A space-industry econometric filter: The **A** matrix as a measure of industry proximity

Fernando de la Torre Cuevas, Universidade de Santiago de Compostela

Michael L. Lahr, Rutgers. The State University of New Jersey

Subnational industrial development has at least three dimensions: time, space, and industry. Time is required for economies to develop—to fall and rise. Space is less obvious, but fundamental to regional science, which recognizes that closer things tend to have more physical, political, social, and, hence, economic influence. Thus, spatial spillover and feedback effects as well as interregional dependencies are key elements of economic growth. This is because neighbouring economy's affect a region's economic performance through investments, trade, consumerism, and commuting behaviour. The industry dimension is predicated on inter-establishment dependencies. These can be inter-industrial linkages as expressed in input-output analysis parlance or supply chains in the field of logistics. Other industry-based agglomeration economies can also attach, springing up as other establishments and/or people locate within the same spatial sphere.

In this paper we use a space-industry econometric filter to introduce spatial and interindustry interactions into a regression model. To test our findings, we present a modest empirical application predicated upon the 53 shires of Galicia (NW Spain). We describe variations in value-added between 2010 and 2018 for 12 different sectors. As explanatory variables we consider agglomeration economies —location, urbanization and diversification—; average firm size; and market potential. We then include our space-industry filter in the model. To account for spatial structures, we use a distance measure between regions as an approximation to transportation costs. To account for industrial structure, we use a symmetric IO table. Our goal is to examine to what extent the inclusion of our spatial and industrial spillover measures improves the explanatory power of the model. We draw some possible policy implications from our empirical results as well.

1. Introduction

1.1. Space and industries matter for Regional Development

Interactions between geography and economy have been discussed since, at least, the early 19th century. According to Harvey (1981), G.W. Hegel is his *Philosophy of Right* (1821) provides a pioneer example. Hegel suggested that modern societies should push beyond their own (geographical) limits to solve their increasing inner contradictions. The work by von Thunen (1826) is conventionally recognised as the first economic geography contribution. Despite these early calls, economics consolidate as a spaceless discipline (Isard, 1960). Regional scientist championed the introduction of spatial considerations in their "interdisciplinary attack" to subnational challenges (Boyce, 2003; Isard, 2003). In the 1990´s contributions by Arthur (1990), Krugman (1991), Krugman and Venables (1995), among many others, revitalised discussions about how space and industry mixes influence economic performance.

Following Marshall´s (1890) approach, the *New Economic Geography* school stressed the relevance of geographical distance between economic agents to assess their performance. Spatial relatedness offers better functioning labour markets, access to intangible knowledge and greater information spillovers across firms. Inter-industry linkages are also considered following research avenues suggested by Myrdall (1959, 1974), Hirschman (1958; 1962) and other authors. Rosenberg (1982) reinforces the argument stressing the importance of interactions between supply and demand in order to understand innovation and growth processes. Innovation systems literature expands these views into a wider institutional context (Asheim, Grillitsch, & Trippl, 2019; Fernandes, Farinha, Ferreira, Asheim, & Rutten, 2021).

Space and industry proximity allow competitive marketplaces and industries to increase their lead over others. Efficiency gains are generated in regions where firms can externalise their internal scale economies (Feser, 1998). These additional rewards are given the name of agglomeration economies. Frenken, Van Oort, & Verburg (2007) identify three different types. This is list is neither exhaustive nor mutually exclusive.

I. *Location economies.* Generated due to firm concentration of an industry in a region (i.e., regional specialization). In this case, firms benefit from Marshallian externalities such as labour market pooling, presence of specialized suppliers and knowledge spillovers (Henderson, 2003).

II. *Urbanization economies*. Efficiency gains derived from socio-economic agglomerations as a whole, regardless industry structure. The denser an agglomeration is, the more likely common productive infrastructure (transportation, R&D centres, universities) is to be placed there. These dynamics resemble Marx´s constant capital economies to a certain extent (Vence Deza, 1995).

III. *Diversification economies (Jacobs' externalities)*. Innovations may occur from the recombination of knowledge present in different industries. Hence, regional industrial diversification may be seen as an extra possible factor behind innovations and growth (Jacobs, 1969). Diversification might also work softening negative external shocks.

Forces in opposite direction have been also identified. Neoclassical approaches (Barro & Sala-i-Martin, 2004) suggest that once a region enters a stage of high economic development, spread effects are more likely to occur (Gezici & Hewings, 2004). In addition, congestion effects derived from excessive agglomeration may also act as centrifugal force (Brakman, Garretsen, Gigengack, Marrewijk, & Wagenvoort, 1996).

Therefore, regional economic development could be understood as the result of interaction between space-industry-related centripetal and centrifugal forces (Márquez, Ramajo, & Hewings, 2015). However, Cartone, Panzera, and Postiglione (2021) point to a certain imbalance in literature favouring spatial effects over inter-industrial interactions.

1.2. Embedding strategies for econometric + input-output modelling

In order to account for inter-industrial linkages, input-output (IO) analysis is arguably one of the most used tools in economic literature (Miller & Blair, 2022). IO has been widely used for studying regional economies (Hewings, 1985; Hewings & Jensen, 1988; Oosterhaven & Hewings, 2014). Regional "imperfections" in terms of data availability, among other motivations, provided scholars with incentives to look for creative solutions in this context (Lahr, 2018). Interaction between (spatial) econometrics might be considered one these innovations. Rey (2000) finds both theoretical and practical motivations for this kind of integrated modelling.

Econometric and regional IO integration was pioneered, among others, by L´Esperance et al. (1977), Conway (1979) and Stevens et al. (1981). Econometric IO models have been implemented in single and multiple region scenarios (Sergio J. Rey & Dev, 1997). In the latter case, they face additional challenges such as accounting for distance and import propensities, among other possible region-specific features.

Rey (1997) identifies three different integration strategies between econometric modelling and input-output analysis: linking, coupling and embedding. Through the linking strategy some contributions use inputs of one model to feed the other one as in a one-way avenue. The coupling strategy presents circular interactions between the IO and the econometric modules. Some authors suggest this approach resembles computable general equilibrium models (Treyz, 1993). Other authors appear to be somehow reluctant to accept such equivalence (West, 1995). It is in expanding the embedding strategy we are interested. Essentially, the embedding strategy consists of using IO coefficients to weight some econometric model specification. Models can be feed with a full technological specification or a partially restricted one as in White and Hewings (1982). LeSage and Rey (2002) compare both embedding approaches and suggest combining them in order to improve forecasting.

