From barrier to resource?
Modelling the border effects on metropolitan functions in Europe

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Abstract
This paper examines the effects of state borders on the performance of metropolitan areas in Europe. A multi-dimensional conceptualization of border effects is elaborated and empirically tested with the help of statistical modelling. The results suggest that Swiss cases and metropolitan areas recently integrated into the EU benefit the most from their border setting. When considering specific effects, a recent opening of the border as a new contact factor and significant differentiation factors have positive impacts on metropolitan functions. Alternatively, the spatial proximity of the border and its long-standing opening have negative impacts.

Border effects, metropolitan functions, border metropolitan areas, Europe

JEL classifications: O18, R10, R11, R12

1. Introduction

The acceleration of the globalization process and the reinforcement of mechanisms of regional integration such as the European Union (EU) have sparked a renewed interest in state borders and the regions that adjoin or straddle them (Anderson and O'Dowd, 1999). From a spatial perspective, the development of border cities is no longer confined to the boundaries of national territories and increasingly concerns cross-border spaces (Sohn and Stambolic, 2015). Depending on the context, the urbanization of border regions is reflected in the concentration of inhabitants, industries and services and is accompanied by the blossoming of cross-border flows of residents, labour, goods and information. In discussing the emblematic case of San Diego-Tijuana some 25 years ago, Herzog (1991) crafted the concept of the cross-border metropolis as a specific product of globalization. Since then, the development of cross-border urban configurations has spread across a variety of regions around the globe (Nugent, 2012). In Europe, city-regions such as Basel, Copenhagen-Malmö, Geneva or Lille are among the most obvious instances of cross-border metropolitan developments (ESPON, 2010).

The urbanization of border regions raises the question of the role and significance of state borders. Such questioning has long remained marked by the predominance of classical theories

of localization that have depicted borders as barriers and border regions as peripheral areas marginalized from an economic and social development point of view. The gradual lifting, from the 1980s onwards, of constraints on trade, financial transactions, and in some cases, mobility of people, has triggered a renewed vision of borders in which the functions of control and protection are losing ground to those of contact and exchange. From barriers, borders have been conceived as bridges or interfaces (O'Dowd, 2002). Although the obstacles that borders can generate should not be ignored, especially after the post 9/11 rebordering, it is recognized that in the era of globalization, border context also offers opportunities for border cities that need to reconsider their development and strategic positioning. Several studies in geography and regional science (see notably van Geenhuizen and Ratti, 2001) have contended that opening borders can serve as a resource for the economic, cultural or political development of border regions. By focusing on the case of cross-border metropolises, Sohn (2014) has notably developed a conceptual framework distinguishing four forms of border-related resources. If the merit of these works lies in a renewed conceptualization of borders, the empirical validation of these insights still appears to be limited. Indeed, the majority of the aforementioned strand of research is based on case studies that say little about the causality of different border-related effects on the development of border regions.

In the field of economics, the impact of integration and thus the (relative) opening of state borders has also been the subject of much research (Niebuhr and Stiller, 2004). Based on a combination of trade and location theories, New Economic Geography (NEG) models tend to show that the removal of border impediments might induce the rise of new economic centres in border regions due to access to foreign demand, increase in market potential and induced agglomeration economies (Niebuhr and Stiller, 2004). Such a positive effect is, however, not the only outcome, and results appear mitigated (Niebuhr and Stiller, 2006). Other empirical econometric approaches have shown that the integration benefits for border regions are not straightforward and remains context-specific. One study particularly relevant to this paper is the research conducted by Brakman *et al.* (2012), who find a positive empirical effect of EU enlargement as measured by the growth of population share along integrated borders. The overall effect of borders on neighbouring cities and regions remains, however, negative. From a theoretical point of view, the major flaws associated with this second strand of research derive from the way that borders are conceived; their multidimensionality and their intrinsic ambivalence is often neglected in favour of a simple and unambiguous understanding of borders as lines (either closed or open) associated with normative assumptions (closed borders have negative effects and open borders should have positive effects).

