Check for updates

Received: 11 January 2018 | Revised: 18 July 2018 | Accepted: 24 July 2018

DOI: 10.1111/twec.12723

ORIGINAL ARTICLE

WILEY The World Economy

The effect of broadband on European Union trade: A regional spatial approach

Javier Barbero[1] | **Ernesto Rodriguez-Crespo**[2]

[1]Directorate B – Growth and Innovation, Territorial Development Unit, European Commission, Joint Research Centre, Seville, Spain;

[2]Department of Economic Structure and Development Economics, Autonomous University of Madrid, Madrid, Spain

KEYWORDS

European Union, information and communication technologies, trade

1 | INTRODUCTION

The European Union (EU) and the European Monetary Union represent institutional initiatives seeking to promote European integration and foster trade flows by abolishing trade tariffs within EU Member States. However, intra-European trade integration has not reached its full potential, according to Chen and Novy (2011), as technical barriers to trade still impede trade within the EU, which raises the importance of implementing trade policies aimed at reducing trade costs within the EU.

Policy measures that stimulate regional trade are necessary, such as those aimed at improving network infrastructure and those targeted at achieving greater access to information and communication technologies (ICT). These two goals are among the key objectives of the European cohesion regional policy 2014–2020 as they constitute a vehicle to reduce disparities among regions and foster European integration (European Commission, 2014a). In an ambitious context of implementing a digital agenda, initiatives such as the connected digital single market and high-speed infrastructure abolishing non-tariff barriers are among the ten priorities of the European Commission's President Jean-Claude Juncker (European Commission, 2014b). These measures are in line with the existence of knowledge flows, which are basic to study and understand regional development (Karlsson , Maier, Trippl, Siedschlag, Owen, & Murphy, 2010).

The objective of this paper is to study the effect of broadband on trade focusing on a regional context in Europe, where ICT may foster European trade integration. Our paper contributes to the existing literature in three ways. First, we use a novel and consistent regional trade database estimated by Thissen, van Oort, Diodato, and Ruijs (2013) that covers trade between and within European regions, allowing for a greater assessment of the current stage regarding European economic integration and providing accurate territorial-based policy recommendations. In a context of scarce regional trade data, we shed light on the effect of ICT infrastructure on trade at regional level in

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2018 The Authors. *The World Economy* Published by John Wiley & Sons Ltd

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Europe. This novel regional trade database has not yet been used to explain the effect of ICT on trade at regional level. Our analysis is highly constrained by the availability of regional statistics and because the variable measuring broadband has been collected only for 2 years. Due to these constraints, we limit our analysis to 2007 and 2010.

Second, we incorporate regional broadband as an ICT infrastructure proxy to contribute to the debate on the effect of infrastructure on trade at regional level in Europe, a topic that has not been treated in previous studies. The current literature about the regional effect of infrastructure on trade has mainly focused on logistics (Alama, Marquez, Navarro, & Suarez, 2015; Alama, Marquez, & Suarez, 2013; Márquez-Ramos, 2016) rather than ICT infrastructure. The only exception is Bensassi, Marquez, Martinez, and Suarez (2015), who incorporate ICT infrastructure, but they only study regional exports from Spain and the priority of the study is logistics, in line with the previous literature. Given that European integration is a wide process that affects European regions as a whole, the inclusion of the highest possible number of regions provides an accurate and consistent explanation of trade patterns and how ICT infrastructure affects them.

Third, this regional framework for ICT infrastructure allows us to explore the existence of spatial dependence, relaxing the assumption of independence of individual flows between regions (LeSage & Pace, 2008). Using spatial econometrics, we are able to control how bilateral trade is affected, not only by the own exporter and importer regional factors, but also how trade performance concerning neighbouring regions affects the bilateral trading relationship between two regions. Hence, we are able to control the existence of neighbouring trade spillovers, which may benefit the bilateral relationship between exporter and importer regions. To address the issue of potential endogeneity of broadband, we follow an instrumental variable approach that exploits the relationship between broadband and household access to Internet.

The rest of the paper is organised as follows. Section 2 is devoted to the theoretical framework, while Section 3 focuses on the literature review. Section 4 presents the methodology, Section 5 explains the variables and data sources, and Section 6 focuses on the estimation results. Finally, Section 7 presents the conclusions and policy recommendations.

2 | THEORETICAL AND CONCEPTUAL FRAMEWORK

2.1 | Theoretical framework: how ICT affects trade

Understanding the role of trade costs is the first step to explain the effect of ICT on trade. ICT contributes to the generation and diffusion of information flows across territories, regardless of territorial disaggregation. Higher ICT use and a greater amount of ICT infrastructure decrease fixed transaction costs which include, among others, entry costs to foreign markets (Freund & Weinhold, 2004), coordination costs related to the production processes (Demirkan, Goul, Kauffman, & Weber, 2009), interaction costs between the firm and the customer (Adjasi & Hinson, 2009) and information costs, such as the customer being able to easily compare the prices set by different sellers (Jungmittag & Welfens, 2009).

Beyond trade costs, there are other channels through which ICT impacts on trade. Complementarities between ICT and innovation cannot be neglected, given that technological progress is related not only to exogenous technology, but also to investments in research and development (Grossman & Helpman, 1995). Innovation also affects trade, and Ghalazian and Furtan (2007) identify the existence of three channels: (i) innovation increases product differentiation; (ii) innovation reduces the costs of production; and (iii) innovation lowers transaction costs. A large degree of innovation is thus related to the existence of a comparative advantage.

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

The structure of production also affects the impact of ICT on trade. Traditional trade theories focused on the volume of trade, where trade flows entirely take place from a specific origin to a specific destination. The Heckscher-Ohlin framework focused on a context of interindustry trade, where the factor endowments anticipated the trade specialisation of countries in different product categories. More recent trade theories explain intra-industry trade, as international trade data show that countries trade different varieties of goods of the same industry (Krugman, 1980). Increasing product sophistication, with a higher demand of inputs, defies these trade theories because production is becoming progressively multi-stage. Hence, firms can decide to produce intermediate inputs at home or abroad through foreign direct investment flows (Antràs & Helpman, 2004).

In this context of multi-stage production, global value chains are completely reshaping international trade by engaging multiple countries in production networks (Baldwin, 2016). Through information and knowledge flows, ICTs contribute to the organisation of global value chains due to the offshoring of manufacturing and other enterprise functions (Grossman & Rossi-Hansberg, 2008). As a consequence, ICTs increase the international fragmentation of production with a higher number of countries engaging in global value chains and hence in international trade (Antràs & Chor, 2013; Juhász & Steinwender, 2018; Overman, Redding, & Venables, 2003).

2.2 | The importance of regions

The current global dispersion of production induced by multi-stage production implies firms' management of different branches separated by large distances due to the reduction of information costs. However, Baldwin (2016) still accounts for the existence of a new spatial paradox where firms tend to form regional clusters despite the global dispersion of production. Accordingly, it is important to shed light about the role of regions engaging in trade, and the effect of ICT on trade does not constitute an exception.

We support the importance of regions using a main statement: distance still matters at the regional level, so that the intensity of knowledge flows increases with greater territorial disaggregation. According to Capello and Spairani (2004), the macroeconomic approach cannot capture the behavioural component of firms' performance. Firms' capacities at the local level actually determine the total capacity of aggregate areas, which is crucial to study the effect of information and knowledge flows (Miguélez & Moreno, 2015). The concept of milieu illustrates this fact: the transmission of knowledge is more rapid at the local level and overcomes problems of hierarchy due to the intensity of face-to-face relationships (Philippopoulos, 2016). Tranos and Nijkamp (2013) show that distance is still relevant to explain the diffusion of Internet at regional level, even after controlling for proximity.