The papers by Tian (2014) and Tian et al. (2020) illustrate how the embedding approach can be further extended in order to account for industrial and spatial interactions. They introduce a variant of the space-time filter proposed by Parent and LeSage (2012). The space-time filter model can be formally written as:

$$\begin{gathered}\mathbf{y}_t = \phi \mathbf{y}_{t-1} + \rho \mathbf{W} \mathbf{y}_t + \theta \mathbf{W} \mathbf{y}_{t-1} + \mathbf{i}\alpha + \mathbf{X}_t \beta + \boldsymbol{\eta}_t \\ \boldsymbol{\eta}_t = \boldsymbol{\mu} + \boldsymbol{\varepsilon}_t\end{gathered} \tag{1}$$

In equation (1) $\mathbf{y}$ is an $n \times 1$ vector of observations for period t, α is the intercept, $\mathbf{i}$ is a summation vector of ones and $\mathbf{X}$ is a matrix containing k non-stochastic explanatory variables and has dimensions $n \times k$. In addition, $\boldsymbol{\eta}$ is a $n \times 1$ vector containing the sum of a random effects vector $\boldsymbol{\mu}$ and a disturbance term $\boldsymbol{\varepsilon}$. Matrix $\mathbf{W}$ represents distances between every pair of regions (o, d) and has dimensions $r \times r$. This matrix is used to weight the dependent variable accounting for spatial interactions.

Tian (2014) introduced a "space-industry filter" to account for spatial and inter-industry interactions affecting a region´s economic performance. The temporal dimension is substituted for an interindustry dimension using a technical coefficient matrix. The dependent variable is weighted on the basis of geographical and industrial proximity. The latter dimension is given by an IO technical coefficient matrix $\mathbf{A}$ with dimensions $n \times n$.

Let $\mathbf{I}_r$ and $\mathbf{I}_n$ be identity matrices with $r \times r$ and $n \times n$ dimensions, respectively. Let $\mathbf{B} = \mathbf{I}_r - \rho\mathbf{W}$ and $\mathbf{C} = \mathbf{I}_n - \phi\mathbf{A}$. The space-industry filter is defined as $\mathbf{C} \otimes \mathbf{B}$ where $\otimes$ stands for the Kronecker product. The filter can be expanded as:

$$\mathbf{C} \otimes \mathbf{B} = \mathbf{I}_{rn} - \rho\mathbf{I}_n \otimes \mathbf{W} - \phi\mathbf{A} \otimes \mathbf{I}_r + \rho\phi\mathbf{A} \otimes \mathbf{W} \tag{2}$$

Multiplying the filter by $\mathbf{y}$ and re-arranging we get:

$$\begin{gathered}(\mathbf{C} \otimes \mathbf{B})\mathbf{y} = \mathbf{X}\beta + \mathbf{E}\boldsymbol{\eta} \\ \mathbf{y} = \rho(\mathbf{I}_n \otimes \mathbf{W})\mathbf{y} + \phi(\mathbf{A} \otimes \mathbf{I}_r)\mathbf{y} + \rho\phi(\mathbf{A} \otimes \mathbf{W})\mathbf{y} + \mathbf{X}\beta + \mathbf{E}\boldsymbol{\eta} + \boldsymbol{\varepsilon} \\ \mathbf{E} = \mathbf{I}_n \otimes \mathbf{i}\end{gathered} \tag{3}$$

In the right-hand side of equation (3), $\rho(\mathbf{I}_n \otimes \mathbf{W})\mathbf{y}$ captures spatial spillovers across regions, $(\mathbf{A} \otimes \mathbf{I}_r)\mathbf{y}$ represents inter-industrial spillovers within a region and $\rho\phi(\mathbf{A} \otimes \mathbf{W})\mathbf{y}$ stands for cross-effects. $\mathbf{E}\boldsymbol{\eta}$ captures industry specific effects, which are assumed to be normally distributed. Regional fixed effects are captured by regional-specific variables in $\mathbf{X}$.

1.3.The aim of this working paper

This paper intends to expand literature in two different directions. First, we test whether considering space-industry interactions yields more robust econometric models. We propose three different models relating gross value-added growth to agglomeration economies. As far as our knowledge goes, the space-industry filter has only been used to provide more refined estimates for location quotients (Tian et al., 2020). Second, we contribute to the study of Galicia´s territorial imbalances. Related to our case study, we find no research to the date that has embedded IO variables into econometric models to explain intra-regional differences and their evolution.

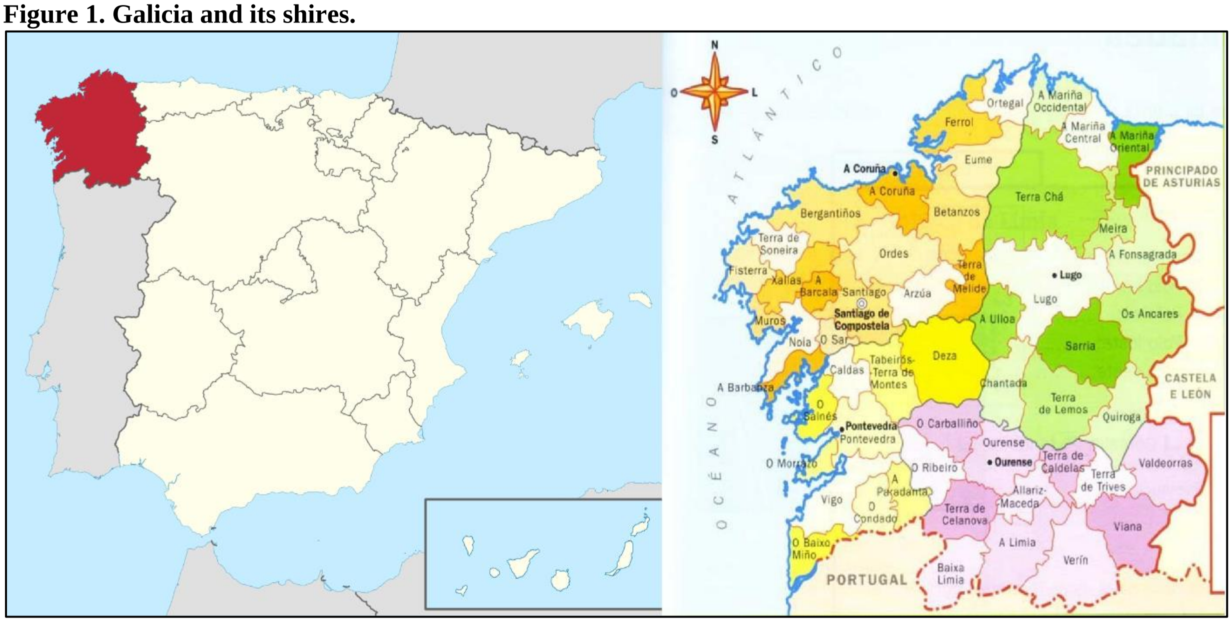
The remainder of the paper is organised as follows. In section 2 we present a modest empirical application. We try to explain gross value-added growth in the industries and shires of Galicia (NW Spain) through agglomeration economies and other control variables. We use a slight variant of Tian´s (2014) space-industry filter. Finally, section 3 concludes stressing this paper´s limitations, suggesting possible research avenues.