If the two aforementioned strands of research largely ignore each other, a meaningful articulation of their respective contributions looks promising. In light of this, the aim of this paper is to model the multiple effects of state borders on the performance of metropolitan areas in Europe. Two research questions are investigated. First, to what extent do border metropolitan areas[1] benefit from or are penalized by their proximity to a border? Second, which aspects related to the border represent an advantage and which represent a disadvantage? To answer these research questions, it is first necessary to elaborate a conceptual framework that disentangles the different dimensions intrinsic to borders and envisage their ambivalent effects (constraining as well as enabling) on the development of border metropolitan areas. In a second step, a statistical modelling of the effects of borders is performed using the data collected by the German Federal Institute for Research on Building, Urban Affairs and Spatial Development

(BBSR) in 2010 for the study of the metropolitan functions of the major urban areas in Europe (BBSR, 2011). The dependent variable is a composite index of metropolitan functions. The independent variables are twofold and distinguish metropolisation-related variables (9) and border-related variables (10). For the latter, interaction effects with the processual dimension of borders are also considered. In total, 124 metropolitan areas are taken into account, including 26 that are located near a national border.

The results highlight the relevance of disentangling the different intrinsic dimensions of borders and considering their ambivalent effects on the development of metropolitan areas. Fifteen out of 26 border metropolitan areas benefit from their border location. This includes the Swiss cases as well as metropolitan areas mainly located in Central Europe. Surprisingly, several cross-border metropolises located in Western Europe do not seem to benefit from their location near international boundaries. When considering specific border effects, a recent opening of the border as a new contact factor and significant differentiation factors (currency, unemployment and corporate tax differentials benefitting the main city) are relevant dimensions of the borders for accumulating metropolitan functions. However, the spatial proximity of the border and its long-standing opening have a negative impact on metropolitan functions.

The remainder of the paper is organized as follows. Section 2 develops a conceptual framework for examining the multiple effects of borders on the development of border metropolitan areas. The data and hypotheses are presented in section 3. Section 4 describes the empirical strategy and the model specifications. The results of the statistical modelling are presented in section 5. Section 6 concludes.

2. The effect of borders on urban development: a conceptual framework

In the last two decades, border studies have experienced a blossoming of new perspectives and conceptualizations. This move has been driven by the diversification of border functions and effects at different levels of social action and in various contexts (Newman, 2011). Such a changing reality of borders has notably been interpreted as a shift from territorial dividing lines to dynamics institutions and multidimensional social processes (Paasi, 1999).

Given the purpose of this paper, the 'traditional' state sense of borders is considered in the present study. However, compared to how borders and their effects are conceptualized and modelled in approaches in regional science, an innovative conceptual framework based on two changes of perspective is developed. First, borders are not only conceived as territorial lines more or less open or closed depending on the level of control applied to them. Instead, they are apprehended according to the different factors that they may display. To achieve this, the four basic border factors identified by Sohn (2014) are mobilized. The *separation* factor is probably the most common factor and is often grasped by means of the metaphor of a barrier. The *contact* factor, which is in essence consubstantial with the first factor, considers borders as an interface. The *differentiation* factor underlines the role of borders as markers of difference, a property deemed essential for the ordering of the world. The last factor is *affirmation*, in the sense that a border entails a symbolic dimension capable of influencing identities, values and preferences.

Second, our framework is not restricted to one-sided or normative understandings of borders as inherently constraining and therefore negative. In the same way that a barrier can represent an obstacle or a protection, an interface can be a source of opportunities or threats (Herzog and Sohn, 2014). The effects of the various border factors on metropolitan areas cannot all be fully defined on the basis of theoretical considerations. In some cases, the sign of the effects (positive or negative) remains uncertain and is an issue of empirical research. The following subsections highlight, for each factor, the expected effects as well as their empirical appraisal.

2.1. Borders as barrier: the separation factor

In the classic locational theories, borders have usually been depicted as obstacles having a negative impact on the development of border regions. For Lösch (1954), borders are considered an artificial distorting element of the market area that leads to the formation of half-market economies. Regarded as an additional distance cost, borders discourage firms from locating in border regions. This barrier effect is complemented by marginalization effects given the peripheral position of border regions and the uncertainties or potential instability linked to the proximity of 'outside' forces that may hamper investments (Hansen, 1983).

Despite this negative apprehension which is still the dominant approach in regional science, it is interesting to note that the classical approach to localization also highlighted the fact that in some cases, relatively closed borders may offer opportunities for cities and regions located in their vicinity (Hansen, 1977). Three rationales can be underlined. The first aspect concerns the development of specific territorial gateways functions in border cities (i.e., storage and transit activities, earnings from customs) and is linked to a positional rent. Usually, such functions tend to concentrate in particular sites where competences and activities agglomerate, creating specific comparative advantages. The second aspect relates to the creation of free zones that aim at by-passing fiscal and regulatory measures or the development of tariff factories in foreign neighbouring areas to penetrate more easily their market. The third aspect points to smuggling and other border-dependent informal activities. Ultimately, these are specific measures that seek to take advantage of or compensate for the drawbacks of barrier effects and have been shown to have positive impacts in some particular contexts only. On a more general level, the negative effects have proven to be more important and widespread than positive impacts restricted to peculiar settings.

