of those verified for the output. Indeed, agricultural employment shows signs of convergence and forestry employment shows evidence of divergence. These trends for the agroforestry output and employment confirm the signs of increasing returns found before for the relationships between these two variables.

Finally, the burnt area, in general, shows signs of divergence over the examined period, showing that the impact of forest fires are concentrated in some municipalities, with the exception of some convergence in 2010, 2011, 2013, and 2015 (2008 and 2011 were the years with less burnt area, as shown in Figure 3).

In regards to beta convergence, the results for the coefficient of convergence are presented in Tables 3–7 for the agricultural (output and employment) and forestry (output and employment) sectors and for the burnt area. In each case (output, employment, and burnt area) we ran, only, one regression to analyze the conditional convergence. The results are not presented here for the absolute convergence, because the results for the coefficient of convergence are similar (to those presented for the conditional convergence) and to avoid presenting an exaggerated number of tables. For analyzing output and employment, we considered the burnt area (in logarithms or in growth) as a conditional variable. In our analysis of the burnt area, the conditional variable was forestry employment growth (to deeper analyze the relationships between forest fires and forestry dynamics).

Table 3. Conditional convergence regression for agricultural output with the logarithms difference as a function of the logarithm in the previous year, across the Portuguese municipalities.

	Period 2008–2015
Model	**Panels Corrected Standard Errors**
Constant	0.730 * (3.950) [0.000]
Output logarithm in the previous year	−0.048 * (−4.080) [0.000]
Burnt area logarithm	0.001 (0.300) [0.765]
Hausman test	430.420 * [0.000]
Modified Wald test for group wise	Yes
Wooldridge test for autocorrelation	Yes

Note: * statistically significant at 1%.

Table 4. Conditional convergence regression for agricultural employment with the logarithms difference as a function of the logarithm in the previous year across the Portuguese municipalities.

	Period 2008–2015
Model	**Panels Corrected Standard Errors**
Constant	0.310 * (5.670) [0.000]
Employment logarithm in the previous year	−0.052 * (−5.600) [0.000]
Burnt area logarithm	0.022 * (5.180) [0.000]
Hausman test	26.320 * [0.000]
Modified Wald test for group wise	Yes
Wooldridge test for autocorrelation	Yes

Note: * statistically significant at 1%.

Table 5. Conditional convergence regression for forestry output with the logarithms difference as a function of the logarithm in the previous year, across the Portuguese municipalities.

	Period 2008–2015
Model	**Panels Corrected Standard Errors**
Constant	1.599 * (5.920) [0.000]
Output logarithm in the previous year	−0.121 * (−6.020) [0.000]
Burnt area growth	−0.000 ** (−2.000) [0.046]
Hausman test	268.060 * [0.000]
Modified Wald test for group wise	Yes
Wooldridge test for autocorrelation	Yes

Note: * statistically significant at 1%; ** statistically significant at 5%.

Table 6. Conditional convergence regression for forestry employment with the logarithms difference as a function of the logarithm in the previous year, across the Portuguese municipalities.

	Period 2008–2015
Model	**Panels Corrected Standard Errors**
Constant	0.145 * (4.350) [0.000]
Employment logarithm in the previous year	−0.021 * (−2.930) [0.003]
Burnt area growth	−0.005 (−1.360) [0.173]
Hausman test	102.310 * [0.000]
Modified Wald test for group wise	Yes
Wooldridge test for autocorrelation	Yes

Note: * statistically significant at 1%.

Table 7. Conditional convergence regression for the burnt area with the logarithms difference as a function of the logarithm in the previous year, across the Portuguese municipalities.

	Period 2008–2015
Model	**Panels Corrected Standard Errors**
Constant	1.832 * (15.860) [0.000]
Burnt area logarithm in the previous year	−0.450 * (−16.530) [0.000]
Forestry employment growth	−0.348 * (−3.260) [0.001]
Hausman test	779.490 * [0.000]
Modified Wald test for group wise	Yes
Wooldridge test for autocorrelation	Yes

Note: * statistically significant at 1%.

Table 3 (representing conditional convergence for the agricultural output) shows that there are statistically significant and relevant signs of convergence (negative coefficient of regression and around 0.048). Comparing this result with that obtained before for the sigma convergence (Figure 4) it is noted that the beta convergence is not enough to have sigma convergence (the beta convergence is a necessary condition, but not sufficient, to have sigma convergence). The conditional variable (burnt area logarithm) is not statistically significant, revealing that the convergence seems to be absolute in this analysis.

Table 4 shows that the signs of convergence are stronger for agricultural employment (coefficient of regression negative and around 0.055) than those found for agricultural output, which are in line with the results found for the sigma convergence (Figure 4). The Table reveals that in this case, the convergence is conditional, and the burnt area logarithm has a positive impact on agricultural employment growth (confirming the results described earlier for the Keynesian analysis). In fact, these results confirm the findings obtained before for the Keynesian analysis, showing that the burnt area does not have any impact on the agricultural output, but improves agricultural employment.

The convergence analysis for the forestry output (Table 5) presents strong signs of convergence (around −0.121) and shows that the effect of the conditional variable (burnt area logarithm) is negligible and close to zero. These results reveal that, as with for agricultural output, the convergence for forestry output seems to be absolute (considering the negligible value for the coefficient of the burnt area). These stronger signs of convergence for the forestry output confirm the results obtained before for the sigma convergence.

The convergence indications for forestry employment (Table 6) are weaker than those found for the forestry output, which is in line with the results outlined in Figure 4, and the conditional variable is not statistically significant. It is worth stressing that the results obtained up to this point show that forest fires (through the burnt area) have little impact on the performance and dynamics of the Portuguese agroforestry sectors, considering the results obtained for the burnt area coefficient in the several estimations. The only evident and statistically significant impact from the burnt area is a positive effect on agricultural employment.

Table 7 shows that there are strong signs of convergence for the burnt area across the Portuguese municipalities, however they are not enough to have sigma convergence (Figure 4). On the other hand, the convergence in the burnt area is conditional toward forestry employment growth, showing that the burnt area growth is negatively influenced by employment growth from the forestry sector. This seems to indicate that bringing more people to forest areas may be an interesting solution in reducing the severity of forest fires. This is an important finding that should be considered by the several stakeholders, namely by the national authorities. It is important to bring new activities for the agroforestry sector and here the policies related with innovation and entrepreneurship may provide an important contribution.

7. Discussions

The objective of this study was to analyze the socioeconomic implications of forest fires in the Portuguese municipalities' agroforestry business sectors over the period 2008–2015, by considering data from Statistics Portugal for output, employment, and burnt area. The statistical information was analyzed with panel data methodologies, namely those derived from Keynesian and convergence theories.

The data analysis shows that, in general, after 2011/2012, output and employment increased on average at a persistent trend in the agroforestry sectors of the Portuguese municipalities. The Portuguese economic crisis has also borne its influence here. In fact, some of the unemployment generated in other sectors, namely in the industry and construction, found solutions within the agroforestry sectors [48]. On the other hand, over the period we considered, the trend for the average burnt area is essentially white noise, demonstrating neither an increasing or decreasing trend and showing the great irregularity in the impact of forest fires in the Portuguese context. The forest fires are agents of landscape disturbances with a great degree of unpredictability [15].

The Keynesian analysis, using the Verdoorn–Kaldor developments, reveals that there are strong increasing returns in the Portuguese agroforestry sectors, which are higher in the agricultural sector. These findings are in line with other works [32]. On the other hand, considering the enlarged Kaldor equation, the burnt area logarithm positively influences employment growth in the agricultural sector and negatively influences the forestry sector. Forest fires seem to have a positive impact on the number of people employed in the Portuguese agricultural sector. The modernization of the agricultural sector seen in recent years seems to have had a positive impact on the dynamics and performance of the sector, creating the right circumstances to absorb the workforce released by other diminishing sectors [48].