2. Empirical application: An Industrial Journey via Galician Shires

2.1. Our study case: Galicia

Galicia is a subnational region situated in Spain's northwest corner. According to the latest consolidated data provided by the Spanish National Statistics Institute, Galicia accounts for 5.2% of national GDP and 5.7% of national population in 2021[1]. Agriculture, cattle, and fishery sectors used to play a central role until the 1970's (Caballero Álvarez, 1978; López Iglesias & Fernández Leiceaga, 2000). In recent decades, Galicia's economy has quickly become more industrial and service-oriented (Carmona Badía, 2022; Carmona Badía & Nadal, 2005).

Figure 1. Galicia and its shires.



Source: own elaboration.

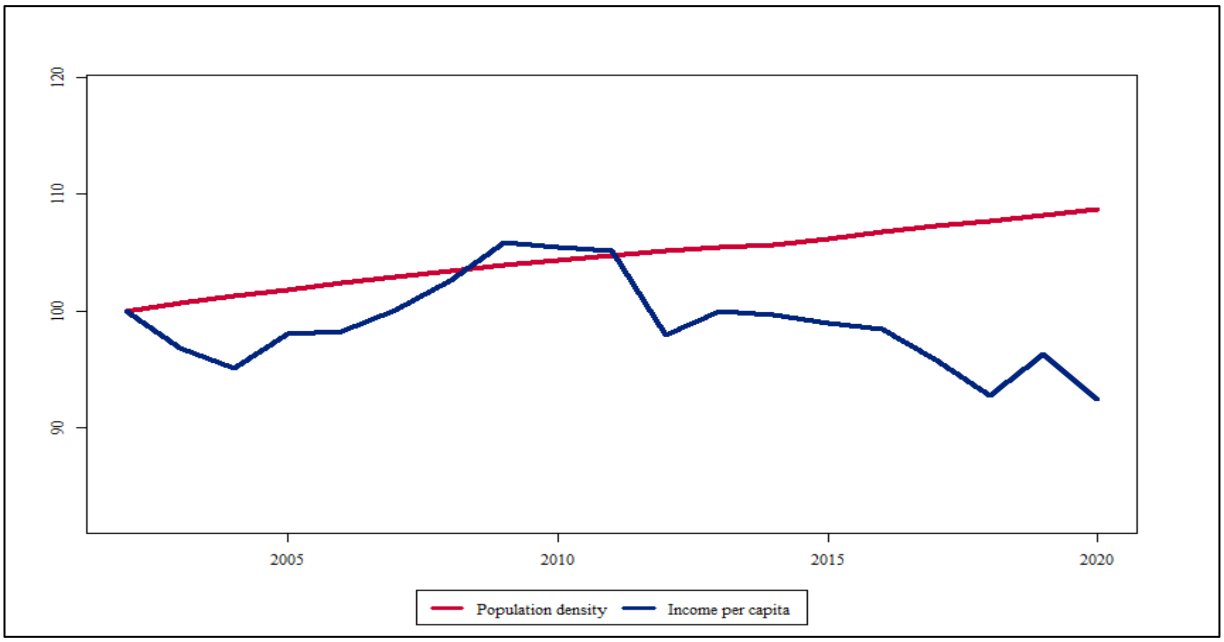
However, López Iglesias (2016) suggests that Galicia's peripheral position within Spanish and European markets remains a barrier to its economic development. Beiras Torrado (2006) has even suggested that Galicia could be an example for the "development of underdevelopment" paradox

[1] Spanish Regional Accounts can be retrieved from: https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736167628&menu=ultiDatos&idp=1254735576581

(Frank, 1966), albeit a European context. Galicia is divided into 53 shires according to its Shire Development Act[2] passed in 1996. This subregion level aims to capture region´s functional areas (Rodríguez González, 1997).

Public discussion and proposals on territorial organisation and industrial development for Galicia go back as far as to the 18th century (Gil Barreiro, 2001). According to Beiras Torrado (1981), a number of propositions were made by Galician entrepreneurs and intellectuals to ameliorate communications and incentive industrial take-off. The first *Galician Agricultural Conference* (Villares, 1994) and the first *Galician Economic Conference* (Roca Cendán, 1982) held in 1864 and 1925 respectively, debated on the need of further industrial development and better communication networks in the region. The latter meeting made a thorough case supporting a new railroad line from Lugo (NE Galicia) bounded to Pontevedra (in the Southwest).

Figure 2. Relative standard deviation for population density and income per capita across shires, 2002=100.