2.2. Borders as interface: the contact factor

As mentioned by Niebuhr and Stiller (2004), reversing Lösch's arguments suggests that the opening of borders for trade may increase the accessible market area of border regions and foster the settlement of firms near the national border. On the condition that the main barrier effects of borders are lifted, the access not only to new markets but also to critical mass in terms of labour, knowledge networks or other assets (such as land), represent key elements for scale and agglomeration economies (Rietveld, 2012). The territorial gateway functions mentioned earlier may also be boosted by increasing cross-border interactions, although this positional benefit might be mitigated by the multiplication of competing border crossing points. Last,

opening borders may induce positive externalities for neighbouring cities and regions due to cross-border spillovers and the development of 'transbordering economies' (Herzog, 1991).

However, the mitigated nature of the results based on empirical analyses suggests that the disadvantages associated with the presence of a border may also have persistent negative effects (Niebuhr and Stiller, 2004). Lasting barrier effects may notably be linked to inherited deficits characterizing border regions, such as insufficient communication infrastructure or a lack of trust among agents on both sides of the border. Beyond the mere opening of a border, it is the time dimension of debordering, its duration, which matters for positive effects to occur. In a less-known register, the opening of borders may also induce a negative impact given the vulnerability of border regions to external threats or cross-border spillovers such as economic downturn, insecurity or crime. However, this effect is dependent on a particular situation, and its significance is likely to remain marginal.

2.3. Borders as markers of difference: the differentiation factor

It is widely acknowledged that borders play an active role in differentiating society and space. The effect of these differences on the development of border regions is, however, not easy to predict, notably given the conditioning impact of borders and their path-dependent effects (Wolf, 2005). When the separation factor predominates, differentiation tends to reinforce the negative effect of the border on the socio-economic development of border regions. This relates to the idea of an additional distance cost, whether in its cognitive, social or institutional dimensions (Boschma, 2005). However, when the border acts as an interface, positive effects may be expected.

One of the key aspects highlighting the potential benefit of border-induced differentiation rests on the exploitation of factor cost differentials such as labour, land or differences in tax and regulations (Sohn, 2014). Based on a cross-border division of labour, the localization of low-cost industries or export-processing factories in border regions represents a remarkable example of such a positive effect of border differential rents (Krätke, 1999). Cross-border labour markets constitute another phenomenon, although often associated with the development of cross-border production networks. The exploitation of complementarities and 'related variety' constitutes another aspect linked to economies of scope (Lundquist and Trippl, 2013).

Negative effects can also be expected out of the confrontation of differences. The persistence of regulatory and institutional differences can notably generate high transaction costs (linked to control and transfers) and interaction costs (linked to cooperation), both being susceptible to impede the development of neighbouring border regions (Rietveld, 2012). The role of non-tangible aspects of distance such as the persistence of cultural (macro) and mental (micro) distances constitute another example of border-related hindrances.

2.4. Borders as symbols: the affirmation factor

The affirmation function of borders is also conditional. Associated with a separation effect (closed border), the symbolic value of the border may reinforce national rebordering dynamics initiated by the state and appear therefore detrimental to the development of border regions. In the context of debordering, the symbolic value of the border becomes involved in place-making strategies at the local and regional scales and refers to the creation of public and club goods such as regional identity and territorial branding (OECD, 2013). Indeed, the presence of a border is a lever that can help reinforce the internal recognition of a cross-border region and its international character and attractiveness (Sohn, 2014).

Table 1. *The multiplicity of border effects on urban development*

	Main rationales for:	
Border factors	Expected negative effect	Expected positive effect
Separation	Barrier effect Marginalization effect	*Positional benefit*
Interface	Lasting barrier effects *Negative cross-border spillovers*	Scale and agglomeration economies Positional benefit Positive cross-border spillovers
Differentiation	Transaction and interaction costs Institutional, cultural and mental distances	Differential rent (value capture) Economies of scope (related variety)
Affirmation (symbol)	Symbol of national rebordering	Regional identity and external branding (public and club goods)

Note: Effects in italic are expected to be marginal.