The convergence research, considering both the absolute and conditional approaches, was performed using the sigma and beta convergence concepts, following, for example, He et al. [46] and Spirkova et al. [47]. The sigma convergence shows signs of a convergence trend for forestry output and agricultural employment. The beta convergence analysis (coefficient of regression) shows that the convergence is more absolute than conditional, with the exception of agricultural employment convergence where, again, the burnt area logarithm (conditional variable) positively influences agricultural employment growth. On the other hand, burnt area growth is negatively influenced by forestry employment growth, showing the importance of increased forestry activities in forest fire prevention.

Additionally, it is worth noting the strong trends of agglomeration (strong increasing returns to scale from the Keynesian analysis) in the agricultural and forestry sectors over the period considered and across the Portuguese municipalities, showing that the Portuguese agroforestry activities became more concentrated in some municipalities in this period [49]. On the other hand, there are signs of beta convergence (not as strong as the evidence of agglomeration) that are not enough to guarantee sigma convergence. In practice it seems that there are strong signs of divergence in the output and employment from the Portuguese agroforestry sectors, as well as in the burnt area. This may be a consequence of land abandonment and of desertification of the interior of Portugal [10].

The study presented here brings interesting insights into the understanding of forest fires, for policymakers and the perceptions of several stakeholders. It is important to bring new and multidisciplinary approaches for the forest fires contexts around the world, namely to improve regional resilience. For this it is important to increase economic dynamics in the rural area in a sustainable way, and to create more employment to attract younger people.

8. Conclusions and Political Implications

As a final remark, one should highlight that the impact of forest fires (burnt area) on the Portuguese agroforestry dynamics and performance seems too moderate. In fact, forest fires seem to improve agricultural employment with coefficients of around 0.069 (from the Keynesian approach) and 0.022 (form the convergence theory). On the other hand, forest fires show some evidence of reducing forestry employment, presenting a coefficient of −0.015 (from the Keynesian theory), though with a statistical significance at 10%. The impact on agroforestry output seems to be residual or negligible.

In terms of political implications, it is important to bring about more activities for the forestry sector in order to reduce the risk of forest fires and to improve the dynamics of this sector (the results show lower scale economies relative to the agricultural sector). On the other hand, it will be important to continue agricultural modernization and its performance to better absorb the labor force released by other sectors. The creation of a common forest policy interconnected with a common agricultural policy, incorporating innovation and entrepreneurship strategies could be an interesting approach. To avoid desertification and land abandonment there should be a priority in the design of new policies. Considering the dimensions of the consequences of forest fires, the related policies must reconsider the relevance given to the socioeconomic impact on the agroforestry sector, where the negative impacts seem to be residual. In any case, the Portuguese agroforestry sector does have several problems, however, they are not a direct consequence of forest fires.

These insights open up new fields of research. In this way, for future studies, it will be important to understand the main factors which create the conditions for forest fires to inadvertently promote agricultural employment. Migration of the workforce from forestry to agriculture may provide an explanation. On the other hand, it will be interesting to further investigate the strong impact of the burnt area on agricultural employment, rather than agricultural output. Considering the negative socioeconomic implications of forest fires evidenced by the literature [11,12], it will also be important to identify the main factors that allow for negative impacts in the agroforestry sector from the Portuguese municipalities to be weak.

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Strategic Cross-Border Water Pollution in Songliao Basin

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Abstract: This paper studies the two-fold impacts of environment regulation related to local officer promotion and water quality assessment of cross-border sections within the framework of the 11th Five-Year Plan. We employ the difference-in-difference (DID) and difference-in-difference-in-difference (DDD) models to a unique dataset on water polluting activities in Songliao Basin counties from 2003 to 2009. Empirical results show that on one hand, regulation and water pollution are negatively correlated, the stricter the regulation is, the less water pollution happens. On the other hand, as no explicit accountability and synergetic governance system were set up by the 11th Five-Year Plan, prefecture-level municipal governments tend to exert the least enforcement efforts in the most downstream counties. We find the evidence of strategic water polluting that the overall output value, new entry into and old business water polluting industries are significantly higher in the most downstream county of a prefecture-level city, relative to other similar counties.

Keywords: cross-border water pollution; Songliao Basin; strategic allocating; the 11th Five Year Plan

1. Introduction

Cross-border water pollution refers to the pollution transferred from upstream to downstream jurisdictions by water flow. Such pollution has strong negative externality as shown by the phenomenon "one point polluted, the whole drainage basin affected" [1]. Due to the Songhua River and Liao River systems, Northeast China suffers from severe cross-border water pollution. The Liaohe River basin is highly industrialized. The industrial structure is composed of processing of agricultural products and byproducts, papermaking, fuel manufacturing, pharmaceutical manufacturing, and nonferrous metal smelting and rolling, all of which contribute to 81.6% of the total COD emissions [2]. In 2005, an explosion in a benzene factory of Jilin Petrochemical Corporation severely polluted the downstream cities of Songhua River including Changchun and Harbin [3]. The central government was shocked by the explosion event, which then explicitly addressed the water pollution challenge by specifying in the 11th Five-Year (2006–2010) Plan quantitative emission reduction targets for chemical oxygen demand (COD). More polluted regions were subject to higher COD reduction targets. The government also set up a monitoring system on cross-border river quality and linked local officials' promotion with these targets for the first time [4–6]. Local officials who failed to the pollution reduction mandates would be removed from office.

Songhua River and Liaohe River both belong to the Northeast geographical unit. They have similar natural characteristics and economic situation which play various important roles in transportation, tourism, irrigation, and so on. The most important is that they are the main source of drinking water for Northeast China. As the main agriculture drainage basin in China, the two rivers both run through major coal, steel, petrochemical, and equipment manufacturing industry hubs [1,2,7,8]. Compared with the other five major rivers in China, rivers in the Northeast have significant inherent characteristics:

freezing of the water surface in winter and a long dry season and having many tributaries (both big and small) with small water flow. As a result, both rivers have poor self-purification capacity and are more vulnerable to border pollution. As of 2017, the central government set up 33 water quality monitoring stations along prefecture borders in Songhua River and Liaohe River to solve the cross-border water pollution problems in Northeast China. The data from these stations show that the water quality of Songliao Basin has had little improvement in recent years.

On the other hand, the pollution prevention and treatment monitoring system in China is relatively decentralized. The central Bureau of Environmental Protection (BEP) formulates the overall environmental goals and monitors enforcement activities of local BEPs. All regional level (province, prefecture, and county) BEPs formulate local environmental regulations as well as monitor the permit systems which require that all industrial projects obtain approval from the local BEPs before production to ensure that new projects meet the basic environmental standards. Regional works are governed by superior environmental authorities while they administratively belong to the government at the same level and are also subject to the strategic development goal of the local government. Disparities between the economic development and the environmental goals of local government have always led to the lax regulatory and in a lower standard of monitoring and enforcement duties to support a "pollution-friendly" investment and business environment [9,10]. Though the cross-border river cross-section assessment system is listed in the 11th Five-year Plan, no explicit accountability or synergetic governance system was set up. Under the pressure from the central government to curb water pollution, growth-driven local governments responded by optimally allocating enforcement efforts among their counties: given geographical differences and the externalities inherent in water pollution, the local government cannot reap the full benefits of pollution reduction in the downstream area of their jurisdiction. Meanwhile, the central government gives the local government considerable power over the enforcement of environmental regulations. Therefore, local government tends to ignore the monitoring of the most downstream counties.

Based on previous studies and current scenario in China, this paper infers that the impact of the 11th Five-year Plan's environmental policies amendment on Northeast China has been two-fold: on one hand, local officers try to control pollution in their regions and lower risks for such promotion, on the other hand, the system structure, especially the non-cooperative mechanism and monitoring technology, drives prefecture-level municipal governments to have much laxer environmental regulations in the most downstream county (district) which attracts more water polluting activities. By transferring negative externalities (pollution) to adjacent downstream regions, the local government can meet both the economic development goals and reduction requirements mandated by the central government.