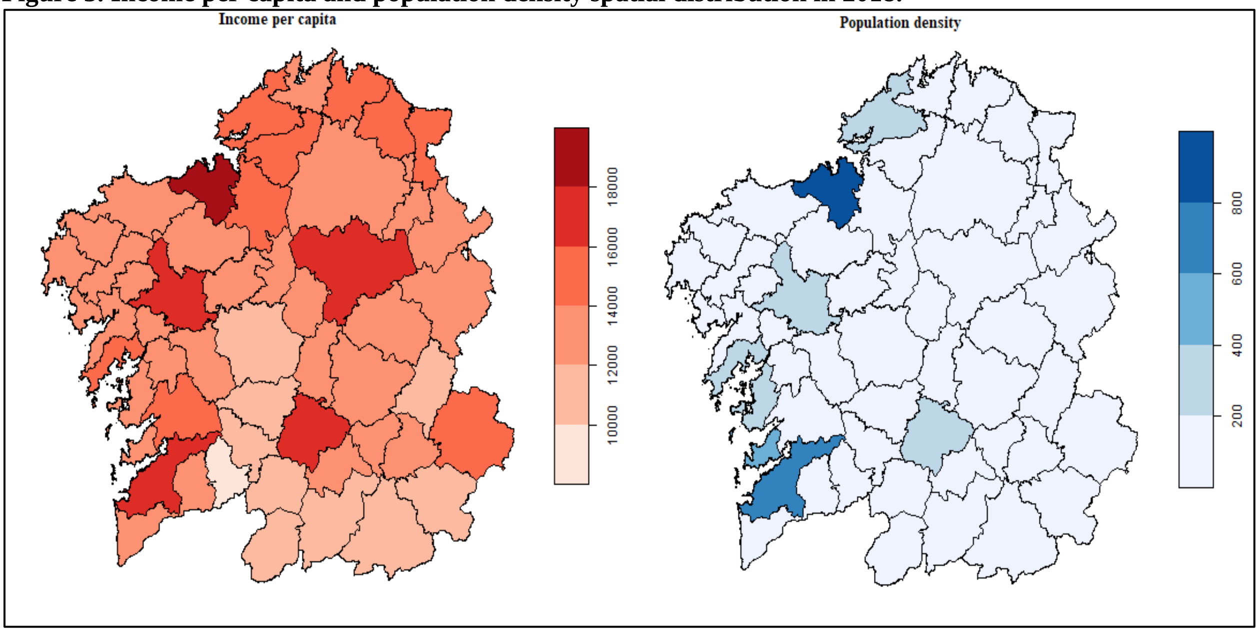
Source: own elaboration.

After the Civil War (1936-1939), we can differentiate two separate periods (Alonso Logroño & Lois González, 1997). From the 1950´s until the 1970´s, economic development was associated with economic divergence. The coastal area (known as *Eixo Atlántico*) benefited from available

[2] Legislation retrieved from: https://www.xunta.gal/dog/Publicados/1996/19960719/Anuncio86B6_gl.html

relatively skilled workforce, agglomeration economies and better infrastructure, thus attracting most of modern economic activities (Pérez Vilariño, 1990). From the 1970´s onwards, a modest process of diffusion across the rest of the region appears to have taken place. Literature in the 1990´s started identifying infrastructure improvements and value-chain fragmentation as two important factors behind this dynamic (Ares Fernández, 1992). However, data suggest that during the first decade of the 21st century income and population became more unevenly distributed across Galician shires (Figure 2).

Figure 3. Income per capita and population density spatial distribution in 2018.



Source: own elaboration.

After the 2008 financial crisis Galician shires showed convergence dynamics in relative terms (e.g., income per capita). However, very much in line with the "regional puzzle" described by Garrido-Yserte and Mancha-Navarro (2009), shires have diverged in absolute terms (population density). Figure 3 illustrates the state of affairs before the Covid-19 outbreak. Shires containing the seven big municipalities of the region[3] present the highest income per capita values. We can also identify an intermediate income per capita group of shires mainly in the northen coast and in some inland zones. Population density shows, in contrast, much more divergent values across

[3] According to IGE: A Coruña, Ferrol, Lugo, Ourense, Pontevedra, Santiago de Compostela and Vigo.

shires. Some shires situated in the *Eixo Atlántico* show great concentration whereas the rest of the region is sparsely populated.

Literature has attempted to explain such imbalances considering time, space and industry dimensions. Martínez Filgueira et al. (2017) focus on how strong imbalances induced by industrialisation in 1950-1970 relate with 21st century demographic dynamics across shires and municipalities. As for the spatial dimension, López-Rodríguez and Manso-Fernández (2018) describe the spatial distribution of market potentials as defined by Harris (1954) across shires. More recently, Peón Pose, Martínez Filgueira and López-Iglesias (2020) analyse different rural areas and find evidence supporting that shorter distance to the main urban centres in Galicia positively influence their income. Regarding industry structures, Pena López and Sánchez Santos (2008) include shift-share-based variables in a four-sector model to analyse average income disparities at the municipality level.

2.2. Regressand and regressors

We now present a modest empirical application. We try to assess how agglomeration economies affect the economic performance of different industries in different shires. We consider the time period 2010-2018. Our model takes as dependent variable the gross value added (GVA) variations over time, industry and shire. Following Frenken et al. (2007), we consider proxies for location, urbanization and diversification economies separately. As suggested by LeSage and Fischer (2008) we use explanatory variables measured for the initial year. In addition, we extend the models introducing a spatial and a space-industry lag for the regressand as previously explained. This way we model shire-industry economic growth as the result of previous shire-industry endowments as well as geographical and industrial spillovers.

Our explanatory variables cover five different dimensions: (i) internal scale economies, (ii) external scale economies, (iii) final demand allocation, (iv) path dependency and (v) spillover effects. Some variables are defined for shires and industries. Other variables lack an industrial specific dimension. We drop the observations for which data on the regressand or any regressor is not available. This mainly concerns relatively small shires with some industries affects by statistical disclosure restrictions. Table 1 summarises the main characteristics for each independent variable.

Table 1. Independent variables, descriptive summary.

	Mean	Median	S.d.	Min	Max	Dimension
Average firm size	4.03	2.52	4.65	1.00	37.97	Shire/industry
Location quotient	1.95	0.82	3.06	0.03	13.56	Shire/industry
Population density	112.23	49.21	174.63	8.81	855.62	Shire
Shannon diversity index	1.93	1.94	0.09	1.71	2.08	Shire
Market potential	12225.26	11912.00	1877.63	8349.00	17473.00	Shire
Lagged GVA	81475.88	20113.00	263881.51	16.00	2775489.00	Shire/industry

Source: own elaboration.

Internal scale economies. We take average firm size as a proxy for internal scale economies and competitiveness.

External scale economies. We introduce external scale economies in our model following the classification provided in section 1.1. For location economies we use an employment-based simple location quotient (SLQ). According to Beaudry and Schiffauerova (2009) this is a commonly used indicator. We formally define our SLQ measure for an industry i and a shire r as:

$$SLQ_i^r = \frac{emp_i^r / emp_\bullet^r}{emp_i^\bullet / emp_\bullet^\bullet} \tag{4}$$

We use • to denote summation across dimensions (industries or shires) in our panel.