To overcome the effect of the distance, firms agglomerate at the regional level to share information flows. This evidence is materialised through the reduction of different export costs. Information and communication technologies reduces transaction costs due to reductions in spatial information frictions (Karlsson et al., 2010; Sichel, 1997). Information and communication technologies can also change urban structure by decreasing the cost of communication and increasing the incentives for firms to move to smaller urban centres (Ioannides, Overman, Rossi-Hansberg, & Schmidheiny, 2008). Information and communication technologies may lower fixed costs of face-to-face interactions at local level (Gaspar & Glaeser, 1998). Consequently, proximity to individuals with a larger degree of knowledge enables acquiring new skills and the diffusion of knowledge (Duranton & Puga, 2005). As pointed before, this reduction in costs is crucial to facilitate trade.

This context of information flows affecting trade at local level leads us inevitably to the European Union, where the ICT's agenda has a prominent role (European Commission, 2014b).

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Departing from this theoretical framework, it is relevant to study the effect of ICT on trade between European regions. In the following section, we do a literature review about studies measuring the ICT impact on trade. Although it is necessary to shed light at the territorial level in Europe about this topic, the evidence is scarce.

3 | LITERATURE REVIEW

3.1 | Empirical evidence about the effect of ICT on trade

To explain the effect of ICT on trade, the literature follows two approaches: ICT usage and ICT infrastructure. Both variables can be studied separately or simultaneously either by constructing a weighted index or by incorporating them as explanatory variables.

Depending on the variable used to measure the effect of ICT on trade, we distinguish three sets of studies: the first set considers ICT use solely, which constitutes the majority of research in the literature. The effect of ICT use on exports has mainly been studied at country level. Freund and Weinhold (2002), using a sample of 31 countries in 2000, find that Internet boosts US trade in services, and Freund and Weinhold (2004), with a sample of 54 countries from 1995 to 1999, also find a positive effect of Internet use on trade. Clarke and Wallsten (2006) study 98 trading countries in 2001 and find a positive effect of Internet use on trade. Lin (2015) focuses on international trade within 200 countries during the period 1990–2006 and finds a positive effect of Internet use on exports.

The second dimension relates to the effect of ICT infrastructure on trade. This framework combines studies at country, region and firm levels. Portugal-Perez and Wilson (2012) generate a weighted ICT-based index for a sample of 101 countries and find a positive effect of ICT infrastructure on exports, and this effect is stronger in developing countries. Abeliansky and Hilbert (2017) compare the effect of ICT use and infrastructure on trade for 122 countries during 1995–2008. They find how ICT use is more important for developed countries, but ICT infrastructure is more important for developing countries. For the case of ICT infrastructure at the firm level, Kneller and Timmis (2016) using data from 46,720 UK firms from 2000 to 2005 find that broadband and narrowband increase trade in services.

3.2 | Further research: empirical evidence about the role of regional trade

In spite of the relevance of shedding light about the effect of broadband on trade at the regional level in Europe, the literature is scarce. The main reason is the lack of official regional trade statistics in Europe. Only a few authors have attempted to estimate regional trade flows for European regions: Llano, Esteban, Pulido, and Pérez (2010) estimate exports from Spanish to European regions during the period 1995–2010, through the C-intereg database. Thissen et al. (2013) estimate trade flows for a sample of 232 European regions trading with each other during the period 2000–2010. Both approaches are totally consistent to use in empirical estimations and capture the geography of European regions accurately.

Departing from this scarcity of data, different authors have estimated regional trade performance in Europe using the C-intereg database. These studies, however, are mainly devoted to studying the impact of port facilities on trade (Alama et al., 2013, 2015; Márquez-Ramos, 2016) or the border impediments to trade (Gallego & Llano, 2014, 2015).

Bensassi et al. (2015) study the effect of broadband on trade at regional level. Using a sample of Spanish regions exporting to 45 countries, their main objective is to study the impact of logistics on trade, in line with the previous literature. With the aim of measuring logistic quality, they

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

also introduce capital stock in information technology for the pre-crisis period 2003–07 and find a positive effect between the stock of ICT and exports.

4 | METHODOLOGY

4.1 | Spatial dependence in trade flows

To fill the gaps detected in the literature review, the objective of this study is to empirically test the effect of broadband on regional trade among European regions, as this will allow for more accurate economic policies at regional level in Europe. To accomplish this objective, we estimate a gravity model of bilateral trade, also known as an origin–destination flow model.

Since the seminal contributions by Anselin (1988), spatial econometrics claims that dependence and spatial heterogeneity in the field of regional economics must be considered to obtain consistent and unbiased results. Consequently, we proceed to augment our gravity equation with spatial econometrics.

The prior step to using spatial econometrics is to test for the presence of spatial dependence. For this purpose, we use the *I* index created by Moran (1950). We hereby show the expression of Moran's *I* index quantifying spatial dependence:

$$I = \frac{N}{\Sigma_i \Sigma_j w_{ij}} \frac{\Sigma_i \Sigma_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\Sigma_i (x_i - \bar{x})^2}, \tag{1}$$

where subscripts *i* and *j* denote origin and destination locations, respectively. w_{ij} represent the specific element *ij* of the contiguity matrix W, and *x* is our variable of interest, whose spatial dependence is tested. Finally, *N* is the total number of spatial units. The contiguity matrix, *W*, is a binary matrix whose elements *ij* are equal to 1 if regions *i* and *j* are contiguous and equal to zero otherwise.

LeSage and Pace (2008) and LeSage and Thomas-Agnan (2015) extend the Anselin (1988) paradigm to define an origin–destination spatial gravity model for regional trade by distinguishing three types of spatial dependence. Considering trade flows from region *A* to region *B*: (i) the origin-based dependence captures the spatial relationship of trade flows from neighbours of *A* to *B*; (ii) the destination-based dependence considers the relationship from *A* to neighbours of *B*; and (iii) the origin–destination-based dependence captures the relationship of trade flows from neighbours of *A* to neighbours of *B*.

These three types of spatial dependence can be expressed using three different matrices: W_O, W_D, and W_{OD} for origin-based, destination-based and origin–destination-based dependences, respectively:[1]

$$\begin{aligned} W_O &= I_n \otimes W, \\ W_D &= W \otimes I_n, \\ W_{OD} &= W_O W_D, \end{aligned} \tag{2}$$

where *W* is the row-standardised contiguity matrix between regions, I_n is the identity matrix and $\otimes$ denotes the Kronecker product.[2]

[1]In this paper, we adopt the destination-centric ordering of the data (LeSage & Pace, 2008) and we write the spatial matrices accordingly.

[2]If the *W* matrix is row-standardized—all rows sum to one—the product of *W* by a variable *x*, *Wx*, is a weighted average of the values of *x* of the neighbouring regions.