This paper provides a scientific basis for decision-making on industrial water pollution control in Northeast China and breaks the assessment mechanism of "bottom line competition" in prefecture-level cities, to achieve the goal of sustainable development.

2. Literature Review

Many studies have analyzed the cross-border water pollution situation after decentralization of authority between the central and local governments from a theoretical perspective. They have concluded that conflicts between interest groups affect the synergy and governance efficiency, resulting in the discharge reduction goal remaining unfulfilled [11–13]. H Sigman used water pollution data from 500 monitoring stations to explore the evidence, which indicated the fact that in the United States, decentralized environment governance in various states caused the spillover of cross-border river pollution, based on which he consequently drew the conclusion that the United States' environment governance decentralization is cost-effective [1,14]. Zeng Wenhui set up an "equalized pollution" model to analyze the motivation of "hitchhiking" activities in upstream regions; this model revealed that the geographic location of provinces has a strong impact on environmental regulations [15]. ME Kahn used data from the main monitoring stations of seven major rivers during 2004 to 2009 and found that after the 11th Five-year Plan linked officer promotion opportunities with water pollution indexes, the COD content reduced faster in provincial boundary stations than in other inland stations; while there is no significant improvement in other sources of water pollution alongside the boundaries [6]. Hu Zhenyun set up a game model on government and enterprise water pollution treatment and found that as the central government calls for ecological civil engineering development, the environmental performance of local government improves and overall corporate emissions are reduced [16]. Jie He [17] assessed payment willingness for cross-border water pollution treatment of 20 cities in Xijiang River Basin; the result showed that upstream regions are relatively unwilling to pay for pollution costs while the willingness of the downstream to pay costs negatively correlates with the upstream pollution levels.

As far as regional socioeconomic development and water pollution problems concerned, the spatial awareness of the government with respect to its strategic decision-making is extremely important. Molly Lipscomb used visual functions of ArcGIS to collect lighting data of river monitoring stations and found that water polluting enterprises, guided by local government strategies, moved to upstream places of the rivers [18]. Zhang Shanshan [19], using the kernel density estimation to study the spatial characteristics of enterprise movement in the Taihu Basin, found that after the establishment of local water environmental regulations, many enterprises moved from upstream to the outskirts or even to places far from rivers and lakes. Zhao Guohao [20] set up a Spatial Autoregressive Model based on data of 285 prefecture-level cities during the period of 2003 to 2015 and concluded that implementation effects vary in different regions; the "bottom competition" was driven by eastern regional governments pushing polluting enterprises to move towards the central and western regions. Haoyi Wu used the Logit Model to study the impact of the 11th Five-year Plan environment policy on new water polluting enterprises, the result of the study showed that the environmental incentive mechanism lacks reasonability as it pushes new polluting enterprises to select sites in central and western regions—the "polluting paradise"—rather than the eastern or coastal regions, and such actions would deteriorate national water pollution throughout the downstream as water sources of the Yangtze River and Yellow River are both located in the western regions [21]. Shi Minjun set up a spatial estimation methodology to calculate COD emission per province per industry and found that during the 11th Five-year Plan period, the development of papermaking and paper products industry in the western regions contributed the most to pollution reduction, while those in central regions contributed the least [22]. Zhao Chen utilized the Distance Distribution Dynamics model to study spatial changes of enterprise activity caused by the environment regulation, and the spatial difference between the upstream and downstream of Yangtze River Basin after the 11th Five-year Plan and found evidence of the industrial transfer in China [23]. Hongbin Cai studied 24 rivers in China and found that after the decentralization due to the 11th Five-year Plan, local environments relaxed their regulations on the most downstream regions, to transfer negative externality caused by pollution, thereby making water polluting activities in such places more frequent [24].

From the above, scholars tend to focus on the following aspects of cross-border water pollution problems.

(1) The process of negotiation and mutual restraint amongst intra-authoritative entities (include central government, local governments, environmental departments, and so on) after decentralization had dramatically reduced the management efficiency in upstream regions. Studies rely on theoretical studies or quantitative research of enterprises and government spatial strategies from a visual perspective, and mostly lack empirical literature.

(2) Some of the existing literature focuses on the four major economic zones, while others focus on the provincial scale or traditional upstream and downstream perspectives. However, most of them ignore the importance of smaller scale, especially the upstream/downstream counties at prefecture-level borders. (a) A study at such a large scale ignores details of many economic activities and makes the results biased. (b) Regions alongside the provincial boundary are rarely economic hubs, due to their small economic volume and low pollution scales, and thus such places could not

represent the holistic water pollution scenario. (c) China's "Key Points of Regional Planning" stipulates that all administrative entities above county level shall be responsible for the real-time water quality monitoring. The prefecture government entities are directly accountable for their corresponding watershed pollution. Administration department of county level of at higher levels shall be responsible for the dynamic monitoring of water sources. The prefecture is the basic administrative unit for water pollution accountability; as such, counties (districts) in conjunction with prefecture-level city borders are the best research objects for this purpose.

(3) Most scholars use monitoring station cross-section data as water pollution indexes, however, this data reflects the aggregation of both local and upstream pollution, which will not provide accurate description for local water pollution. Moreover, monitoring stations were randomly located, and do not cover all the administrative borders in northeast China.

(4) After the 11th Five-year Plan, the central government strategically re-allocated polluting enterprises to achieve the goals of economic growth and environment protection by enforcing stronger pollution control policy. Accordingly, enterprises reacted to the regulations as well. While research the strategic allocation of enterprises based on governmental policies, previous study did not verify the relationship between the intensity of environmental regulation and water polluting enterprise activities.

This paper is however based on the concept of cross-border water pollution. Using water polluting enterprise activities as a substitute for monitoring data, we employ an optimal assessment model to systematically analyze the allocating of pollution activities between counties by prefecture-level governments within the framework of the 11th Five-Year Plan.

First, we focus on the cross-border water pollution at the prefecture-level basis, rather than the economic zone or traditional upstream/downstream (divided by a point in the drainage basin) basis.

Second, we take microenterprises production activities (total industrial output value and quantity of new/old enterprises) as substitute variables for water pollution indexes to determine the point sources for local pollution.

Third, we first verify the relationship of regulation and water polluting activities in the context of the different environment policies stipulated by the 11th Five-year Plan, and then, study the spatial differences of regulation in conjunction with the river, to further assess the government strategy allocating water polluting enterprises.

Fourth, we not only focus on water pollution activities of counties on the borders, but also take into account water polluting activities of nonborder riverside counties to achieve a more realistic outcome.

3. Materials and Methods

3.1. Sample Introduction

We expect to see rising levels of water pollution in the most downstream county of a prefecture-level city, as a result of the prefecture-level municipal governments' mandates, since the rivers flows through the city and there are multiple districts (the same administrative level to counties) in a city. Thus, this research refers to the samples from districts and counties as being the same, and considers them as county samples. To illustrate our empirical strategy, we design the Figure 1. As non-riverside regions are not directly affected by river pollution, we only focus on type-A, type-B, and type-I counties along the rivers.

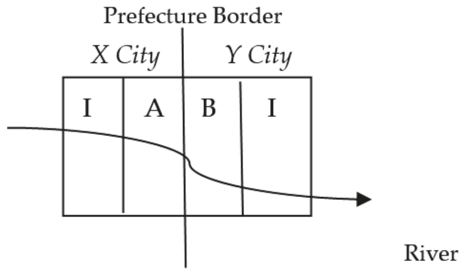

Figure 1. Heuristic map of counties at the prefecture border. Caption: Suppose a river in Songliao Basin flows from west to the east, crossing A, B, and I riverside counties. A is the most downstream county in an upstream city *X*, B is the most upstream county in a downstream city *Y*, and I is the inner riverside county. Counties A and B are neighbor counties separated by the prefecture border. We call the two counties A and B a county group. Unlike counties A and B, riverside county I is not located at the borders. Counties will be divided into "types" according to their relative locations against prefecture borders. The actual county distribution is shown in Figure 2. We call the three types of counties type-A, type-B, and type-I counties.