For urbanization economies we calculate a population density measure based on daytime population as defined by the Galician Statistical Institute (IGE)[4]. IGE considers the average number of full-time equivalent people who spend the day in the municipality. To obtain this indicator the resident population is added to the population balance between non-residents who spend the day (entry population) and residents who do not spend the day (exit population). The area of each shire is retrieved from official geographical information files[5].

Diversification economies are somehow more difficult to capture with the data we have in hand. Literature suggests a variety of entropy measures to proxy economic diversification (Attaran &

[4] Daytime population data can be retrieved from: https://www.ige.gal/igebdt/igeapi/datos/9042/0:201113,1:0,9913:12
[5] Geographical data for Galicia can be retrieved from: https://mapas.xunta.gal/gl

Zwick, 1987). We calculate the Shannon diversity index as for Attaran (1986) among many others. The index is defined for each shire as:

$$H^r = -\sum_{i=1}^{n} (emp_i^r / emp_\bullet^r) \times \ln(emp_i^r / emp_\bullet^r) \qquad (5)$$

The higher the value, the higher diversity of industries in a shire.

Final demand allocation. We control for final demand allocation as a demand-side factor influencing economic growth. We calculate a market potential (MP) measure using disposable income per capita g after redistribution. We weight income according to the distance between shires. Formally:

$$MP^r = \hat{\mathbf{g}}\mathbf{W}\mathbf{i} \qquad (6)$$

Path dependency. We introduce GVA values for the base year to account for β-convergence. The bigger de industry in the base year, the smaller growth rate expected during the time period covered. Although imperfectly, this variable allows us to consider possible congestion diseconomies derived from excessive capacity concentration within a territory (Combes & Gobillon, 2015).

Spillover effects. As anticipated in section 1.3 our aim is to explore if the inclusion of spillover effects in our regression model can lead to superior outcomes. We follow the developments explained in equations (1)-(3). Spillovers are introduced as if they were lags weighting the regressand. Formally we have:

$$\begin{array}{c} (\mathbf{I}_n \otimes \mathbf{W})\mathbf{y} \\ (\mathbf{A} \otimes \mathbf{I}_r)\mathbf{y} \\ (\mathbf{A} \otimes \mathbf{W})\mathbf{y} \end{array} \qquad (7)$$

Equation in (7) account for spatial and industrial spillovers as well as cross-effects, respectively.

Matrix **W** stands for travel time by road between shire capitals. For the main diagonal, we follow Keeble et al. (1982) to calculate an internal distance measure. We consider an average 90 km/h travel speed.

Mathematically:

$$w_{ij} = (1/90) \times \sqrt{\frac{area\ of\ the\ region}{\pi}} \quad \forall i = j \tag{8}$$

We normalise matrix **W** to make its rows sum one.

Matrix **A** reflects Galicia´s technological structure calculated on the basis of published IO data[6]. Different from Tian´s (2014) original formulation, we normalise a technical coefficient matrix so that all columns sum one. In addition, we transpose this matrix to weight our regressand considering backward (i.e.: intermediate demand) linkages. Let **Z** stand for a matrix of intermediate demand flows and $\mathbf{z}_{\bullet j}$ for a vector containing the sum of each of its columns. Furthermore, let $'$ denote transposition. Matrix **A** is formally defined as:

$$\mathbf{A} = \left[\mathbf{Z}\left(\hat{\mathbf{z}}_{\bullet j}\right)^{-1}\right]' \tag{9}$$

With these slight modifications, interindustry spillovers might be introduced in the regression model in a way which is more coherent with the economic meaning of the IO demand models.

2.3. Three alternative specifications

We now present three different model specifications. The first model (OLS-1) includes all regressors in table 1. We exclude spatial or interindustry spillovers. In the second model (OLS-2) we introduce spatial spillovers. Essentially, we estimate a spatial autoregressive model. Finally, our third model (OLS-3) includes our modified version of the space-industry filter. All three models include industry-specific fixed effects. In a more formal fashion, we have:

$$\begin{gathered}
\mathbf{y} = \mathbf{X}\beta + \mathbf{E}\boldsymbol{\eta} + \boldsymbol{\varepsilon} \\
\mathbf{y} = \mathbf{X}\beta + \rho(\mathbf{I}_n \otimes \mathbf{W})\mathbf{y} + \mathbf{E}\boldsymbol{\eta} + \boldsymbol{\varepsilon} \\
\mathbf{y} = \mathbf{X}\beta + \rho(\mathbf{I}_n \otimes \mathbf{W})\mathbf{y} + \phi(\mathbf{A} \otimes \mathbf{I}_r)\mathbf{y} + \rho\phi(\mathbf{A} \otimes \mathbf{W})\mathbf{y} + \mathbf{E}\boldsymbol{\eta} + \boldsymbol{\varepsilon}
\end{gathered} \tag{10}$$

---

[6] IO data for Galicia can be retrieved from:
https://www.ige.gal/web/mostrar_actividade_estatistica.jsp?idioma=gl&codigo=0307007003

We estimate the parameters of our regressions using ordinary least squares (OLS). All independent variables, except for the Shannon diversity index, are taken in logarithms. Since our regressand is a growth rate, the results of our level-log model can be interpretated in terms of elasticities.

2.4.Results

Table 2 summarises the results obtained with our three model specifications. In our first model we do not include spillover measures. Two variables present the greater influence, albeit in different directions. First, market potential shows a positive and significant effect on GVA growth. This result suggests that sector performance in a given is influenced by income placed elsewhere. Second, lagged GVA levels appear to negatively influence GVA growth confirming the existence of β-convergence: the bigger an industry was in 2010, the less its GVA grew between 2010 and 2018. Proxy variables for internal and external scale economies positively influence GVA growth too, albeit showing smaller and statistically non-significant effects. Overall, the model´s fit is low, and the F-statistic test cannot reject the null hypothesis is that all of the regression coefficients are equal to zero.

Our second and third models include spatial-interindustry spillover effects. In doing so, the model´s fit improves substantially according to R^2 and residual standard errors. The F-statistic test for these models allows to reject the null hypothesis of all regression coefficients being zero. Moreover, all explanatory variables appear to be statistically significant in models 2 and 3 with the exception of the Shannon diversity index. Average firm size, location economies and urbanization economies show positive influence in GVA growth. This suggests the importance of both internal and external scale economies within each shire.