We follow this framework, and we incorporate elements denoting spatial proximity in (2) into the gravity equation, in line with other studies (Alama et al., 2013, 2015; Márquez-Ramos, 2016).

$$\begin{aligned}\ln Trade_{ij} = {} & \beta_0 + \beta_1 \ln BRB_{i,t-1} + \beta_2 \ln BRB_{j,t-1} + \beta_3 \ln\left(GDP_i \times GDP_j\right) \\ & + \beta_4 \ln(GDPpc_i) + \beta_5 \ln\left(GDPpc_j\right) + \delta_z\, z_{ij} + \rho_1 W_O \ln Trade_{ij,t} \\ & + \rho_2 W_D \ln Trade_{ij,t} + \rho_3 W_{OD} \ln Trade_{ij,t} + u_{ij},\end{aligned} \tag{3}$$

where subscripts i and j refer to the exporting and importing regions, respectively, and ln denotes the natural logarithm of the variable. $Trade_{ij}$ are the trade flows from region i to region j, $BRB_{i,t-1}$ and $BRB_{j,t-1}$ are the 1-year lagged ICT broadband infrastructure of the exporter and the importer, respectively, $GDP_i \times GDP_j$ is the product of GDP of the trading regions, and $GDPpc_i$ and $GDPpc_j$ are the GDP per capita of the exporter and the importer regions, respectively. z_{ij} is a vector of time-invariant bilateral trade variables, including the distance between regions, $Distance_{ij}$, dummy variables that control for regions and countries sharing a common border, $RegionContiguity_{ij}$ and $CountryContiguity_{ij}$ respectively, a dummy variable that accounts for domestic trade flows, $Domestic_{ij}$, and a variable that takes the value of one if both trading regions are part of the same country and zero otherwise, $SameCountry_{ij}$.

The rationale for including these variables is as follows. *BRB* is our variable of interest, and we expect a positive coefficient as broadband reduces trade costs and facilitates communication between trading regions. Country size and distance have accompanied gravity models since the start as explanatory variables, given that bilateral trade increases with higher GDP and decreases with greater distances. Despite the advances in ICT and the reductions in transport costs in the last decades, distance is still a relevant component to explain trade patterns (Florax, Groot, Linders, & Nijkamp, 2011). Given that GDP does not fully capture the economic development of a region, we follow Egger (2005) and introduce GDP per capita as an additional indicator to complement GDP, which we expect will have a positive relation with bilateral exports.

The inclusion of control variables for country and regional contiguity is in line with prior studies. At country level, contiguity is related to the observable measures of trade costs (Anderson, 2011). As Eaton and Kortum (2002) show how distance increases geographical barriers to trade and weakens comparative advantage, the fact of sharing a common border tends to concentrate trade flows between the specific countries sharing the border. In the context of regional trade, Lafourcade and Paluzie (2011) state how those regions located close to the borders tend to concentrate a larger share of trade flows.

Moreover, we include a set of control variables to capture additional effects concerning trade within and between regions. In the case of regional trade, as indicated before, the border effect has been included since McCallum's (1995) seminal paper. Other authors have also found significant border effects (Daumal & Zignago, 2010; Gallego & Llano, 2015). As a result of this, we follow Gallego and Llano (2014) to control for trade flows between contiguous regions using dummy variables. Controlling for trade flows partially corrupted due to using parameterised estimations is a concern when working with regional trade databases to avoid flawed results. This is the reason to control for domestic trade flows specifically. Parameters ρ_1, ρ_2 and ρ_3 denote the spatial origin, destination and origin–destination neighbouring effect, respectively, and constitute the spatial autoregressive parameters in the gravity equation. The inclusion of these spatial interaction parameters allows us to account for cross-sectional dependence of trade flows and hence to control directly for the existence of MRTs (Behrens, Ertur, & Koch, 2012; LeSage & Pace, 2009). If $\rho_1 = \rho_2 = \rho_3 = 0$, implying the rejection of spatial dependence, the specification reduces to the standard regional gravity equation augmented with broadband.

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

4.2 | The presence of endogeneity in the gravity equation

The inclusion of spatial lags of the dependent variables in the model introduces endogeneity. Kelejian and Prucha (1998) introduce a generalised spatial two-stage least-squares estimator. Drukker, Egger, and Prucha (2013) extend this model allowing for additional endogenous regressors and suggest using the exogenous explanatory variables and their first and second-order spatial lags as instruments, to control for the endogeneity of the spatial lags, and other external instruments to control for the endogeneity of the additional endogenous regressors.

Another potential endogeneity problem arises when studying the empirical relationship between ICT and trade. In the context of the effect of bilateral trade agreements on exports, Baier and Bergstrand (2007) identify three potential and universal causes for endogeneity: variable measurement errors, reverse causality and omitted variable bias. Endogenous variables decrease the magnitude of coefficients and are a major concern for trade theory (Trefler, 1993).

Empirical studies examining the effect of ICT on exports under a gravity model approach cite endogeneity due to reverse causality as a major shortcoming (Clarke & Wallsten, 2006; Freund & Weinhold, 2004), while other authors also point to the existence of omitted variable bias (Freund & Weinhold, 2002).

Solutions to this problem range from pure theoretical modelling (Freund & Weinhold, 2004) to suitable empirical estimators, with instrumental variables being most common methodology (Adjasi & Hinson, 2009; Clarke & Wallsten, 2006; Kneller & Timmis, 2016). The task of finding a suitable instrument for ICT at the regional level is challenging due to the lack of data sources for the time period of the sample. However, we can exploit the relationship between ICT infrastructure and household access to Internet to construct a suitable instrument. Usage of ICT by firms and household relies on the existence of an installed cable network, revealing the percentage of households with access to Internet as a suitable instrument for ICT infrastructure. Our instrumental variable at the regional level, the percentage of households with access to Internet, has also been used in previous studies to control for the endogeneity of ICT (Abramovsky & Griffith, 2006), and it is in line with the instruments for broadband chosen in other studies, such as the number of IP addresses (Timmis, 2013) or the population residing in dwellings (Dettling, 2017).

The difference of time spans between the instruments and the explanatory variables are not a major shortcoming for our study. In fact, the consideration of ICT as general-purpose technologies (Helpman & Trajtenberg, 1998) shows how the adoption of ICT by households and firms requires time to evaluate the benefits involved in using new technologies. Accordingly, we can also explore the use of household access to Internet in future years as instruments of ICT infrastructure in the current time period. Given that the instrument and the explanatory variables are from different time periods, they are not affected by shocks occurring in the same time period.

5 | DATA AND VARIABLES

Although information flows are more intense at regional level and regional studies may capture more accurately the economic geography, the lack of official trade data between regions and within countries is the reason for the scarcity of empirical trade studies at the regional level on the effect of broadband on trade. To this extent, we use a novel regional trade data set that covers trade within a representative number of European regions. For this analysis, we consider trade regarding 232 European regions at the NUTS 2 level. The time period considered is two cross-sections at 2007 and 2010. Although greater time periods allow implementing panel data techniques to

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

capture the evolution of the variables overtime, regional statistics force us to overcome the problem of fitting and harmonising data from three different databases described below and adjust them to the same time period. For our harmonised and homogenised analysis, the data are coincident only at two specific time periods: 2007 and 2010.

We now describe the main features concerning Thissen et al.'s (2013) regional trade database. Using freight data and following the theoretical roots dictated by the NEG, Thissen et al. (2013) apply a supply-and-use methodology to European trade statistics at the country level and assign regional weights to obtain regional trade flows for European regions at the NUTS 2 level. By considering additional features like the fact of re-exporting, Thissen et al. (2013) apply corrections to guarantee non-dependent and consistent regional trade data, a fact which creates a novel database completely suitable for empirical estimations. Both inter and intraregional trade flows are estimated using freight data exclusively and without using a parameterised NEG models. Thissen et al.'s (2013) regional trade database covers the periods 2000–10, and it does not contain zeros in the data, so we are relieved from issues related to the logarithm of zeros for the dependent variable.