3. Empirical data and hypotheses

The data on the metropolitan functions of the European metropolitan areas mobilized in the present study were gathered by the BBSR in 2010. According to this study, metropolitan areas are characterized by a spatial concentration of a large variety of metropolitan functions. In total, 8480 locations were investigated Europe-wide on the basis of 38 indicators covering the following functional areas: politics, economy, science, transport and culture. The identification and delineation of metropolitan areas is based on a bottom-up approach. The first step defines spatial densities of metropolitan functions at municipal level. The second step identifies spatial clusters by merging the significant locations of metropolitan functions. The last step defines metropolitan areas by means of an accessibility model (use of a car travel time of 60 minutes around the clusters). This results in the identification of 125 metropolitan areas covering approximately 10% of the European space, 50% of the related population and 65% of the GDP.

The following subsections describe the ways in which the border metropolitan areas have been identified and how the dependent variable as well as the independent variables have been computed.

3.1. Border metropolitan areas in Europe

Among the 125 metropolitan areas identified by the BBSR, 124 cases have been mobilized in this research[2]. The identification of border metropolitan areas is based on a criteria of Euclidian distance between the metropolitan core, place where metropolitan functions tend to concentrate and the nearest international border. To set the appropriate distance, different thresholds have been set, and the results have been compared with exogenous sources (ESPON 2010). The relevant distance threshold has been judged at 40 km, which corresponds to 26 metropolitan areas (Figure 1).