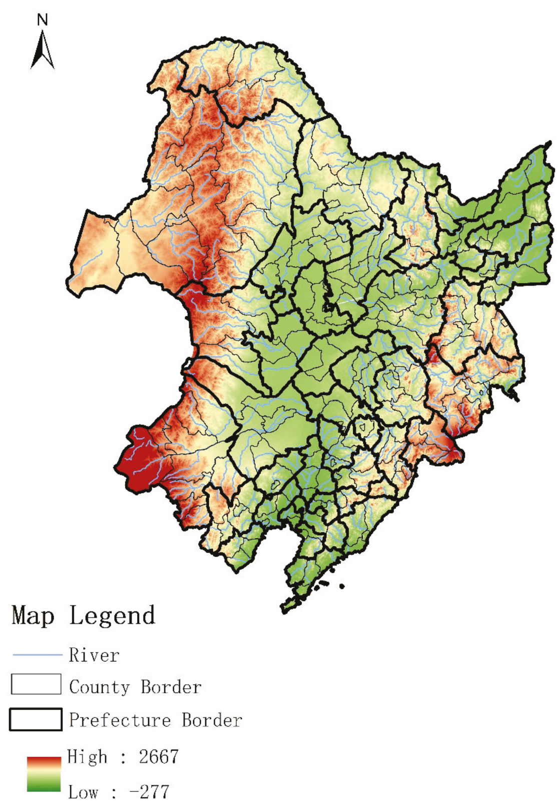

Figure 2. The relative position of each county in the Songliao Basin. Notes: Due to limited space, we have listed the details (list of the type-A, type-B, and type-I counties) in the Supplementary Materials, to be viewed by interested readers.

3.2. Empirical Design

The main purpose of the empirical analysis is to identify the effect of environmental policy on local industrial production activities. Therefore, we can verify the relationship of regulation and water polluting activities in the context of the different environment policies stipulated by the 11th Five-year Plan. Then, by comparing differences of industrial production activities in type-A, type-B, and type-I counties, we can identify the cross-border pollution brought by spatial strategy of prefecture-level municipal government.

According our empirical design, Hypothesis 1 verifies the relationship of regulation intensity and water polluting activities (overall output value is the proxy variable). The expected results are negatively correlated. In Hypothesis 2, we empirically test that type-A county has the most water pollution activities. Therefore, the environmental regulation of type-A county is more relaxed than type-B and type-I counties. By the above argument we find the evidence of strategic pollution by prefecture municipal government (see DID analysis).

In the DDD analysis section, first we compare the effects of environmental regulations in seven water pollution industries. Then we empirically examine the changes in the number of new and old enterprises in type-A, type-B, and type-I counties. This will provide evidence that the prefecture-level municipal governments strategically reduce the enforcement of environmental protection in their administrative region.

3.2.1. Differences-in-Differences Method (DID) Model Setting

To observe impact brought about by the 11th Five-year Plan water pollution regulation, this paper uses a globally universal policy assessment method: Differences-in-Differences Method (DID) [25–27]. Its basic thought is to simulate natural experiment, divide observing objects into a control group (not affected by policies) and treatment group (affected by policies), and then compare changes of the two groups before and after the implementation of policies to assess their real policy effects. If changes of the treatment group are significantly greater than those in the control group, it indicates that the policy effect is remarkable; otherwise the policy effect is unremarkable.

Before 2006, the central government documents did not provide for the linking of pollution reduction targets with the officer promotion incentive system. In August of the same year, the BEP and the National Development and Reform Commission announced an overall control plan for COD during the period of the 11th Five-year Plan (2006–2010), correlating government officer assessment and promotion with the environmental protection target [28–30]. We posit that water pollution activities in locations with stringent regulations would decrease more than in locations with relatively lax regulations after 2006. However, before 2006, regulation stringency was almost uniform across counties. This is a standard DID exercise, where the production activities of water-polluting enterprises before 2006 are the control group.

Hypothesis 1. Regulation strength is inversely correlated to water polluting activities.

The DID basic econometric model is presented as follows

$$\begin{aligned} y_{ct} = \varphi R_c \times Post_t + \beta_{04} Year_{2004} + \beta_{05} Year_{2005} + \beta_{06} Year_{2006} + \beta_{07} Year_{2007} + \beta_{08} Year_{2008} \\ + \beta_{09} Year_{2009} + \alpha_c + \delta_t + \varepsilon_{ct} \end{aligned} \quad (1)$$

y_{ct} indicates the production activities of water polluting industries in county c during the year t; R_c refers to regulation strength of county c, indicating the implementation of environmental polices of different counties after the 11th Five-year Plan; and $Post_t$ is the visual variable of treatment period, for $\forall_t \geq 2006$, $Post_t = 1$, otherwise $Post_t = 0$. $R_c \times Post_t$ is the interaction term of policy regulation and time visual variable, coefficient φ (differences-in-differences estimator) measures the effect of policy which can show the regulation effects; a negative φ value indicates that government regulation strength is inversely correlated to enterprise activities, while a positive φ value indicates otherwise. α_c and δ_t are essential fixed constituent parts of model setting, the former represents the fixed effect of counties, capturing time-invariant characteristics (such as weather, geographic features, natural resources, etc.), belonging to region c; the latter represents the annul fixed effect, capturing annul factors that have the same impact on all counties (such as macroeconomic fluctuation, business cycle, financial & monetary policies, etc.); and ε_{ct} is the random error term.

$Year_{it}(t \in [2004, 2009])$ is the annul dummy variable; for given years its value is set as 1, otherwise $Year_{it} = 0$. $\beta_{04} \sim \beta_{09}$ are its corresponding coefficients to observe water polluting production activity fluctuation over time; a positive value of these coefficients indicates growing industrial activities in that year, while a negative value indicates otherwise; the 11th Five-year Plan came into force in 2006; limited by the data availability, samples are chosen from 2003 to 2009. Taking the year 2003 as base period to analyze water polluting activity trend during 2004 to 2009; ε_{ct} represents error items that could hardly be observed by measurement methods.

By comparing differences of water polluting activities (output value, numbers of new and old enterprises) in different locations of a river, we can find the evidence of the downstream effect. As shown in Figure 3, after 2006, compared to the other two type counties (B and I), the output value of water polluting industries grew faster in type-A counties. The statistical results provide an opportunity for implementing a difference-in-difference (DID) strategy. Specifically, water polluting industries in type-A counties are treatment groups, while water polluting production activity in type-B and type-I counties are control groups.

From this, we propose Hypothesis 2:

Hypothesis 2. Within the entire Songliao basin, the type-A county is the most laxly regulated region which attracts more water polluting activities.

The DID basic model is presented as follows

$$y_{ct} = \varphi Type_c \times Post_t + \beta_{04} Year_{2004} + \beta_{05} Year_{2005} + \beta_{06} Year_{2006} + \beta_{07} Year_{2007} + \beta_{08} Year_{2008} + \beta_{09} Year_{2009} + \alpha_c + \delta_t + \varepsilon_{ct} \quad (2)$$

$Type_c$ is the county type. It is set as 1 if county c is the type-A county, $Post_t$ represents visual variable before and after the treatment, for $\forall t \geq 2006$, $Post_t = 1$, otherwise $Post_t = 0$. Only after 2006, the value of type-A counties interaction term $Type_c \times Post_t$ is set as 1. Positive value of factor φ indicates that after 2006, compared to type-I and type-B counties, water polluting activities in type-A counties grew faster; negative value of factor φ indicates the opposite; $\alpha_c, \delta_t, \varepsilon_{ct}$ and dependent variable y_{ct} have the same meaning as the above.