Using Thissen et al.'s (2013) database entails a major problem. One of the potential data issues is the estimation of domestic trade flows, which are defined as trade flows occurring within a region, at the local level. In contrast to inter and intraregional trade flows, domestic trade data are estimated using a NEG model with parameters. Hence, these domestic trade data suffer a cross-hauling issue that arises due to the impossibility of not accounting for simultaneous trade of a coincident product category between two regions within the same country. Cross-hauling data imply that this simultaneous domestic trade is unaccounted, so domestic trade data may be partially corrupted. As we point out in Results section, by implementing regressions with and without domestic trade flows, we find that using cross-hauling domestic trade flows does not imply problems with either the estimation or the interpretation of the coefficients.

The ICT broadband infrastructure is the main variable of our analysis, resulting from the average of three regional indicators related to the information society: international Internet backbone capacity, peak traffic at IXP and IP addresses. Data are available only for 2006 and 2009, which limits us to a cross-sectional analysis exclusively.

The regional broadband data are retrieved from ESPON (European Spatial Planning Observation Network), a programme funded by the 28 European Member States plus Iceland, Lichtenstein, Norway and Switzerland, whose main objective is to develop accurate regional-based indicators to redesign the European territorial development.

For the instrumental variable of percentage of households with access to Internet at home at regional and country levels, we use data from Eurostat. For 2007 and 2010, the regional variable is only available for 72 and 114 regions in our sample, respectively, whereas for 2014 and 2017, it is available for 137 and 139 regions, respectively. At country level, this information is available for all countries in our sample for the four time periods. Moreover, the correlation between current and future rates of household access to Internet is very high, and the rate has increased for all regions and countries.[3]

Even though we use different sources to create our database, all of the variables are harmonised and consistent, so our results are not biased due to data collection issues. Table A1 in the Appendix shows the list of variables and their source, while Table A2 displays the main descriptive statistics.

[3]Correlation between the rates of households with access to the Internet at country level is equal to 0.945, between 2007 and 2014 data, and 0.957, between 2010 and 2017, respectively.

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 1 Moran's I test of spatial dependence

Spatial dependence	Origin		Destination		Origin to destination	
Year	2007	2010	2007	2010	2007	2010
Observed Moran I	0.5893	0.5837	0.6097	0.6103	0.3836	0.3789
Expected Moran I	−0.0001	−0.0001	−0.0001	−0.0001	−0.0001	−0.0001
p-value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

6 | RESULTS

In this section, we present the results obtained for the gravity regression. We proceed as follows: First, we test for spatial dependence computing the Moran's I index on the residuals of the non-spatial gravity equation estimations.[4] Second, after finding spatial dependence in the residuals, we estimate the spatial origin–destination gravity Equation (3) using a two-step instrumental variable estimator under different specifications to correct for the possible endogeneity of the broadband variable.

Table 1 displays the results for the Moran's test calculation by comparing the observed Moran's *I* index with the expected one under the null hypothesis with no spatial dependence. Results support the existence of spatial dependence under the consideration of the three types of spatial dependence—origin-based, destination-based, and origin–destination-based—simultaneously. The existence of spatial dependence is in line with other studies covering trade at regional level (Alama et al., 2013, 2015; Márquez-Ramos, 2016). In the context of our study, this spatial dependence takes place with broadband as an explanatory variable, implying that the increase in regional trade flows may occur not only due to higher broadband, but also because neighbouring regions' trade patterns influence bilateral trade flows.

The existence of spatial dependence would lead to biased estimated coefficients if the true model is spatial and OLS is estimated (LeSage & Pace, 2009). To produce unbiased estimates, we estimate the spatial gravity model presented in (3).

Tables 2 and 3 present the estimation results for both time periods, respectively. Model (1) controls for the endogeneity of the spatial lags of the dependent variable, whereas the rest of the models also control for the endogeneity of the broadband variables using different instruments. In model (2), we use 7-year lead values of regional household access to Internet. As this variable is not available for all regions, the sample size of this model is smaller. In models (3) and (4), broadband is instrumented using country-level variables of household access to Internet in the current period and with 7-year lead values, respectively. Finally, model (5) uses 7-year lead values of access to Internet at regional level and country data when regional is not available to maintain the full sample. Descriptive statistics of these instruments are presented in Table A3 in Appendix.

For each model, we report *F*-statistics of weak instruments, revealing that the instruments are significantly correlated with the spatial lags of the dependent variable and with the origin and destination broadband variables. Testing for over-identification in spatial models is less important as over-identifying restrictions are included in the model using the instruments proposed by Drukker et al. (2013) to control for the endogeneity of the spatial lag of the dependent variable—by including the first and second-order spatial lags of all exogenous variables.

[4]Estimation results of the non-spatial gravity equation are available under request.

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 2 Instrumental variables' spatial two-stage least-squares results for 2007

Model	(1)	(2)	(3)	(4)	(5)
$\ln(BRB_{i,t-1})$	0.046***	0.149***	0.090***	0.090***	0.076***
	(0.002)	(0.006)	(0.004)	(0.004)	(0.004)
$\ln(BRB_{j,t-1})$	0.020***	0.090***	0.026***	0.026***	0.006
	(0.002)	(0.006)	(0.004)	(0.004)	(0.004)
$\ln(GDP_i \times GDP_j)$	0.451***	0.466***	0.448***	0.448***	0.458***
	(0.006)	(0.010)	(0.007)	(0.007)	(0.007)
$\ln(GDPpc_i)$	−0.177***	−0.328***	−0.201***	−0.201***	−0.202***
	(0.006)	(0.013)	(0.006)	(0.006)	(0.006)
$\ln(GDPpc_j)$	−0.214***	−0.334***	−0.207***	−0.207***	−0.201***
	(0.006)	(0.013)	(0.006)	(0.006)	(0.006)
$\ln(Distance_{ij})$	−0.337***	−0.394***	−0.343***	−0.343***	−0.343***
	(0.007)	(0.013)	(0.008)	(0.008)	(0.007)
$RegionContiguity_{ij}$	−0.527***	−0.493***	−0.444***	−0.444***	−0.481***
	(0.025)	(0.040)	(0.026)	(0.026)	(0.026)
$CountryContiguity_{ij}$	0.371***	0.491***	0.407***	0.407***	0.388***
	(0.009)	(0.018)	(0.009)	(0.009)	(0.009)
$Domestic_{ij}$	5.342***	4.128***	5.312***	5.312***	5.317***
	(0.044)	(0.072)	(0.045)	(0.045)	(0.045)
$SameCountry_{ij}$	0.498***	1.536***	0.547***	0.547***	0.521***
	(0.013)	(0.031)	(0.013)	(0.013)	(0.013)
Intercept	4.484***	7.878***	4.799***	4.799***	4.640***
	(0.101)	(0.214)	(0.106)	(0.106)	(0.104)
$W_O \ln(Trade)_{ij}$	0.457***	0.325***	0.439***	0.439***	0.455***
	(0.007)	(0.012)	(0.007)	(0.007)	(0.007)
$W_D \ln(Trade)_{ij}$	0.464***	0.315***	0.418***	0.418***	0.429***
	(0.007)	(0.012)	(0.007)	(0.007)	(0.007)
$W_{OD} \ln(Trade)_{ij}$	−0.446***	−0.279***	−0.410***	−0.410***	−0.424***
	(0.007)	(0.013)	(0.008)	(0.008)	(0.008)
Weak instruments F					
$W_O \ln(Trade)_{ij}$	1,278***	883***	1,581***	1,581***	1,599***
$W_D \ln(Trade)_{ij}$	1,262***	923***	1,656***	1,656***	1,673***
$W_{OD} \ln(Trade)_{ij}$	2,834***	1965***	3.188***	3.188***	3,226***
$ln(BRB_{i,t-1})$		333***	809***	809***	871***
$ln(BRB_{j,t-1})$		333***	809***	809***	879***
Adjusted R^2	0.887	0.875	0.881	0.881	0.883
Observations	52,441	18,769	52,441	52,441	52,441
Regions	229	137	229	229	229
Countries	23	19	23	23	23

Notes: Standard errors in parentheses. ***Denote coefficient significant at 1%. The dependent variable in all regressions is the logarithm of trade flows.