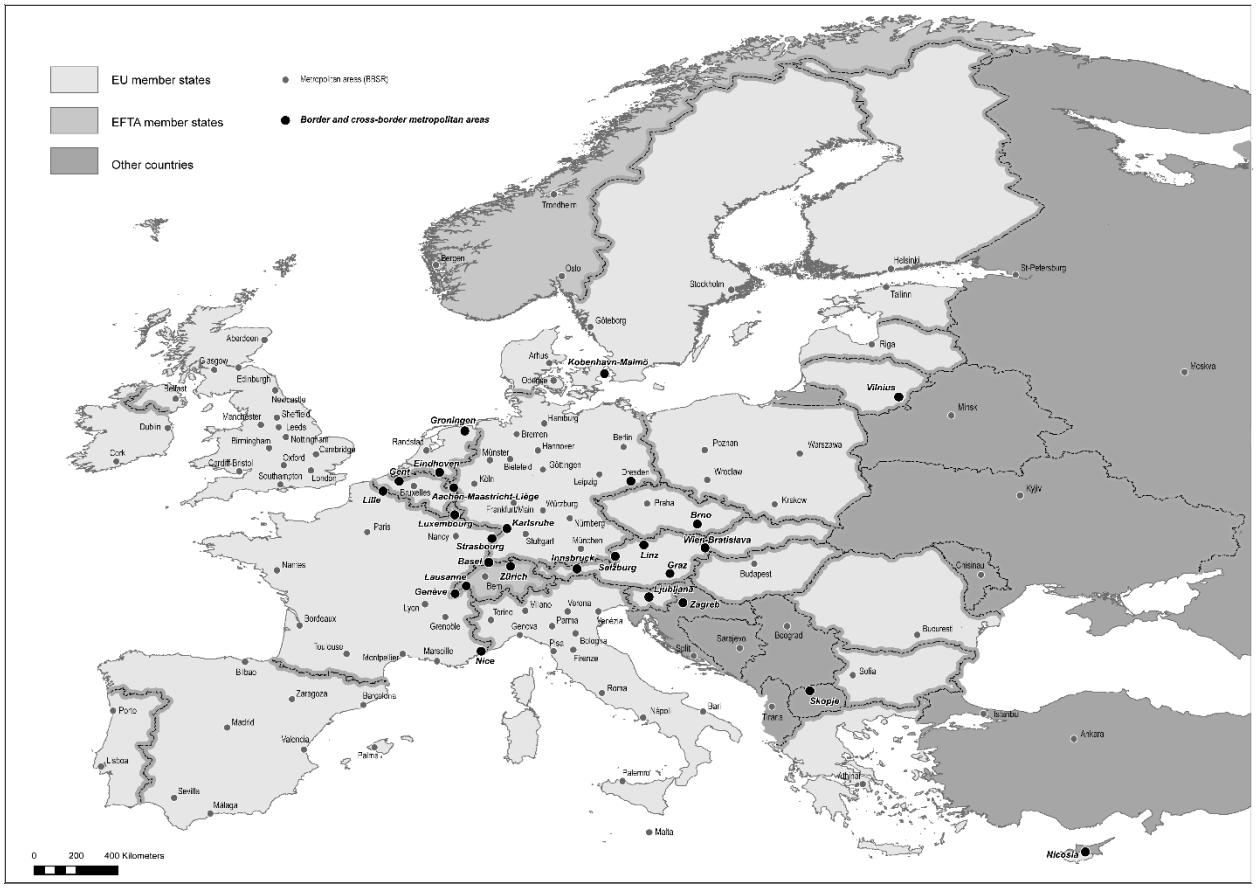

Figure 1. *Metropolitan areas in Europe*
Source: BBSR, 2011

3.2. The dependent variable

In a world where statistics are still largely the prerogative of states, the measurement of metropolitan economic performance remains a major challenge (Coomes, 1998). The value of the index produced by the BBSR is that it provides comparability across the major European metropolitan areas[3]. More specifically, the index of metropolitan functions is based on five domains (politics, economy, science, transport and culture) that are equally weighted (20%) (BBSR, 2011). Each of these domains is subdivided into groups of indicators that represent the

different aspects constitutive of metropolitan functions. The index ranges from 100 (London) to 1.8 (Cork).

To use this index as the dependent variable, an adaptation of its composition was deemed necessary. The domain involving national and supranational political activities named 'politics' was removed, and the index was recalculated on the basis of the four remaining domains. If national and international decision-making and control functions have a strong impact on the social framework condition and outreach of metropolises, these activities are not likely to be influenced by the proximity of a border. Regarding state capitals, the majority are located away from international borders, the choice of location being linked to political decisions and the historical process of state building. At the supranational level, the location of EU institutions and agencies, UN offices, international organizations and NGOs result from international agreements that have little to do with the proximity of a border.

3.3. The independent variables

To understand the effect of borders on the dependent variable, two rosters of independent variables were elaborated using various sources. The first list of variables has been used to control for metropolisation-related variables, i.e., variables that apply to all metropolitan areas. The second list of variables has been used to assess whether significant relationships exist between the level of metropolitan functions and specific border effects.

3.3.1. *Metropolisation-related variables*

The roster of 9 metropolisation-related variables includes the following:

Population. There is a large body of literature that refers to the relevance of agglomeration economies for explaining the performance of cities, and in particular the importance of their size (Polèse, 2005). As summarized by Turok (2004), bigger seems to be better. Based on this scholarship, it is expected that the number of inhabitants of metropolitan areas has a positive effect on the performance of metropolitan functions. The variable *population* was provided by the BBSR study (2011).

GDP per Capita. The gross domestic product (GDP) per capita in the metropolitan areas constitutes a good proxy for controlling for their relative economic performance. This continuous variable provided by the BBSR study is expected to have a positive influence on the dependent variable.

Diversification. At a national or regional level, industrial diversity may enhance economic performance, especially by improving the ability of countries or regions to limit the negative effects of asymmetric shocks. Countries or nations that are highly dependent on one specific sector may have more cyclical economic performance, as evidenced by Wagner & Deller (1998). The empirical setting mobilises the Rodgers (1957) diversification index (DIV) using value-added shares for 6 NACE sectors (A; B-E; F; G-J; K-N; O-U) on aggregated NUTS-3 regions (with data coming mainly from EUROSTAT).

Capital and international city. The exclusion of politics from the index constituting the dependent variable makes it possible to use this factor as an independent variable. The literature on the effect of the territorial status of cities on economic performance is rather limited (Ades and Glaeser, 1995). As noted by Sassen (2001), capital and primary cities tend to concentrate high human capital and talent and therefore act as gateways through which flows of knowledge, capital and labour gravitate. Being the seat of a national government or of supranational institutions and their related activities thus constitute an important driver for metropolitan development and outreach. Based on the information provided by the BBSR study, this variable is expected to show a positive influence, and was coded '0' for metropolitan areas without significant political functions and '1' for metropolitan areas that have such activities.

Federal states. It is assumed that federal political systems offer better conditions for regions and particularly metropolitan areas to develop growth and competitiveness strategies based on their competitive advantages compared with centralized countries (Trippl, 2010). More political autonomy and greater responsibility are the main reasons. Based on information retrieved from the Forum of Federations (2015), metropolitan areas located in centralized countries have been coded '0', and metropolitan areas located in federal states have been coded '1'.