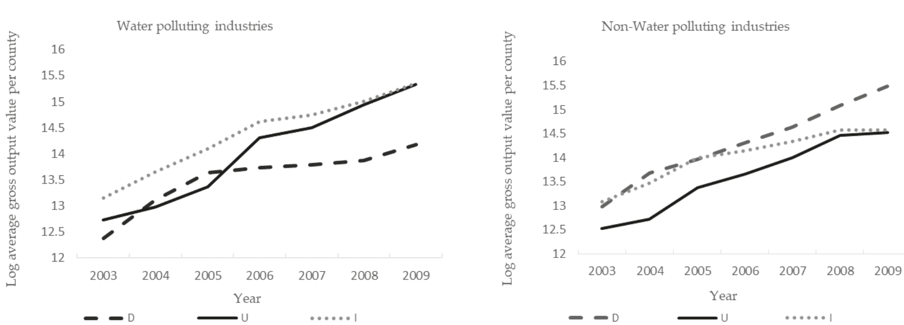

Figure 3. The spatial distribution of water-polluting and nonwater-polluting industries output value in Songliao Basin.

3.2.2. DDD (Differences-in-Differences-in-Differences) Model Setting

The problem of DID estimation method may correlate some time-varying county characteristics with $R_c \times Post_t$ and bias the estimation of φ. County factors including aggregation effect, input–output of transaction parties in a vertical industrial chain, and labor market efficiency, might change with time and cause deviation in the φ value; hence, it is hard for models (1) and (2) to cover all the influence factors.

To overcome this problem, factors listed below should be taken into consideration: there is regulation effect on heterogeneity between water polluting and nonwater polluting industries, taking the latter as control group and the former as treatment group to set up the DDD estimation model:

$$y_{ict} = \phi R_c \times Post_t \times Dirty_i + R_c \times Post_t + Dirty_i \times Post_t + Dirty_i \times R_c + e_{ict} \quad (3)$$

We construct a balanced panel data set; each observation represents the situation in a two-digit industry in a county in a year. y_{ict} represents the production activities of i industry in c county in the year t; $Dirty_i$ indicates the industry nature, if industry i is water polluting, $Dirty_i = 1$, otherwise $Dirty_i = 0$. The major advantage of the DDD model is that it allows us to include the county-year fixed effect $R_c \times Post_t$ which not only controls time-varying and time-invariant county characteristics (such as producing technology spillover, local public policies, labor quality, etc.) that could not be controlled by the DID model. Moreover, the DDD model also covers industry-year fixed effects $Dirty_i \times Post_t$ that capture all time-varying and time-invariant industrial characteristics, such as specific industrial technologies and government industrial policies. Furthermore, we include industry–county fixed effect $Dirty_i \times R_c$ to allow production activities to differ across counties. e_{ict} represents error items that are hard to observe or measure by econometric method, error items of different periods in the same industry (county) may be serially correlated, and such potential spatial and time serial correlation should be controlled by using county and industrial two-way robust standard errors. In DDD model (3), by controlling factors that may affect policy effects, biased estimation of φ caused by factors other than policies (namely the industry changing over time and the industry changing over counties, which are time-related) is avoided, to get the most accurate ϕ value representing the policy effect. The focus of our DDD analysis is the triple interaction term $R_c \times Post_t \times Dirty_i$, so ϕ is the parameter of primary interest to us which measures the pure effect of policy. A negative value of ϕ indicates that the 11th Five-year Plan water polluting regulations are inversely correlated with water polluting industrial production activities—the stricter the regulation is, the faster the production activities diminished. On the contrary, a positive value of ϕ indicates that the 11th Five-year Plan water polluting regulations are positively correlated with water polluting industrial production activities—the stricter the regulations are, the faster the production activities grow.

3.3. Variable Selection and Data Sources

We focus on the main streams and tributaries of Songhua River and Liao River in northeast China, each of which cross at least one prefecture-level city border. In the Songliao Basin, we first identify 168 riverside counties (such as counties A and B) located at prefecture-level city borders. Then we identify 49 riverside counties (such as counties I) that are not located at prefecture borders. Our final sample has 217 counties in total, of which there are 84 type-A counties, 84 type-B counties, and 49 type-I counties. While the 11th Five-year Plan came into force in 2006, we construct a sample with data ranging from 2003 to 2008.

3.3.1. Water Pollution Regulation Index

Water polluting regulation is always multidimensional and complex [31,32]; environmental departments of various regional (province, prefecture, and county) level governments are responsible for formulating and implementing local environmental regulations. Generally, they use preproject license and postproject punishment as managerial measures. License system stipulates that all industrial projects must get permission before production begins from local environmental authorities, to ensure that the new projects conform to applicable standards. Postproject punishments include warnings, revoking of business licenses, lawsuits, etc. Many scholars use postproject measures, which when compared with preproject ones directly aim at pollution, with easy to acquire postproject data; yet enterprises may react fiercely against such punishments with some under the table counter-measure, which constantly and dramatically reduce the punishment efforts.

a. The County-Level COD Reduction Mandate

Generally speaking, the environmental regulations are stricter in developed regions where polluting industries play important roles. In the 11th Five-year Plan, the central government's water pollution criteria only targeted COD emissions. Therefore, this paper only considers the COD index. According to realistic experiences and research demands, we adapt COD emission reduction target distribution formula by China SEPA in 2006 to estimate the pre-operational water pollution regulation stringency of each county.

Original formula: $COD_{c,05-10} = COD_{p,05-10} \times \frac{P_{c,2005}}{\sum_{j=1}^{J} P_{j,2005}}$

Bringing in economy proportions and industrial structure factors of the counties:

$$COD_{c,05-10} = COD_{p,05-10} \times \sum_{i=1}^{39} \mu_i \frac{y_{ic}}{y_{ip}} \tag{4}$$

$COD_{p,05-10}$ emission reduction target data of the provinces are from China SEPA: Using the study results of Wu Haoyi for reference, μ_i is the weight which represents each industry's proportion of total industrial COD emission[21]; y_{ic} and y_{ip} represent output value of enterprises from i industry in various riverside counties and such value from i industry in each province p, respectively, and this data comes from China Industry Business Performance Data.

b. The Environment-Related Text Proportion of Each County's Government Report

Measures of water polluting substances include COD, as well as levels of permanganate, ammonia, nitrogen, etc. Environmental efforts of local governments are not confined to just COD reduction, as a consequence. We developed an alternative stringency measure based on each county's government report to measure the government's desire to reduce pollution. Under pressure from superior government and local citizens, regional governments have to talk about environment issues in the annual work report. The government work report has an important role in local government documents; it covers accomplishments and problems regarding aspects including economic development, living standards of residents, import and export, environment protection, etc., of the previous year; it also involves setting up detailed goals for the next year. As government work reports are based on accurate statistical data and could reflect local work focus, thus the textual proportion regarding specific policies are usually taken to measure regional officers' efforts on expected goals [33]. This document takes the proportion of environment-related text (including environment, power consumption, emission reduction, environment protection, ecology, pollution discharge, etc.) in regional government work reports as the substitute variable for environment regulation. Government work reports from 2003 to 2009 were taken from the Internet with only 132 counties (districts) available, of which 62 are type-A counties, 46 are type-B counties, and are 24 type-I counties.

3.3.2. Enterprise Production Activity Indexes

We take overall output value and the numbers of new and old enterprises of water polluting and nonwater polluting enterprises in 2003–2009 as proxy variables for enterprise activities. According to the "Classifying Standard of Water Polluting Industries" announced by the Ministry of Environmental Protection in 2010, the seven polluting industries are agricultural product and byproduct processing, textile manufacturing, clothing manufacturing, papermaking, petrochemical fuel manufacturing, chemical engineering, and nonferrous metal smelting; other industries are all classified as nonwater polluting ones [34,35]. The data comes from China Industry Business Performance Database which discloses basic information—such as assets and liabilities, industrial product revenue, operating status, and so on—of enterprises above designated size. We take advantage of microenterprise-level as well as industry-level data to give microdata support to study polluting enterprise activities in Northeast China (four provinces and regions) and to find polluting point sources [36].