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE 3 Instrumental variables' spatial two-stage least-squares results for 2010

Model	(1)	(2)	(3)	(4)	(5)
$ln(BRB_{i,t-1})$	0.066***	0.200***	0.120***	0.120***	0.115***
	(0.003)	(0.008)	(0.005)	(0.005)	(0.005)
$ln(BRB_{j,t-1})$	0.014***	0.115***	0.028***	0.028***	0.020***
	(0.003)	(0.007)	(0.005)	(0.005)	(0.005)
$\ln(GDP_i \times GDP_j)$	0.450***	0.364***	0.421***	0.421***	0.422***
	(0.006)	(0.011)	(0.008)	(0.008)	(0.008)
$\ln(GDPpc_i)$	−0.169***	−0.307***	−0.177***	−0.177***	−0.179***
	(0.006)	(0.013)	(0.007)	(0.007)	(0.007)
$\ln(GDPpc_j)$	−0.243***	−0.327***	−0.224***	−0.224***	−0.221***
	(0.007)	(0.013)	(0.007)	(0.007)	(0.007)
$\ln(Distance_{ij})$	−0.360***	−0.353***	−0.351***	−0.351***	−0.348***
	(0.008)	(0.013)	(0.008)	(0.008)	(0.008)
$RegionContiguity_{ij}$	−0.517***	−0.564***	−0.463***	−0.463***	−0.485***
	(0.027)	(0.042)	(0.028)	(0.028)	(0.028)
$CountryContiguity_{ij}$	0.384***	0.507***	0.411***	0.411***	0.402***
	(0.009)	(0.019)	(0.010)	(0.010)	(0.010)
$Domestic_{ij}$	5.522***	4.578***	5.529***	5.529***	5.539***
	(0.047)	(0.074)	(0.048)	(0.048)	(0.047)
$SameCountry_{ij}$	0.457***	1.471***	0.503***	0.503***	0.492***
	(0.013)	(0.032)	(0.014)	(0.014)	(0.014)
Intercept	4.787***	7.636***	4.829***	4.829***	4.768***
	(0.113)	(0.221)	(0.116)	(0.116)	(0.115)
$W_O \ln(Trade)_{ij}$	0.441***	0.355***	0.438***	0.438***	0.448***
	(0.007)	(0.012)	(0.008)	(0.008)	(0.008)
$W_D \ln(Trade)_{ij}$	0.443***	0.343***	0.407***	0.407***	0.415***
	(0.007)	(0.012)	(0.008)	(0.008)	(0.008)
$W_{OD} \ln(Trade)_{ij}$	−0.422***	−0.297***	−0.398***	−0.398***	−0.406***
	(0.008)	(0.013)	(0.008)	(0.008)	(0.008)
Weak instruments *F*					
$W_O \ln(Trade)_{ij}$	1,039***	707.5***	1,321***	1,321***	1,325***
$W_D \ln(Trade)_{ij}$	979***	744.6***	1,424***	1,424***	1,441***
$W_{OD} \ln(Trade)_{ij}$	2,352***	1,491.0***	2,686***	2,686***	2,702***
$ln(BRB_{i,t-1})$		524.9***	1,304***	1,304***	1,307***
$ln(BRB_{j,t-1})$		524.9***	1,304***	1,304***	1,403***
Adjusted R^2	0.879	0.870	0.875	0.875	0.877
Observations	53,824	19,321	53,824	53,824	53,824
Regions	232	139	232	232	232
Countries	23	19	23	23	23

Notes: Standard errors in parentheses. ***Denote coefficient significant at 1%. The dependent variable in all regressions is the logarithm of trade flows.

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

In all the models, *F*-values for each instrumented variable first-stage regressions exceed the threshold of 10, showing that the instrumental variable can be considered strong, in line with Staiger and Stock (1997).

Estimation results for model (2) are the ones that display the largest differences with respect to the other models. This is attributed to the reduction in sample size. Nevertheless, all coefficients are significant and of the same sign as in the other estimated models. Results for models (3) and (4) are almost identical due to the high correlation between the current and future household Internet access instrumental variables.

In all estimations, the three spatial lag parameters, ρ_1, ρ_2, and ρ_3, are statistically significant, implying that trade flows are not only affected by factors concerning the two trading regions, but also positively affected by the existing trade between neighbouring regions, and that it is important to consider the three kinds of spatial dependence: origin, destination and origin to destination.

Results show that the estimated effect of broadband on trade is positive and statistically significant for both the exporter and the importer region, in line with the previous literature at country level. The positive broadband coefficients are greater for the exporter than for the importer region both in 2007 and in 2010. Coefficients are slightly higher in the year 2007 than in 2010. Also, the broadband coefficients are always positive and significant, not depending on the ICT variable to be used as instrument. We find that our highest broadband coefficient for the exporter region, 0.200, is between the range obtained at country level (0.05, Freund & Weinhold, 2002; 0.02, Freund & Weinhold, 2004; 0.335, Lin, 2015; 0.514, Abeliansky & Hilbert, 2017) and lower than the one obtained at regional level (0.341, Bensassi et al., 2015).

These positive and significant coefficients for broadband hold across the different estimated models for both periods, with the exception of model (5) for 2007, which is positive but not significant. To sum up, our results imply the following consequences for the effect of broadband on trade at regional level: first, the greater broadband coefficients for the exporter regions suggest that these regions benefit more from a reduction of trade costs due to broadband usage. Second, although the coefficients are slightly lower in 2010 than in 2007, we find that there are still opportunities to increase the adoption of broadband. Third, our results are in line with those obtained at previous studies at country level, but lower than Bensassi et al.'s (2015) coefficients at the regional level. This fact may be explained because we do not only restrict to exports from Spanish regions, but also incorporate a wide range of EU regions. These regions present different rates of broadband adoption than Spanish regions.

The distance coefficients are in line with the negative effect expected in the basic gravity models. As stated before, coefficients are larger for the spatial gravity in the presence of sparse matrices than for the traditional gravity equation. Negative but significant coefficients for GDP per capita denote the existence of an absorption effect—an inverse relationship between income per capita and trade flows (Márquez-Ramos, 2016).