EU history. This variable reflects the different stages in the European integration process (i.e., enlargement stages). It is assumed that the longer a state has been a member of the EU, the stronger the benefit of integration on the metropolitan functions of the cities territorially embedded (see notably Longhi and Musolesi, 2007). This positive impact relates to the increase of the potential market access of EU members and to the duration of exposure. Based on the analysis of the historical process of EU enlargement, an ordinal variable was computed: Old member states at the origin of the European Economic Community (EEC) in 1957 were coded '1', member states that joined the ECC between 1973 and 1995 were coded '2', new member states integrated in the UE between 2004 and 2007 '3', EFTA member states '4' and other states '5'. Furthermore, dummy variables were also considered to test for potential nonlinear effects.

Intra-polycentricity. This variable aims at grasping the polycentric setting within metropolitan areas. Although the influence of polycentricity on the performance of metropolitan areas remains unclear, given the lack of empirical research (Meijers and Burger, 2010), one can expect a positive effect due to the mitigation of agglomeration disadvantages such as congestion or pollution (Fujita *et al.*, 1997). The definition of Morphological Urban Areas (MUAs) by ESPON (2010) has been used to assess the absence of intra-polycentricity (coded '0') or its presence (coded '1').

Inter-polycentricity. The impact of polycentricity at the macro-regional scale raises the question of the extent of the regionalization of urban externalities. Following doubts noted by Parr (2004) and empirically confirmed by Meijers and Burger (2010), inter-polycentricity is expected to have a negative impact due to diminishing agglomeration economies. In this study, the variable refers to the presence of several metropolitan areas within a radius of maximum 100 km. Monocentric settings were coded '0' and polycentric settings were coded '1'.

Border setting. The last variable adopted for analysing the drivers of metropolitan functions is the territorial setting of metropolitan areas. Metropolitan areas in which the main urban centre is located further than 40 km from the nearest border have been coded '0'; the rest, corresponding to border and cross-border cases, has been coded '1'. Given the multidimensionality of borders supported in this paper, the expected sign of this 'aggregated variable' cannot be determined based on theoretical considerations.

Table 2. *Metropolisation-related variables definition*

Variable	Explanation	Related concept	Expected sign of the parameter est.
Population	Number of inhabitants of the MA *(million)*	Agglomeration economies	+
GDP per capita	GDP per capita in the MA *(*1000 € / inhabitant)*	Relative economic performance	+
Diversification	Rodgers diversification index (DIV) constructed using value-added shares for 6 NACE sectors (A ; B-E ; F ; G-J ; K-N ; O-U) on aggregated NUTS-3 regions	Less dependence on one specific sector	+
Capital and international city	Seat of national gov. and/or international organizations: no (0); yes (1)	Political spill-over effects	+
Federal states	MA located in a centralized country (0) and in a federal country (1)	Political autonomy	+
EU history	Stage in the European integration process: Non EU or EFTA members (1); EFTA member states (2); New EU member states (2004-2007) (3); EU member states (1973-1995) (4); EU old member states (1957) (5)	Europeanisation and integration benefit	+
Intra-polycentricity	Polycentric setting within the MA: no (0); yes (1)	Mitigation of agglomeration disadvantages	+
Inter-polycentricity	Polycentric setting at the regional scale (closest MA less than 100 km): no (0); yes (1)	Diminishing agglomeration economies	-
Border setting	Border and cross-border MA: no (0); yes (1)	Border effects	+/-

3.3.2. *Border-related variables*

Border-related independent variables have been defined according to the theoretical framework presented in Table 1. The roster of 10 variables has been split according to the separation (1), contact (3), differentiation (5) and affirmation (1) functions attributed to borders. Because the metropolitan functions that constitute our dependent variable relate to a stock that accumulates over time, it is the historical dimension of the process of bordering that counts more than the current status of borders. Similarly preference has been given to structural effects at the expense of conjuncture effects.

Proximity. Within the classical location theories, it is assumed that the spatial proximity to a border represents an obstacle and induces half-circle market areas. As far as the urban development of a city is concerned, it is assumed that the vicinity to a border also entails some distortion. To grasp such a distance-related barrier effect, the metropolitan areas whose main urban agglomeration (i.e., MUA) is not directly adjacent to a border have been coded '0', those that are contiguous to a border have been coded '1'. The expected sign of the variable is negative.