Spatial and interindustry spillovers positively influence GVA growth. The of the other regressors remain unchanged when such spillover measures are introduced. The size of the effects attributed to the independent variables varies between models. This seems a logical outcome since in models 2 and 3 we indirectly consider effects across shires and industries. In model 1 explanatory variables could only influence the regressand within shire/industry boundaries. In models 2 and 3 the effects can be imported/exported. Therefore, some adjustment might be expected. The only surprising result yielded by model 3 is a negative sign for the space-industry cross-effects. This could be related to congestion dynamics as in the case of the lagged GVA variable. For instance, if two industries are already geographically and technologically related up to a certain threshold level, we can expect some sort of diminish returns. Kitsos et al. (2023) try to capture this reality using quantile regressions.

Table 2. Results for three OLS model specifications.

	OLS-1	OLS-2	OLS-3
Average firm size (log)	0.718 (0.522)	0.619** (0.288)	0.453*** (0.150)
Location quotient (log)	0.878 (0.549)	0.835** (0.339)	0.632*** (0.227)
Population density (log)	0.626 (0.412)	0.843** (0.339)	0.417*** (0.126)
Shannon diversity index	0.306 (0.858)	-0.009 (0.870)	-0.680 (0.745)
Market potential (log)	2.726* (1.621)	2.909*** (1.123)	1.386** (0.618)
Lagged GVA (log)	-1.180* (0.699)	-0.983*** (0.316)	-0.552*** (0.121)
Spatial dependence		5.824** (2.670)	3.395*** (0.707)
Interindustry dependence			0.798*** (0.199)
Cross-effects			-0.764*** (0.179)
Observations	591	591	591
R^2	0.087	0.493	0.746
Adjusted R^2	0.059	0.476	0.736
Residual Std. Error	3.311 (df = 573)	2.469 (df = 572)	1.753 (df = 570)
F Statistic	1.241 (df = 6; 573)	2.218** (df = 7; 572)	4.917*** (df = 9; 570)
Notes:	Significant at the ***1 percent level, ** 5 percent, and *10 percent levels.		

Source: own elaboration.

Even though it is not the purpose of this paper to present thorough policy recommendations the evidence we find may support some modest remarks. First, we have shown how internal and external scale economies have significant positive effects on economic growth. Therefore, policies including incentives to increase firm size, clusters/specialised industrial parks and (to some extent) denser population centres might be considered. Second, shires and industries in Galicia could benefit from a better transportation network. Spatially weighted supply and demand variables show positive significant effects on economic growth. Interestingly, the intuition of those in the late 19th

and early 20th centuries might still be of some use in the present time. Fostering denser interindustry networks also appears to be beneficial for the region. This could be confirming the emphasis done by some strands of literature on the virtues of firm interactions (B. T. Asheim, Smith, & Oughton, 2011; Foray, 2014).

3. Concluding remarks

This paper is a preliminary attempt applying a space-industry filter to explain gross value-added growth across time, shires, and sectors in Galicia (NW Spain). Our research explores three elements of novelty in literature. First, we explore can an econometric model be improved by quantify external economies both within and across regions and industries. According to widely used indicators, the properties of our regression model improve when we introduce spatial and interindustry spillovers.

Second, we expand the use of spatial econometric techniques to study the spatial and industrial structure of Galicia, our study case. To the best of our knowledge, there are only a few contributions aimed to address Galicia´s geographical imbalances in terms of economic development. As far as we know, no contribution has used an econometric IO perspective to elaborate economic growth analysis for the Galician shires. Third, we present some preliminary results that, with further research, could lead to meaningful policy recommendations. However, we should stress again that these observations are based on rather preliminary results and cannot be understood as proper guidance to policy makers yet.

Necessary future work includes, in first place, testing our model´s properties beyond commonly used statistics. We also need to systematically check whether additional control variables can be significant or not. In second place, our model can be further revised to better test other literature hypothesises. In third place, alternative econometric strategies, such as quantile regressions could also be considered as an appropriate extension to explain agglomeration and congestion dynamics. Embedding entire interregional IO matrices in our regression models could also allow for our models to jointly consider space, time and industries. Finally, robust empirical testing requires moving from a study case towards larger datasets such as EUREGIO (Thissen, Lankhuizen, van Oort, Los, & Diodato, 2018) or the interregional dataset compiled by Huang and Koutroumpis (2023). This tasks, however, lie beyond the purpose of the present working paper.

4. References

Alonso Logroño, M. P., & Lois González, R. C. (1997). Proceso de industrialización y organización del espacio en un territorio periférico: Galicia. *Boletín de La Asociación de Geógrafos Españoles*, (24), 147–168.

Ares Fernández, J. J. (1992). La base industrial y sus especializaciones. Análisis de la diversificación y la localización. In F. González Laxe (Ed.), *Estructura económica de Galicia* (pp. 223–251). Madrid: Espasa.

Arthur, B. W. (1990). Positive Feedbacks in the Economy or technology can tilt the competitive balance. *Scientific American*, *262*(2), 92–99. https://www.jstor.org/stable/24996687

Asheim, B., Grillitsch, M., & Trippl, M. (2019). Sistemas rexionais de innovación: pasado, presente e futuro. *Revista Galega de Economía*, *28*(2), 4–22. https://doi.org/10.15304/rge.28.2.6190

Asheim, B., Smith, H. L., & Oughton, C. (2011). Regional Innovation Systems: Theory, Empirics and Policy. *Regional Studies*, *45*(7), 875–891. https://doi.org/10.1080/00343404.2011.596701

Attaran, M. (1986). Industrial diversity and economic performance in U.S. areas. *The Annals of Regional Science*, *20*(2), 44–54. https://doi.org/10.1007/BF01287240

Attaran, M., & Zwick, M. (1987). Entropy and other measures of industrial diversification. *Quarterly Journal of Business and Economics*, *26*(4), 17–34. https://www.jstor.org/stable/40472898

Barro, R. J., & Sala-i-Martin, X. (2004). *Economic Growth* (2nd ed.). Cambridge: MIT Press.

Beaudry, C., & Schiffauerova, A. (2009). Who's right, Marshall or Jacobs? The localization versus urbanization debate. *Research Policy*, *38*(2), 318–337. https://doi.org/10.1016/j.respol.2008.11.010

Beiras Torrado, X. M. (1981). *O atraso económico de Galicia* (2nd ed). Vigo: Galaxia.

Beiras Torrado, X. M. (2006). *Economía galega e autonomía política. Discurso inaugural lido na solemne apertura do curso académico 2006-2007*. Santiago de Compostela: Universidade de Santiago de Compostela, Servizo de Publicacións e Intercambio Científico.