Control variables are positive and strongly significant with the exception of $RegionContiguity_{ij}$ when origin or destination spatial dependence is considered, as the introduction of spatial dependence mitigates the effect of regional contiguity and trade spillovers capture part of the effect of contiguity. Finally, both variables $Domestic_{ij}$ and $SameCountry_{ij}$ are positive and significant, as expected. Given the large magnitude of coefficients denoting domestic trade, this fact reinforces the existence of a home bias, where consumer preferences are oriented towards the consumption of domestic products and a large trade share concentrates within regions, rather than between regions (Daumal & Zignago, 2010; Gallego & Llano, 2015; McCallum, 1995).

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

7 | CONCLUSIONS

In contrast to previous studies only examining the effect of ICT on trade at country level or only a minority of EU regions, we have focused on EU regions as a whole, given the ambitious measures concerning ICT adoption in Europe, as well as the efforts to promote further trade integration beyond the liberalisation of tariffs between EU Member States. For this purpose, we use a novel regional trade database to evaluate the effect of broadband on regional trade in a large sample of 232 European regions in two specific years: 2007 and 2010, using a gravity framework. After confirming the existence of spatial dependence, we use a specific spatial estimator tailored for large databases which avoids flawed results. We find evidence of a positive and significant effect of broadband on trade, and the relative importance of broadband for the exporter and the importer regions depends on the type of spatial dependence under consideration. Proximity between regions increases the effect of ICT on trade due to the knowledge exchange in trade spillovers.

Although these results may seem to be a mere replication of the positive relationship between ICT and trade for countries applied to regions, it is important to remark how information flows exchange is more intense at regional level, as well as the importance of defining accurate territorial-based policies rather than neutral: these policies are expanded from the core to the remaining territories (McCann & Rodriguez-Pose, 2011) and this is particularly relevant for our study in the light of the spatially based neighbourhood effects. Thus, it is important to shed light on the role of regional performance in Europe, a topic which we cover using a novel regional trade database.

Our results can be relevant for policy recommendations moving towards efficient allocation of European budget: apart from the aforementioned territorial-based development policies, the initiative of smart specialisation in Europe requires identifying elements acting as regional comparative advantage (European Commission, 2014c). In our case, we find how both ICT and proximity can help to trigger regional trade competitiveness. In addition to that, these results can contribute to the assessment of EU Cohesion Policy 2014–20, where regional disparities still persist in Europe. More specifically, proximity and ICT usage as a tool to promote inter-regional trade would alleviate the concept of lagging regions which is still a major challenge for European integration, as mentioned in a recent regional report published by the European Commission (2017). It is necessary to weigh two types of policies: first, those policies implementing ICT development at European regions and second, policies contributing to knowledge sharing between neighbouring firms, since firms located in a specific region can benefit from trade performance concerning firms in neighbouring regions.

Although these first insights definitively open a new paradigm at the regional evidence about the ICTs' effects on trade, our study presents some important concerns to be addressed in further studies. First, a detailed analysis on sectoral trade data would contribute to greater detail in the context of place-based territorial development strategies. Second, future studies may consider the disaggregation of regions according to their regional income levels, since the effect of broadband on trade may be different for high- and low-income regions.

ACKNOWLEDGEMENTS

This study is dedicated to Raymond Florax, inspiring spatial and regional econometrician. We thank the editor, Richard Kneller, and an anonymous reviewer, as well as Inmaculada C. Álvarez, Margarita Billón, Inmaculada Martínez-Zarzoso and Rocío Sánchez-Mangas for useful comments and suggestions. This paper has benefited from comments received by participants at the XLIII International Conference on Regional Science (Seville, Spain), the XIX Workshop in Economic

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Integration (Valencia, Spain) and an internal seminar at the Department of Agricultural Economics at the Georg-August University of Göettingen (Germany). We also thank Mark Thissen for providing us with the novel regional trade data set used in this paper. Rodriguez-Crespo acknowledges financial support from Autonomous University of Madrid under grant FPI-UAM 2014. The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

ORCID

Javier Barbero http://orcid.org/0000-0002-2155-3996
Ernesto Rodriguez-Crespo http://orcid.org/0000-0002-0189-3715

REFERENCES

Abeliansky, A., & Hilbert, M. (2017). Digital technology and international trade: Is it the quantity of subscriptions or the quality of data speed that matters? *Telecommunications Policy*, *41*(1), 35–48. https://doi.org/10.1016/j.telpol.2016.11.001

Abramovsky, L., & Griffith, R. (2006). Outsourcing and offshoring of business services: How important is ICT? *Journal of the European Economic Association*, *4*(2–3), 594–601. https://doi.org/10.1162/jeea.2006.4.2-3.594

Adjasi, C., & Hinson, R. (2009). The internet and export: Some cross-country evidence from selected African countries. *Journal of Internet Commerce*, *8*(3–4), 309–324. https://doi.org/10.1080/15332860903467730

Alama, L., Marquez, L., Navarro, J., & Suarez, C. (2015). A two-methodology comparison study of a spatial gravity model in the context of interregional trade flows. *Applied economics*, *47*(14), 1481–1493. https://doi.org/10.1080/00036846.2014.997929

Alama, L., Marquez, L., & Suarez, C. (2013). Trade and transport connectivity: A spatial approach. *Applied Economics*, *45*(18), 2563–2566. https://doi.org/10.1080/00036846.2012.669466

Anderson, J. (2011). Measurement of protection. In D. Greenaway, R. Falvey, U. Kreickemeier & D. Bernhofen (Eds.). *Palgrave handbook of international trade* (pp. 321–348). Basingstoke, UK: Palgrave. https://doi.org/10.1007/978-0-230-30531-1_11

Anselin, L. (1988). *Spatial econometrics: Methods and models*. Dordrecht, the Netherlands: Kluwer Academic. https://doi.org/10.1007/978-94-015-7799-1

Antràs, P., & Chor, D. (2013). Organizing the global value chain. *Econometrica*, *81*(6), 2127–2204. https://doi.org/10.3982/ecta10813

Antràs, P., & Helpman, E. (2004). Global sourcing. *Journal of Political Economy*, *112*(3), 552–580. https://doi.org/10.1086/383099

Baier, S., & Bergstrand, J. (2007). Do free trade agreements actually increase members' international trade? *Journal of International Economics*, *71*(1), 72–95. https://doi.org/10.1016/j.jinteco.2006.02.005

Baldwin, R. (2016). *The great convergence: Information technology and the new globalization*. Cambridge, MA: The Belknap Harvard University Press.

Behrens, K., Ertur, C., & Koch, W. (2012). 'Dual' gravity: Using spatial econometrics to control for multilateral resistance. *Journal of Applied Econometrics*, *27*(5), 773–794. https://doi.org/10.1002/jae.1231

Bensassi, S., Marquez, L., Martinez, I., & Suarez, C. (2015). Relationship between logistics infrastructure and trade: Evidence from Spanish regional exports. *Transportation Research Part A: Policy and Practice*, *72*, 47–61. https://doi.org/10.1016/j.tra.2014.11.007

Capello, R., & Spairani, A. (2004). The role of collective learning in ICT adoption and use. In H. L. De Groot, P. Nijkamp, & R. R. Strough (Eds.), *Entrepreneurship and regional economic development, a spatial perspective* (pp. 198–224). Cheltenham, UK: Edward Elgar Publishing.