Rebordering. With the collapse of the Soviet Union and the territorial restructurings that followed that major geopolitical event, several borders have been shifted or reasserted across the eastern part of the continent. In some cases that directly concern border metropolitan areas investigated in this paper (i.e., Vilnius, Zagreb, Skopje), the situation has evolved from a fairly open border during the communist era to a currently closed or highly controlled border.

Debordering. In the course of EU integration, state borders have been progressively opened. This variable takes into account the historical dimension of this process because the longer a border has been opened, the greater the positive expected outcomes for border metropolitan areas. Four categories of borders have been distinguished based on a historical assessment of their bordering trajectory. Borders that are not currently open have been coded '0'. Borders that have been open for less than 10 years have been coded '1', between 10 and 20 years '2', and more than 20 years '3'.

Market potential. Within an open border context, border metropolitan areas are supposed to benefit from their potential access to new foreign markets and resources due to scale and agglomeration economies. To measure the significance of such a positive expected effect, the potential of cross-border interactions has been analysed by means of a gravity model. The variable was calculated using the population of the metropolitan area and its nearest Functional Urban Area (FUA) provided by ESPON (2010) and the time distance by road between the two. For cases in which no FUAs were available, the population of the nearest border urban agglomeration with a population of more than 50,000 inhabitants was used. Where more than one FUA is located across the border, the gravity measure for the metropolitan area and each cross border FUA were summed.

Language. Language differences from one country to another hamper information exchange and raise the communication costs (Nijkamp *et al.*, 1990). Based on information provided by the study conducted by MKW and Empirica (2009), the existence of such a border-related language barrier has been coded '1' when the same language is spoken on either side of the border, '2' when different languages allowing a common understanding are spoken and '3' when the two languages are significantly different and do not allow mutual understanding.

Currency difference. The impact of currency differences on the development of metropolitan functions within border regions can be interpreted in two different ways. Rose and van Wincoop (2001) have shown that currency unions significantly reduce trade barriers associated with national borders. On the cross-border regional scale, it is thus expected that a currency difference generates transaction costs, which has a negative impact on the development of metropolitan functions. However, it can be argued that currency difference allows for exchange

rate benefits, which may have a positive impact on certain cross-border activities and trade (Chandra et al. 2014). This dummy variable has been coded '0' when the currency is used on either side of a border and '1' when different currencies exist.

GDP differential. Cross-border GDP per capita differentials constitute a key driver for cross-border functional integration (Decoville et al., 2013). This variable represents a source of differential benefit and is expected to have a positive impact on metropolitan functions. GDP per capita data are provided by EUROSTAT at NUTS3 level. To analyse structural differentials, the GDP per capita average values between 2000 and 2010 were taken into consideration according to the following formula

$$GDPdiff = \sum_i wi \frac{GDPc - GDPpi}{GDPc}$$

where $GDPc$ is the GDP per capita for the core region and $GDPpi$ stands for the periphery's GDP per capita. wi are weights used for multiple cross-border relationships (with more than one bordering region), constructed using the population shares of each bordering region. In this case, the 'core region' is always located in the country that has the greatest concentration of metropolitan functions.

Unemployment rate differential. Cross-border unemployment rate differences constitute another source of differential benefit for border metropolitan areas. Based on EUROSTAT data at the NUTS3 level, the cross-border difference of average unemployment rates (2000-2010) is calculated as follows

$$Ucb = \sum_i wi\,(Upi - Uc)$$

where Uc is the unemployment rate in the core region and Upi stands for the periphery's unemployment rate. wi are weights used for multiple cross-border relationships (with more than one bordering region), constructed using the population shares of each bordering region.

Corporate tax rate differential. Corporate tax rates play an important role in firm location strategies, and the proximity to a border may offer opportunities to take advantage of differential tax rates. The data mobilized to compute this variable are provided by KPMG (2015) and the period under consideration ranges from 2006 to 2010. The variable is calculated as follows

$$CTdiff = \sum_{i=1}^{n} \frac{(CTpi - CTc)}{n}$$

where CTc is the corporate tax rate in the core region and $CTpi$ stands for the periphery's corporate tax rate. wi are weights used for multiple cross-border relationships (with n bordering region), constructed using the population shares of each bordering region.

CB branding. Borders may be mobilized by local and regional stakeholders as positive symbols in cross-border branding strategies. Based on a survey of the websites of cross-border cooperation structures, this variable highlights the absence (noted '0') or the existence (noted '1') of cross-border external branding activities. The effect of the variable is expected to be positive.