Brakman, S., Garretsen, H., Gigengack, R., Marrewijk, C., & Wagenvoort, R. (1996). Negative feedbacks in the economy and industrial location. *Journal of Regional Science*, *36*(4), 631–651. https://doi.org/10.1111/j.1467-9787.1996.tb01122.x

Caballero Álvarez, A. (1978). Los sectores clave del crecimiento económico: el caso de Galicia. *Boletín de Estudios Económicos*, *33*(105), 45–83.

Carmona Badía, X. (2022). Mellores, pero non moi distintos: a industria na Galicia autonómica. In R. Villares (Ed.), *Os tempos son chegados. Un balance da Galicia autonómica* (pp. 160–175). Parlamento de Galicia. https://www.researchgate.net/publication/366409117

Carmona Badía, X., & Nadal, J. (2005). *El empeño industrial de Galicia*. A Coruña: Fundación Pedro Barrié de la Maza.

Cartone, A., Panzera, D., & Postiglione, P. (2021). Regional economic disparities, spatial dependence and proximity structures. *Regional Science Policy & Practice*, (August), 1–17. https://doi.org/10.1111/rsp3.12482

Combes, P. P., & Gobillon, L. (2015). The Empirics of Agglomeration Economies. In *Handbook of Regional and Urban Economics* (Vol. 5, pp. 247–348). Elsevier B.V. https://doi.org/10.1016/B978-0-444-59517-1.00005-2

Conway, R. S. (1979). Simulation properties of a regional interindustry econometric model. *Papers of the Regional Science Association*, *43*(1), 45–57. https://doi.org/10.1007/BF01935606

Fernandes, C., Farinha, L., Ferreira, J. J., Asheim, B., & Rutten, R. (2021). Regional innovation systems: what can we learn from 25 years of scientific achievements? *Regional Studies*, *55*(3), 377–389. https://doi.org/10.1080/00343404.2020.1782878

Feser, E. J. (1998). Entreprises, External Economies and Economic Development. *Journal of Planning Literature*, *12*(3), 283–302.

Foray, D. (2014). *Smart Specialisation. Opportunities and Challenges for Regional Innovation Policy*. Routledge. https://doi.org/10.4324/9781315773063

Frank, A. G. (1966). The Development of Underdevelopment. *Monthly Review*, *18*(4), 17–31.

Frenken, K., Van Oort, F., & Verburg, T. (2007). Related variety, unrelated variety and regional economic growth. *Regional Studies*, *41*(5), 685–697. https://doi.org/10.1080/00343400601120296

Garrido-Yserte, R., & Mancha-Navarro, T. (2009). The Spanish Regional Puzzle: Convergence, Divergence and Structural Change. In *Regional Policy, Economic Growth and Convergence* (pp. 103–124). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-02178-7_5

Gezici, F., & Hewings, G. J. D. (2004). Regional convergence and the economic performance of peripheral areas in Turkey. *Review of Urban and Regional Development Studies*, *16*(2), 113–132. https://doi.org/10.1111/j.1467-940X.2004.00082.x

Gil Barreiro, J. M. (2001). El atraso económico y el sistema de transporte terrestre en la Galicia del siglo XIX. *Revista Galega de Economía*, *10*(1), 1–21.

Harris, C. D. (1954). The, Market as a Factor in the Localization of Industry in the United States. *Annals of the Association of American Geographers*, *44*(4), 315–348. https://doi.org/10.1080/00045605409352140

Harvey, D. (1981). The Spatial Fix – Hegel, Von Thunen, and Marx. *Antipode*, *13*(3), 1–12. https://doi.org/10.1111/j.1467-8330.1981.tb00312.x

Hegel, G. W. F. (1821). *The Philosophy of right; The Philosophy of history*. Chicago: Encyclopaedia Britannica.

Henderson, J. V. (2003). Marshall's scale economies. *Journal of Urban Economics*, *53*(1), 1–28. https://doi.org/10.1016/S0094-1190(02)00505-3

Hewings, G. J. D. (1985). *Regional Input-Output Analysis* (Reprint; G. I. Thrall, Ed.). West Virginia University Research Repository, 2020.

Hewings, G. J. D., & Jensen, R. C. (1988). Emerging challenges in regional input-output analysis. *The Annals of Regional Science*, *22*(1), 43–53. https://doi.org/10.1007/BF01952842

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

Hirschman, A. O., & Lindblom, C. E. (1962). Economic development, research and development, policy making: Some converging views. *Behavioural Science*, *7*(2), 211–222. https://doi.org/10.1002/bs.3830070206

Huang, S., & Koutroumpis, P. (2023). European multi regional input output data for 2008–2018. *Scientific Data*, *10*(1), 218. https://doi.org/10.1038/s41597-023-02117-y

Jacobs, J. (1969). *The Economy of Cities*. New York: Vintage.

Keeble, D., Owens, P. L., & Thompson, C. (1982). Regional accessibility and economic potential in the European community. *Regional Studies*, *16*(6), 419–432. https://doi.org/10.1080/09595238200185421

Kitsos, T., Grabner, S. M., & Carrascal-Incera, A. (2023). Industrial Embeddedness and Regional Economic Resistance in Europe. *Economic Geography*, *90*(1), 1–26. https://doi.org/10.1080/00130095.2023.2174514

Krugman, P., & Venables, A. J. (1995). Globalization and the Inequality of Nations. *The Quarterly Journal of Economics*, *110*(4), 857–880. https://doi.org/10.2307/2946642

Krugman, Paul. (1991). Increasing Returns and Economic Geography. *Journal of Political Economy*, *99*(3), 483–499. https://doi.org/10.1086/261763

L´Esperance, W. L., King, A. E., & Slens, R. H. (1977). Conjoining an Ohio input- output model with an econometric model of Ohio. *Regional Science Perspectives*, *7*(2), 54–77. http://ageconsearch.umn.edu

Lahr, M. L. (2018). Regional input-output analysis: an appraisal of an imperfect world. In J. Callicó López & E. J. González Robles (Eds.), *Estudios Regionales. Un Enfoque Insumo-Producto* (pp. 213–235). Guadalajara, México: Universidad de Guadalajara. https://doi.org/10.7282/T3H1340W

LeSage, J. P., & Fischer, M. M. (2008). Spatial Growth Regressions: Model Specification, Estimation and Interpretation. *Spatial Economic Analysis*, *3*(3), 275–304. https://doi.org/10.1080/17421770802353758