The descriptive statistics of aforesaid variables is shown in Table 1.

Table 1. Variable selection and descriptive statistics.

Variable	Max	Min	Mean	S.D.
Polluting enterprise industrial output value (in RMB 1000)	109,255,517	48,101	8,378,143	33,812,897
Nonpolluting enterprise industrial output value (in RMB 1000)	117,367,556	12,011	10,824,156	50,305,103
Number of new polluting enterprises	52	0	5.603	9.35
Number of old polluting enterprises	32	0	4.115	6.893
$COD_{c,05-10}$	1.622	0.0002	0.276	0.55
Environment protection related text proportion ($Avg.Text\%$)	5.452	1.115	3.309	1.208

4. Results and Discussion

4.1. DID

4.1.1. Identifying the Relationship between Regulation and Polluting Activities (Assumption 1)

By observing the regression results of DID in Table 2, the results indicate that when taking all samples as a whole—the estimated results in columns (1) and (2)—the coefficients of interaction items are all negative and significant, indicating that intensity of regulation is negatively correlated with water polluting enterprise activities. Water pollution activities in locations with stringent regulations decrease more than in locations with relatively lax regulations. Thus, the empirical results accord with the anticipated values and indicate the pollution reduction effects of the environmental policies of the 11th Five-year Plan. All annual dummy variable coefficients are positive and continuously growing, demonstrating that water polluting activities in Songliao basin are growing and expanding annually.

Table 2. Impact of pollution regulations on regional industrial activities (difference-in-difference (DID) method).

The Dependent Variable: Log (Total Output Value in Each Industry in Each Region in Each Year)				
	Water Polluting Industries			Non Water Polluting Industries
	(1)	(2)	(3)	(4)
$COD * Post_{2006}$	−0.827 *** (−20.77)			
$Avg.Text * Post_{2006}$		−1.736 *** (−4.07)		
$Upstream * Post_{2006}$			1.910 *** (14.739)	0.385 (0.632)
$Year_{2004}$	0.050 (0.012)	0.022 (0.25)	0.319 * (1.787)	0.062 (1.40)
$Year_{2005}$	1.162 *** (3.086)	0.683 * (1.671)	0.547 ** (2.08)	1.319 ** (2.249)
$Year_{2006}$	3.821 *** (16.613)	0.991 ** (2.32)	1.847 *** (5.142)	0.764 (0.716)

Table 2. *Cont.*

The Dependent Variable: Log (Total Output Value in Each Industry in Each Region in Each Year)				
	Water Polluting Industries			Non Water Polluting Industries
	(1)	(2)	(3)	(4)
$Year_{2007}$	4.103 *** (17.836)	2.839 *** (5.083)	3.978 *** (9.002)	2.440 *** (4.463)
$Year_{2008}$	4.400 *** (19.277)	3.349 *** (6.325)	4.442 *** (12.634)	3.771 *** (8.27)
$Year_{2009}$	4.276 *** (18.835)	4.660 *** (8.758)	2.933 *** (3.015)	2.108 ** (3.658)
Region fixed effects	Yes	Yes	Yes	Yes
Observations	1519	1519	1519	1519
R^2	0.605	0.630	0.794	0.745

Notes: The first figures on each term are the corresponding regression coefficient values. ***, **, * are significant at 1%, 5%, and 10%, respectively, and the values in brackets are *t* values.

4.1.2. Identification of Strategic Allocating Polluting Activities by Prefecture-Level Municipal Government (Assumption 2)

In the estimated results of column (3), the interaction item coefficient is positive and significant. Based on Figure 3, the model clearly shows that "strategic pollution" plays an important role even though there may exist many uncontrolled complex factors that affect the result. Water pollution production activity increased more in the most downstream county (type-A counties) in a prefecture-level city after 2006. In the above, we prove that the intensity of regulation is negatively related to polluting activities, showing a relatively laxer water pollution regulation in the most downstream county (type-A counties) in a prefecture-level city than that in the two other counties. In column (4), for nonwater polluting industries, we do not find a significant increase in type-A counties relative to the other two counties. The positive externality of good water quality cannot be shared by all other areas of a prefecture-level city. Therefore, governments deliberately arrange polluting activities in the most downstream county to acquire the economic benefits of their administrative jurisdiction, and unilaterally transfer negative polluting externality to downstream regions, while assuring that the monitoring station data are able to meet discharge reduction requirements set by the central government. The concentration of water polluting activities in type-A counties provides solid evidence for demonstrating strategic allocating by prefecture-level Municipal government.

4.2. DDD

4.2.1. Identifying the Relationship between Regulation and Polluting Activities

The DDD model could solve the potential endogenous problem caused by omitted time-varying county characteristics; the first 2 columns of Table 3 show the regression results with COD discharge as the regulation measure. The 1st column shows the average impact of regulation on the selected water polluting industry; the triple interaction coefficient is negative and significant. The intensity of regulation is negatively correlated with water polluting enterprise activities corresponding to columns (1) and (2) of DID in Table 2. To test regulation effect of each water polluting industry, in column (2), the average impact of regulation policies on seven water polluting industries (agricultural product and byproduct processing, textile manufacturing, clothing manufacturing, papermaking, petrochemical fuel manufacturing, chemical engineering, and nonferrous metal smelting) are respectively shown, indicating negative and significant regulation effect that corresponds to overall triple interaction coefficient value. The intensity of regulations is ranked as follows (from strong to weak), textile manufacturing, clothing manufacturing, nonferrous metals smelting, agricultural products and byproduct processing, chemical engineering, petrochemical fuel manufacturing, and papermaking.

The regression results of taking the environment-related text proportion in the government work report as regulation measures are shown as column (3) and (4), the coefficients are still negative and statistically significant with similar results as the first two columns, indicating the former selection of the regulation variable is correct.

Table 3. Impact of water pollution regulations on regional industrial activities (difference-in-difference-in-difference (DDD) method).

The Dependent Variable: Log (Total Output Value in Each Industry in Each Region in Each Year)				
	(1)	(2)	(3)	(4)
$COD * Post_{2006} * Dirty$	−0.403 *** (−15.796)			
$COD * Post_{2006} * Agricultural\ product\ and\ by\ product\ processing$		−0.310 *** (−8.515)		
$COD * Post_{2006} * Textile\ manufacturing$		−0.484 *** (−10.643)		
$COD * Post_{2006} * Clothing\ manufacturing$		−0.466 *** (−9.943)		
$COD * Post_{2006} * Papermaking$		−0.121 *** (−5.024)		
$COD * Post_{2006} * Petrochemical\ fuel\ manufacturing$		−0.211 *** (−6.416)		
$COD * Post_{2006} * Chemical\ engineering$		−0.235 *** (−6.821)		
$COD * Post_{2006} * Non-ferrous\ metals\ smelting$		−0.333 *** (−9.09)		
$Avg.Text*$Post2006 * Dirty			−0.418 *** (−6.236)	
$Avg.Text * Agricultural\ product\ and\ by\ product\ processing$				0.258 *** (−7.172)
$Avg.Text * Textile\ manufacturing$				0.391 *** (−5.009)
$Avg.Text * Post_{2006} * Clothing\ manufacturing$				0.496 *** (−7.103)
$Avg.Text * Papermaking$				−0.292 ** (−2.814)
$Avg.Text * Petrochemical\ fuel\ manufacturing$				0.247 *** (−2.107)
$Avg.Text * Chemical\ engineering$				0.358 *** (−3.268)
$Avg.Text * Non-ferrous\ metals\ smelting$				0.375 *** (−4.018)
County-year fixed effects	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes
Region-industry fixed effects	Yes	Yes	Yes	Yes
Observations	3038	3038	1848	1848
R^2-adj	0.429	0.852	0.844	0.93

Notes: The first figures in each line are the corresponding regression coefficient values. ***, ** are significant at 1% and 5%, respectively and the values in brackets are *t*-values.