Chen, N., & Novy, D. (2011). Gravity, trade integration, and heterogeneity across industries. *Journal of International Economics*, *85*(2), 206–221. https://doi.org/10.1016/j.jinteco.2011.07.005

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Clarke, G., & Wallsten, S. (2006). Has the internet increased trade? Developed and developing country evidence. *Economic Inquiry*, *44*(3), 465–484. https://doi.org/10.1093/ei/cbj026

Daumal, M., & Zignago, S. (2010). Measure and determinants of border effects of Brazilian states. *Papers in Regional Science*, *89*(4), 735–758. https://doi.org/10.1111/j.1435-5957.2009.00265.x

Demirkan, H., Goul, M., Kauffman, R., & Weber, D. M. (2009). *Does distance matter? The influence of ICT on bilateral trade flows* (GlobDev 2009, Paper 17). Retrieved from http://aisel.aisnet.org/globdev2009/17

Dettling, L. (2017). Broadband in the labor market: The impact of residential high-speed internet on married women's labor force participation. *ILR Review*, *70*(2), 451–482. https://doi.org/10.1177/0019793916644721

Drukker, D. M., Egger, P., & Prucha, I. R. (2013). On two-step estimation of a spatial autoregressive model with autoregressive disturbances and endogenous regressors. *Econometric Reviews*, *32*(5–6), 686–733. https://doi.org/10.1080/07474938.2013.741020

Duranton, G., & Puga, D. (2005). From sectoral to functional urban specialization. *Journal of Urban Economics*, *57*(2), 343–370. https://doi.org/10.1016/j.jue.2004.12.002

Eaton, J., & Kortum, S. (2002). Technology, geography, and trade. *Econometrica*, *70*(5), 1741–1779. https://doi.org/10.1111/1468-0262.00352

Egger, P. (2005). Alternative techniques for estimation of cross-section gravity models. *Review of International Economics*, *13*(5), 881–891. https://doi.org/10.1111/j.1467-9396.2005.00542.x

European Commission (2014a). *Cohesion Policy 2014–2020: Momentum builds*. *Panorama 48*: Winter 2013. Brussels, Belgium: European Commission.

European Commission (2014b). *Ten priorities for Europe: A new start for Europe: An EU agenda for jobs, growth, fairness and democratic change. The European Union Explained Series*. Brussels, Belgium: European Commission.

European Commission (2014c). *National/regional innovation strategies for Smart Specialisation (RIS3): Cohesion Policy 2014–2020*. Factsheet. Brussels, Belgium: European Commission.

European Commission (2017). *Competitiveness in low-income and low-growth regions: The lagging regions report*. Number SWD(2017) 132. Brussels, Belgium: European Commission.

Florax, R. J., de Groot, H. L., Linders, G. J., & Nijkamp, P. (2011). Persistent Distance Decay Effects in International Trade. In M. Jovanovic (Ed.). *International handbook on the economics of economic integration volume 2* (pp. 324–346). Cheltenham, UK: Edward Elgar. https://doi.org/10.4337/9781849806008.00025

Freund, C., & Weinhold, D. (2002). The internet and international trade in services. *American Economic Review*, *92*(2), 236–240. https://doi.org/10.1257/000282802320189320

Freund, C., & Weinhold, D. (2004). The effect of the internet on international trade. *Journal of International Economics*, *62*(1), 171–189. https://doi.org/10.1016/S0022-1996(03)00059-X

Gallego, N., & Llano, C. (2014). The border effect and the nonlinear relationship between trade and distance. *Review of International Economics*, *22*(5), 1016–1048. https://doi.org/10.1111/roie.12152

Gallego, N., & Llano, C. (2015). Thick and thin borders in the European Union: How deep internal integration is within countries, and how shallow between them. *The World Economy*, *38*(12), 1850–1879. https://doi.org/10.1111/twec.12242

Gaspar, J., & Glaeser, E. (1998). Information technology and the future of cities. *Journal of Urban Economics*, *43*(1), 136–156. https://doi.org/10.1006/juec.1996.2031

Ghalazian, P. L., & Furtan, W. H. (2007). The effect of innovation on agricultural and agri–food exports in OECD countries. *Journal of Agricultural and Resource Economics*, *32*(3), 448–461. https://doi.org/10.2307/40982690

Grossman, G. M., & Helpman, E. (1995). Technology and trade. In G. Grossman & K. Rogoff (Eds.). *Handbook of international economics volume 3* (pp. 1279–1337). Amsterdam, the Netherlands: North Holland. https://doi.org/10.1016/s1573-4404(05)80005-x

Grossman, G. M., & Rossi-Hansberg, E. (2008). Trading tasks: A simple theory of offshoring. *American Economic Review*, *98*(5), 1978–1997. https://doi.org/10.1257/aer.98.5.1978

Helpman, E., & Trajtenberg, M. (1998). A time to sow and a time to reap: growth based on general purpose technologies. In E. Helpman (Ed.), *General purpose technologies and economic growth* (pp. 55–84). Cambridge, MA: MIT Press.

Ioannides, Y., Overman, H. G., Rossi-Hansberg, E., & Schmidheiny, K. (2008). The effect of information and communication technologies on urban structure. *Economic Policy*, *23*(54), 201–242. https://doi.org/10.1111/j.1468-0327.2008.00200.x

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Juhász, R., & Steinwender, C. (2018). *Spinning the web: The impact of ICT on trade in intermediates and technology diffusion*. (National Bureau of Economic Research Working paper No. 24590). Retrieved from National Bureau of Economic Research website: http://www.nber.org/papers/w24590.pdf

Jungmittag, A., & Welfens, P. (2009). Liberalization of EU telecommunications and trade: Theory, gravity equation analysis and policy implications. *International Economics and Economic Policy*, *6*(1), 23–39. https://doi.org/10.1007/s10368-009-0125-4

Karlsson, C., Maier, G., Trippl, M., Siedschlag, I., Owen, R., & Murphy, G. (2010). *ICT and regional economic dynamics: A literature review* (European Commission, Joint Research Centre, Institute for Prospective Technological Studies Publication No. JRC59920). Retrieved from European Commission, Joint Research Centre, Institute for Prospective Technological Studies website: https://publications.europa.eu/en/publication-detail/-/publication/49038fb7-d0e6-4564-8dda-c0449a96c06b/language-en

Kelejian, H., & Prucha, I. (1998). A generalized spatial two-stage least squares procedure for estimating a spatial autoregressive model with autoregressive disturbances. *Journal of Real Estate Finance and Economics*, *17*(1), 99–121. https://doi.org/10.1023/A:1007707430416

Kneller, R., & Timmis, J. (2016). ICT and exporting: The effects of broadband on the extensive margin of business service exports. *Review of International Economics*, *24*(4), 757–796. https://doi.org/10.1111/roie.12237

Krugman, P. (1980). Scale economies, product differentiation, and the pattern of trade. *American Economic Review*, *70*(5), 950–959. https://doi.org/10.2307/1805774

Lafourcade, M., & Paluzie, E. (2011). European integration, foreign direct investment (FDI), and the geography of French trade. *Regional Studies*, *45*(4), 419–439. https://doi.org/10.1080/00343401003713357

LeSage, J. P., & Pace, R. (2008). Spatial econometric modeling of origin-destination flows. *Journal of Regional Science*, *48*(5), 941–967. https://doi.org/10.1111/j.1467-9787.2008.00573.x

LeSage, J. P., & Pace, R. (2009). *Introduction to spatial econometrics*. Boca Raton, FL: CRC Press. https://doi.org/10.1201/CHSTATEXMON

LeSage, J. P., & Thomas-Agnan, C. (2015). Interpreting spatial econometric origin-destination flow models. *Journal of Regional Science*, *55*(2), 188–208. https://doi.org/10.1111/jors.12114