LeSage, J. P., & Rey, S. J. (2002). Restrictions in Integrated Econometric + Input-Output Modeling. In G.J.D. Hewings, M. Sonis & D. Boyce (Eds.), *Trade, Networks and Hierarchies. Modelling Regional and Interregional Economies* (pp. 251-266). Berlin: Springer. https://doi.org/10.1007/978-3-662-04786-6_13

López-Rodríguez, J., & Manso-Fernández, G. (2018). A estrutura espacial de Galicia. Análise a partir do cálculo dos potenciais de mercado a nivel comarcal, 1991-2016. *Revista Galega de Economía*, *27*(2), 61–74. https://doi.org/10.15304/rge.27.2.5658

Márquez, M. A., Ramajo, J., & Hewings, G. J. D. (2015). Regional growth and spatial spillovers: Evidence from an SpVAR for the Spanish regions. *Papers in Regional Science*, *94*(November 2015), S1–S18. https://doi.org/10.1111/pirs.12102

Marshall, A. (1890). *Principles of economics*. Bristol: Overstone Press.

Martínez Filgueira, X., Peón, D., & López Iglesias, E. (2017). Intra-rural divides and regional planning: an analysis of a traditional emigration region (Galicia, Spain). *European Planning Studies*, *25*(7), 1237–1255. https://doi.org/10.1080/09654313.2017.1319465

Miller, R. E., & Blair, P. D. (2022). *Input – Output Analysis. Foundations and Extensions* (3rd ed). Cambridge: Cambridge University Press.

Myrdal, G. (1959). *Economic Theory and Under-developed Regions*. México D.F.: Fondo de Cultura Económica.

Myrdal, G. (1974). What Is Development? *Journal of Economic Issues*, *8*(4), 729–736. https://doi.org/10.1080/00213624.1974.11503225

Nathan Rosenberg. (1982). *Inside the Black Box: Technology and Economics*. Cambridge: Cambridge University Press.

Oosterhaven, J., & Hewings, G. J. D. (2014). Interregional Input–Output Models. In M. M. Fischer & P. Nijkamp (Eds.), *Handbook of Regional Science* (pp. 875–901). Berlin: Springer. https://doi.org/10.1007/978-3-642-23430-9_43

Parent, O., & LeSage, J. P. (2012). Spatial dynamic panel data models with random effects. *Regional Science and Urban Economics*, *42*(4), 727–738. https://doi.org/10.1016/j.regsciurbeco.2012.04.008

Pena López, A., & Sánchez Santos, J. M. (2008). Disparidades económicas intrarregionales a escala municipal: evidencia empírica para el caso gallego. *Revista de Estudios Regionales*, (81), 15–43.

Peón Pose, D., Martínez Filgueira, X. M., & López Iglesias, E. (2020). Productive vs. residential economy: Factors behind the recovery of rural areas in socioeconomic decline. *Revista Galega de Economía*, *29*(2), 1–30. https://doi.org/10.15304/rge.29.2.6744

Pérez Vilariño, J. (1990). As cidades alineadas do Atlántico e a economía política metropolitana en Galicia. *Revista Galega de Economía*, (0), 159–176.

Rey, S J. (1997). Integrating Regional Econometric and Input—Output Models: An Evaluation of Embedding Strategies. *Environment and Planning A: Economy and Space*, *29*(6), 1057–1072. https://doi.org/10.1068/a291057

Rey, Sergio J. (2000). Integrated regional econometric + input-output modeling: Issues and opportunities. *Papers in Regional Science*, *79*(3), 271–292. https://doi.org/10.1111/j.1435-5597.2000.tb00772.x

Rey, Sergio J., & Dev, B. (1997). Integrating Econometric and Input-Output Models in a Multiregional Context. *Growth and Change*, *28*(2), 222–243. https://doi.org/10.1111/j.1468-2257.1997.tb00771.x

Roca Cendán, M. (1982). *Lois Peña Novo: Vida e pensamento político e económico*. Sada: Ediciós do Castro.

Rodríguez González, R. (1997). Villa y comarca funcional en Galicia. *Investigaciones Geográficas (España)*, (18), 115–130.

Stevens, B. H., Treyz, G. I., & Kindahl, J. K. (1981). Conjoining an Input-Output Model and a Policy Analysis Model: A Case Study of the Regional Economic Effects of Expanding a Port Facility. *Environment and Planning A: Economy and Space*, *13*(8), 1029–1038. https://doi.org/10.1068/a131029

Thissen, M., Lankhuizen, M., van Oort, F., Los, B., & Diodato, D. (2018). *EUREGIO: The construction of a global IO DATABASE with regional detail for Europe for 2000-2010* (No. 2018-084/VI; Tinbergen Institute Discussion Paper). http://www.tinbergen.nl

Tian, Z. (2014). Exploring the Space-Industry Filter in Regional Industrial Models. *53rd Meeting of the Southern Regional Science Association*. https://www.researchgate.net/publication/309114457

Tian, Z., Gottlieb, P. D., & Goetz, S. J. (2020). Measuring industry co-location across county borders. *Spatial Economic Analysis, 15*(1), 92–113. https://doi.org/10.1080/17421772.2020.1673898

Treyz, G. I. (1993). *Regional Economic Modeling: A Systematic Approach to Economic Forecasting and Policy Analysis*. Dordrecht: Springer Netherlands. https://doi.org/10.1007/978-94-017-2874-4

Vence Deza, X. (1995). La ciencia, la tecnología y la producción en Marx: la importancia del concepto de trabajador colectivo. In *Economía de la Innovación y del cambio tecnológico: una revisión crítica* (pp. 50–105). Madrid: Siglo XXI.

Villares, R. (1994). *Congreso Agrícola Gallego de 1864*. Sada: Ediciós do Castro.

von Thunen, J. H. (1826). *The Isolated State*. Hamburg: Perthes.

West, G. R. (1995). Comparison of Input–Output, Input–Output + Econometric and Computable General Equilibrium Impact Models at the Regional Level. *Economic Systems Research*, *7*(2), 209–227. https://doi.org/10.1080/09535319500000021

White, E. N., & Hewings, G. J. D. (1982). Space-time employment modelling: some results using seemingly unrelated regression estimators. *Journal of Regional Science*, *22*(3), 283–302. https://doi.org/10.1111/j.1467-9787.1982.tb00753.x