4.2.2. Spatial Transfer of Water Polluting Activities

DID results show that after the execution of 11th Five-year Plan came into force in 2006, the overall regulation improved; prefecture-level municipal governments strategically lowered the environmental protection strength in the most downstream counties within their administrative regions. The pollution regulation in type-A counties is not as strict as that of other regions, and water polluting enterprises react to such differences according to their own interests. Thus, we need to clarify the overall factors that may affect water polluting enterprise location and production selection, based on which we can assume that regulated by central government's environmental policies, old water polluting enterprises weigh the costs–benefits and transfer their business from type-I and type-B counties to type-A counties, while new water polluting enterprises set up their factories in the most downstream counties of prefecture-level cities. In this section, we use spatial transfer of new/old water polluting enterprise into/out of various locations of rivers to verify the strategic allocating of the prefecture-level municipal government. Based on previous experiments, the year 2000 has been taken as a dividing point for new and old enterprises for their establishment information index selection so as to calculate the number of new/old riverside enterprises. DDD setting of model (3) is to test the response of new/old water polluting riverside enterprises to regulation policies.

The coefficients of column (1) and (4) in Table 4 are significantly positive, indicating that after the 11th Five-year Plan announced the environmental policy adjustment, and as regulations in various riverside regions got stricter, the number of new polluting enterprises in type-A counties increased. Coefficients in columns (2), (3), (5), and (6) are significantly negative, and the absolute values of coefficient in type-I counties are smaller than those in type-B counties, indicating that as water polluting regulation got stricter, production activities by new polluting enterprises in type-I and type-B counties decreased; while within the same prefecture-level city, county B is located upstream of the river in county I. To prevent upstream pollution, lower the aggregation effect of monitoring data of water pollution and fulfill the environmental requirements set up by central government, local governments stopped new water polluting enterprises from establishing factories in upstream regions [37]. From the spatial difference of new enterprise locations, it could be seen that for water polluting enterprises, counties with relatively lax regulation (the most downstream counties of prefecture-level cities) are more attractive, reflecting the strategic allocating of the government for water polluting enterprises.

Table 4. Impact of water pollution regulation on new and old enterprises.

The Dependent Variable	**Log (Number of New Water Polluting Enterprises +1)**					
	A	*I*	*B*	*A*	*I*	*B*
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
$COD * Post_{2006} * Dirty$	1.431 *** (19.436)	−0.096 ** (−2.016)	−0.211 *** (−6.810)			
$Avg.Text * Post_{2006} * Dirty$				1.028 *** (4.957)	−0.771 *** (−3.493)	−0.868 *** (−4.079)
The Dependent Variable	**Log (Number of Old Water Polluting Enterprises +1)**					
	A	*I*	*B*	*A*	*I*	*B*
	(7)	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**
$COD * Post_{2006} * Dirty$	−0.023 (−0.475)	−0.127 * (−1.674)	−1.073 *** (−6.939)			
$Avg.Text * Post_{2006} * Dirty$				−0.017 (−0.250)	−0.066 ** (−2.000)	−0.749 *** (−5.463)
Region-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
County-industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1176	686	1176	868	336	644

Notes: The first figures on each term are the corresponding regression coefficient values. ***, **, * are significant at 1%, 5%, and 10%, respectively, and the values in brackets are *t* values.

All coefficients in column (7) to (12) of Table 4 are negative, meaning that strict regulation would cut the number of old water polluting enterprises in all riverside counties (A, B, and I). As it only takes two years from factory relocation to production restart [23,38], the costs and interests factor would drive old water polluting enterprises away to look for new polluting shelters. The coefficients of column (7) and (10) are not significant, which show that after the 11th Five-year Plan announced the environmental policy adjustment, as regulations in various riverside regions got stricter, the number of old polluting enterprises in type-I counties stayed almost the same, with few moving away. Coefficients in columns (8), (9), (11), and (12) are all significant and absolute values of type-I counties are less than that of type-B counties. Affected by the regulation, type-B water polluting enterprises relocated more than type-I counties, the mechanism of which is similar to that of new enterprise location selection. During the period of the 11th Five-year Plan, as regulation became stricter and government performance was correlated to environmental indexes, in order to lower cumulative pollution in the administrative zone, and improve taxes, punishments, and other managements for upstream regions, regional government resorted to strategically allocates water polluting enterprises each place along the river, which can be verified empirically by the data on relocation of such polluting enterprises.

From above, type-A counties undertake the water polluting industries from type-B and type-I counties. Undertaking pollution industry transfer has not only brought opportunities for local economic development, but it also has produced a series of problems such as environmental pollution, ecological imbalance, and has put the health of local residents at risk in the process of economic development. Meanwhile, health problems caused by water pollution may also directly affect the basic living conditions of the residents in type-A counties. Potential health deteriorating risks must be given more attention in a timely manner. Not only are the source control and end-treatment needed in the type-A counties, but some measures just as environmental hazard assessment and ecological compensation and repair also should be used to take the inhabitants health risk of undertaking polluted industries to a minimum.

5. Other Robustness Checks

5.1. Time-lag of Policy Effectiveness

The government needs to weigh the overall planning and allocating of polluting industries, based on which they can decide the fate of enterprises (moving away or staying) so as to balance economic development and environmental protection. Enterprises need to choose between regulation costs and revenue changes caused by changes in policy [39]. Thus, regional policies targeting water polluting enterprises may not get feedback right away, as the reaction of enterprises to policies are somewhat lagging, testing the time-lag is of importance to policy-makers and realistic in value, the test model of which is set as (5)

$$y_{ict} = \sum_{j=0}^{3} \varphi_j R_c \times Year_{2006+j} \times Dirty_i + \eta_{ct} + \omega_{it} + \lambda_{ic} + e_{ict} \quad (5)$$

$Year_{2006+j}$ represents the annually dummy variable, as the 11th Five-year Plan came into force in 2006, taking only the period of 2006 to 2009 as policy effective time and interpreting other variables and marks in the same manner as model (3); the regression results are shown in Table 5.

Table 5. Regression results of policy effective duration test.

The Dependent Variable: Log (Total Output Value in Each Industry in Each Region in Each Year)		
	(1)	**(2)**
$COD * Year_{2006} * Dirty$	0.012	
$COD * Year_{2007} * Dirty$	0.047	
$COD * Year_{2008} * Dirty$	−0.590 ***	
$COD * Year_{2009} * Dirty$	−0.682 ***	
$Avg.Text * Year_{2006} * Dirty$		0.036
$Avg.Text * Year_{2007} * Dirty$		0.113 *
$Avg.Text * Year_{2008} * Dirty$		−0.485 ***
$Avg.Text * Year_{2009} * Dirty$		−0.732 ***
County-year fixed effects	Yes	Yes
Industry-year fixed effects	Yes	Yes
Region-industry fixed effects	Yes	Yes
Observations	3038	1848
R^2-adj	0.822	0.861

Notes: The first figures on each term are the corresponding regression coefficient values. ***, * are significant at 1% and 10%, respectively, and the values in brackets are *t*-values.

In Table 5, when using the COD reduction mandates as the stringency measure, the value of φ is positive and nonsignificant in 2006 and 2007; in 2008, the regulation effect coefficient is negative for the first time and with statistical significance, and in the next year, the value remains negative. Results are similar when taking environment-related text proportion in the government work report as a measure of regulation. It demonstrates that the impact of the 11th Five-year Plan's water pollution regulations on corresponding industries is not instantaneous but lagging. We calculate the time-lag before negative effects first emerge by empirical analysis—namely, the policy time-lag—to provide a reference point for future policy formulation.