Lin, F. (2015). Estimating the effect of the internet on international trade. *Journal of International Trade and Economic Development*, *24*(3), 409–428. https://doi.org/10.1080/09638199.2014.881906

Llano, C., Esteban, A., Pulido, A., & Pérez, J. (2010). Opening the interregional trade black box: The C-intereg database for the Spanish economy (1995–2005). *International Regional Science Review*, *33*(3), 302–337. https://doi.org/10.1177/0160017610370701

Márquez-Ramos, L. (2016). Port facilities, regional spillovers and exports: Empirical evidence from Spain. *Papers in Regional Science*, *95*(2), 329–351. https://doi.org//10.1111/pirs.12127

McCallum, J. (1995). National borders matter: Canada-U.S. regional trade patterns. *American Economic Review*, *85*(3), 615–623. https://doi.org/10.2307/2118191

McCann, P., & Rodriguez-Pose, A. (2011). Why and when development policy should be place-based. In OECD (Ed.). *OECD regional outlook 2011: Building resilient regions for stronger economies* (pp. 203–214). Paris, France: OECD Publishing. https://doi.org/10.1787/9789264120983-16-en

Miguélez, R., & Moreno, R. (2015). Knowledge flows and the absorptive capacity of regions. *Research Policy*, *44*(4), 833–848. https://doi.org/10.1016/j.respol.2015.01.016

Moran, P. A. (1950). Notes on continuous stochastic phenomena. *Biometrika*, *37*(1–2), 17–23. https://doi.org/10.2307/2332142

Overman, H. G., Redding, S., & Venables, A. (2003). The economic geography of trade, production and income: A survey of empirics. In E. Choi & J. Harrigan (Eds.). *Handbook of international trade* (pp. 350–387). Malden, MA: Blackwell Publishing. https://doi.org/10.1002/9780470756461.ch12

Philippopoulos, A. (2016). Milieu, territory, atmosphere: new spaces of knowledge. In A. Cusinato & A. Philippopoulos (Eds.). *Knowledge creating milieus in Europe* (pp. 79–95). Berlin, Germany: Springer. https://doi.org/10.1007/978-3-642-45173-7_5

Portugal-Perez, A., & Wilson, J. S. (2012). Export performance and trade facilitation reform: Hard and soft infrastructure. *World Development*, *40*(7), 1295–1307. https://doi.org/10.1016/j.worlddev.2011.12.002

Sichel, D. (1997). *The computer revolution: An economic perspective*. Washington, DC: Brookings.

Staiger, B. Y., & Stock, J. H. (1997). Instrumental variables regression with weak instruments. *Econometrica*, *65*(3), 557–586. https://doi.org/10.2307/2171753

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

Thissen, M., van Oort, F., Diodato, D., & Ruijs, A. (2013). *Regional competitiveness and Smart specialization in Europe: Place-based development in International Economics Networks*. Cheltenham, UK: Edward Elgar. https://doi.org/10.4337/9781782545163

Timmis, J. (2013). *Internet adoption and firm exports: a new instrumental variable approach* (Research paper No. 2013/05). Nottingham, UK: University of Nottingham. Retrieved from University of Nottingham website: https://www.nottingham.ac.uk/gep/documents/conferences/2013/postgraduate-conference/papers/jonathan-timmis.pdf

Tranos, E., & Nijkamp, P. (2013). The death of distance revisited: Cyber-place, physical and relational proximities. *Journal of Regional Science*, *53*(5), 855–873. https://doi.org/10.1111/jors.12021

Trefler, D. (1993). Trade liberalization and the theory of endogenous protection: An econometric study of U.S. import policy. *Journal of Political Economy*, *101*(1), 138–160. https://doi.org/10.2307/2138677

How to cite this article: Barbero J, Rodriguez-Crespo E. The effect of broadband on European Union trade: A regional spatial approach. *World Econ*. 2018;41:2895–2913. https://doi.org/10.1111/twec.12723

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

APPENDIX

ADDITIONAL TABLES

TABLE A1 List of variables and sources

Variable	Description	Source
$Trade_{ij}$	Trade between regions i and j (in millions of €)	Thissen et al. (2013)
$BRB_{i,t-1}$, $BRB_{j,t-1}$	ICT broadband 1 year lagged for regions i and j, respectively (normalised index)	ESPON
GDP_i, GDP_j	Gross domestic product for regions i and j (in millions of €)	Eurostat
$GDPpc_i$, $GDPpc_j$	GDP per capita for regions i and j, respectively (in € per inhabitant)	Eurostat
$Distance_{ij}$	Bilateral distance between regions i and j (in kilometres)	Eurostat GISCO
$RegionContiguity_{ij}$	Dummy variable that takes value 1 if both regions share a common border within the region and 0 otherwise	Eurostat GISCO
$CountryContiguity_{ij}$	Dummy variable that takes value 1 if both regions share a common border between countries and 0 otherwise	Eurostat GISCO
$Domestic_{ij}$	Dummy variable that takes value 1 for domestic trade and 0 otherwise	Calculated
$SameCountry_{ij}$	Dummy variable that takes value 1 if both regions are from the same country and 0 otherwise	Calculated
$HHinternet_i$, $HHinternet_j$	Percentage of households with access to the internet at home	Eurostat

Note: ESPON: European Spatial Planning Observation Network. GISCO: the Geographic Information System of the Commission.

TABLE A2 Descriptive statistics

	Mean	*SD*	Minimum	Maximum
Year 2007 (52,441 observations; 229 regions)				
Trade (in millions of €)	372.90	6282.89	0.04	574161.80
BRD (normalised index)	2.48	6.65	0.01	60.91
GDP (in millions of €)	51841.42	56132.38	1,098	552,691
GDPpc (in € per inhabitant)	26521.40	10908.46	5,800	76,500
Distance (in kilometres)	1085.94	642.45	0.39	5079.92
Year 2010 (53,824 observations; 232 regions)				
Trade (in millions of €)	362.53	6320.73	0.02	609810.30
BRD (normalised index)	3.25	8.08	0.00	68.71
GDP (in millions of €)	51010.19	58447.91	1,148	60.93
GDPpc (in € per inhabitant)	25865.73	10802.09	5,900	77,900
Distance (in kilometres)	1103.94	652.22	0.39	5079.92

Note: As our trade data are square—all regions trade with all other regions—the descriptive statistics of the country-specific variables are identical for the exporter and the importer.

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License

TABLE A3 Descriptive statistics of the percentage of household with access to the internet at home instrumental variables

	Mean	*SD*	Minimum	Maximum
Used in 2007 equations				
Model 2: regional future	79.80	9.00	54	99
Model 3: country current	57.66	14.52	25	83
Model 4: country future	82.74	7.96	65	96
Model 5: region + country future	82.37	8.72	54	99
Used in 2010 equations				
Model 2: regional future	85.72	7.00	67	100
Model 3: country current	72.23	11.23	46	91
Model 4: country future	87.91	6.27	71	98
Model 5: region + country future	87.65	7.03	67	100

14679701, 2018, 11, Downloaded from https://onlinelibrary.wiley.com/doi/10.1111/twec.12723 by Universidad Autonoma De Madrid, Wiley Online Library on [16/12/2022]. See the Terms and Conditions (https://onlinelibrary.wiley.com/terms-and-conditions) on Wiley Online Library for rules of use; OA articles are governed by the applicable Creative Commons License