5.2. Enterprise Ownership

Compared with private enterprises, state-owned enterprises bear heavier social responsibilities such as exploring employment solutions, maintaining social economic order, etc. Unlike profit-oriented private enterprises, state-owned enterprises may react insensitively to environmental regulations. Columns (2) and (3) in Table 6 demonstrate the regulation effect of state-owned and private enterprises; the triple interaction terms of both are negative while those for the latter are significant, and strong regulation has little impact on state-owned enterprises, but can drive a steep downturn in the production activities of private enterprises, just as anticipated.

Table 6. Robustness test of enterprise heterogeneity.

The Dependent Variable: Log (Total Output Value in Each Industry in Each Region in Each Year +1)							
	(1) All	**(2) SOE**	**(3) Private**	**(4) Foreign**	**(5) Domestic**	**(6) Large**	**(7) Small**
$COD * Post_{2006} * Dirty$	−0.403 ***	−0.036	−0.412 ***	−0.006	−0.388 ***	−0.091	−0.129 ***
	(15.796)	(−0.214)	(−12.973)	(−0.38)	(−2.813)	(−0.596)	(−3.117)
Region-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County-industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3038	3038	3038	3038	3038	3038	3038
R^2-adj	0.702	0.564	0.638	0.263	0.526	0.505	0.640

Notes: The first figures on each term are the corresponding regression coefficient values. *** is significant at 1%, and the values in brackets are *t*-values.

5.3. Enterprise Nationality

Generally, foreign enterprises often bound by more stringent environment regulation in their own countries and therefore are not sensitive to regulation changes in China [40]. We divided enterprise samples into domestic and foreign to explore how the regulation effect impacts them. We list foreign enterprises as a whole instead of further classifying their nationality (the 4th column in Table 6 shows only the average regulation effect); though the coefficient for foreign and domestic enterprises are negative, the absolute value of the former is smaller than the latter and is statistically insignificant, indicating that domestic enterprises are more easily affected by environment regulations.

5.4. Enterprise Scale

China Industry Business Performance Data collects data from enterprises with annual sales revenue of RMB 5 million or higher, and there is variation in the sales amount of the overall samples. To further clarify whether the estimated result is affected by enterprise scale or not, we divide the samples into two subsamples according to annual sales amount, wherein big enterprises refer to the ones with larger sales than the average sales of overall samples, and small enterprises refer to the others; the estimated results are shown in columns (6) and (7) of Table 6. Both coefficients are negative; absolute value of the latter is larger and statistically significant, indicating that small enterprises are more easily affected by policy regulation. The promulgation of environment regulations calls for the enterprises investing more on environment protection issues. Under the same environmental protection standards and cost, the larger the scale and the more the output an enterprise has, the more additional production and operation costs it can afford—that is, they enjoy the benefit of economy of scale—while small enterprises are more easily confined by capital, thus being more sensitive to regulation measures at the same level, just as has been theoretically anticipated. The regression results are similar when taking environment-regulated text as measure for regulation.

5.5. Enterprise Location

Samples in this research are situated on the main streams and branches of the Songliao Basin in Heilongjiang, Jilin, Liaoning, and Inner Mongolia. They were further subdivided into subsamples of four provinces to test the differences in the impact of the 11th Five-Year Plan's water pollution regulation on the production activities of water polluting industries in 4 provinces. As shown in columns (1), (2), (3), and (4) of Table 7, the triple interaction item coefficient of four subsamples are all negative with the absolute values ranked from big to small—Jilin, Liaoning, Heilongjiang, and Inner Mongolia—of which only the first three pass the significance test of different levels. The Jilin section of Songhua River runs through industrial concentration areas. During the 11th Five-year Plan period, major national projects such as the "100-billion level" petrochemical industry base in Jilin City and the "10-million-ton level" oil & gas base were under construction and require for more environmental protection efforts [41]. Moreover, as environment restraints of the 11th Five-year Plan directly result from the emergency situation caused by the explosion at Jilin Petrochemical Corporation's benzene factory, regulation is at its most stringent, as it conforms to reality. Economic development, the investment environment, and degree of opening of city clusters in Central and South Liaoning are better than that of other Northeast regions. Based on the various environment measures formulated and enhanced environment protection, it is verified that the impact of the regulation in Liaoning is lower than Jilin but higher than Heilongjiang and the five "league" cities in Inner Mongolia.

When we divide the overall sample into industrial zone and non-industrial zone subsamples, triple interaction coefficients of both are negative and the latter is significant. This research suggests that enterprises in non-industrial zones are more subject to water pollution regulations. As anticipated, with well-equipped discharge facilities available for all enterprises in industrial zones, the benefits brought about by economy of scale are more accessible, and the pollution treatment costs for fulfilling environment standards are lower.

Table 7. Regional robustness test of the enterprise location.

The Dependent Variable: Log (Total Output Value in Each Industry in Each Region in Each Year +1)							
	(1) All	(2) Heilongjiang	(3) Jilin	(4) Liaoning	(5) Inner Mongolia	(6) Industrial Zone	(7) Non-Industrial
$COD * Post_{2006} * Dirty$	0.403 *** (15.796)	−0.296 ** (−2.063)	−0.607 *** (−3.981)	−0.345 ** (−2.12)	−0.088 (−0.719)	−0.118 (−0.978)	−0.212 *** (−2.725)
Region-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
County-industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3038	3038	3038	3038	3038	3038	3038
R^2-adj	0.702	0.613	0.721	0.552	0.656	0.578	0.710

Notes: The first figures on each term are the corresponding regression coefficient values. ***, ** are significant at 1% and 5%, respectively, and the values in brackets are *t*-values.

6. Conclusions and Suggestions

Using water polluting enterprise activities as a substitute for monitoring data, we employ optimal assessment models to systematically analyze the strategic allocating by the prefecture municipal government within the framework of the 11th Five-Year Plan, based on which this paper draws the following conclusions:

(1) The 11th Five-year Plan's environmental regulation policies are significantly effective and negatively related to water polluting enterprise activities; water polluting production activity increased more in the most downstream county of a prefecture-level city than the other two type counties.

(2) Regulation in the most downstream county of a prefecture-level city is relatively lax compared to the other two upstream counties where regulation is attracted by water polluting activities. The local government not only achieves economic interests brought about by such activities, but also unilaterally transfers negative polluting externality to downstream regions outside. Meanwhile the monitoring data are able to meet the discharge reduction requirements set by the central government in China.

(3) As environmental regulations get stricter in riverside regions (a) the number of new water polluting enterprises in type-A counties grows, while the number in type-I and type-B counties shrinks. (b) Few old enterprises move out of type-A counties, while those in the other two types of counties show an opposite trend. (c) To prevent downstream effects, compared to type-I counties, water polluting enterprise activities fluctuate more intensively in type-B counties.

(4) Regulation effects for the seven water polluting industries from strong to weak: Textile manufacturing, clothing manufacturing, nonferrous metals smelting, agricultural product and byproduct processing, chemical engineering, petrochemical fuel manufacturing, and papermaking. Robustness results show that the regulation hysteresis effect lasts for two years. Compared to state-owned/large/foreign enterprises, time-lag in Heilongjiang/Inner Mongolia or industrial parks, there is greater impact of the 11th Five-year Plan on private/small/domestic enterprises, enterprises in Jilin/Liaoning or outside industrial parks.

Therefore, the following policies are recommended. Establish uniform environmental standards and a management system to deal with strategic reactions of local governments; establish a complete cross-border assessment system; formulate an explicit environmental control coordinating framework and incorporate the norms of adjacent administrative zones into local government performance assessments, which will reduce cross-border differences in environmental performance; and establish a market-based transaction system for pollution rights to compensate the regions whose environment is fragile but do not enjoy compensatory benefits.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/10/12/4713/s1.

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