Table 3. *Border-related variables definition*

Variable	Explanation	Related concept	Expected sign of the parameter est.
Separation factors			
Proximity	Location of the main Morphological Urban Area: distant from the nearest border (0); contiguous to the nearest border (1)	Distortion of the urban development	-
Rebordering	Bordering trajectory: from closed borders to open borders (0); from open borders to closed borders (1)	Separation effect	-
Contact factors			
Debordering	Historical depth of the opening of borders: not currently open (0); less than 10 years (1); between 10 and 20 years (2); more than 20 years (3)	Reduction of borders' impediments	+
Market potential	Potential for cross-border interactions based on gravity model	Scale and agglomeration economies	+
Differentiation factors			
Language	Existence of a language barrier: same language (1); different language but common understanding (2); different languages (3)	Transaction cost	-
Currency difference	Same currency on either side of the border (0); different currencies (1)	Transaction cost or differential benefit	-/+
GDP differential	Cross-border GDP per capita differentials (*in %, average 2000-2010*)	Differential benefit	+
Unemployment rate differential	Unemployment rate difference (*in percentage points, average 2000-2010*)	Differential benefit	+
Corporate tax rate differential	Corporate tax rate difference (*in percentage points, average 2006-2010*)	Differential benefit	+
Affirmation factor			
CB branding	Existence of cross-border branding activities: no (0); yes (1)	Public or club goods	+

4. Research strategy and model specifications

To investigate the relevant dimensions of a border location in explaining metropolitan performances, three successive models are analysed:

i. A simple Tobit model;
ii. A nested Tobit model;
iii. An endogenous-class Tobit model.

4.1. Tobit model

The Tobit model used for this analysis is a Type I censored regression model, in which the dependent variable y_i (measured as an index of metropolitan functions) can only be observed within the [0;100] range

$$y_i = \begin{cases} 0 \text{ if } y_i^* \leq 0 \\ y_i^* \text{ if } 0 < y_i^* < 100 \\ 100 \text{ if } y_i^* \geq 100 \end{cases}$$

with the latent variable y_i^* being

$$y_i^* = \beta_i^j \, x_i^j + \beta_i^D \, D_i + \varepsilon_i$$

x^j is a vector of j explanatory (metropolisation-related) variables, and D is the border setting dummy for identifying border metropolitan areas. ε_i is a vector of residuals.
To account for the small size of our dataset (only 124 metropolitan areas), bootstrapped standard errors (with 5000 replications) are computed and the results of stepwise investigations for identifying significant variables are reported[4].

4.2. Nested Tobit model

To investigate the multi-dimensional aspects of the border, it is necessary to go further than a simple dummy variable identifying the border metropolitan areas. Therefore, a Nested Tobit model is used in which the first step relates the index of metropolitan functions to several characteristics of the border on the specific subset of (26) border areas and the second step relates the index of metropolitan functions to the metropolisation-related variables on the whole sample of (124) metropolitan areas. In this case, robust standard errors are reported instead of bootstrapped standard errors because of the very limited number of cases in the first step and the very high degree of specificity of each case (a specific combination of all border-related variables). In the Nested Tobit model, interaction effects between the variable *Debordering* and the other border-related variables are considered. In other words, it is assumed that the temporal settings of debordering may have non-linear effects.

4.3. Endogenous-class Tobit model

In the first step of the Nested Tobit model, the number of degrees of freedom is limited due to the small number of border metropolitan areas. Even if the results seem rather robust to (small) changes in the specification and if the stepwise procedure is used to select only significant results, the limitations of this Nested model are obvious. That is why another model that attempts to identify and cluster border metropolitan areas with similar characteristics is constructed. In this new Tobit model, the clustering of groups of observations is made endogenous. For each potential number of groups in the range [2; 6], a systematic computation is performed, for all potential clustering of the border cases of the Tobit model, including dummies for each group. Log likelihood is used as a selection criterion to identify the most relevant combination of all cases for each potential number of groups, and the same criterion (along with AIC and BIC criteria) is used to select the "optimal" number of groups.

5. Estimation results

5.1. Tobit model

The results of the estimation of the Tobit model are reported in Table 4. The baseline model (column 1) only includes the metropolisation-related variables, with EU history as an ordered variable. As expected, an increase in population, in GDP per capita and in the Rodgers diversification index are related with an increase in the index of metropolitan functions. Thus, it seems that agglomeration economies, better relative economic performance and a stronger diversification of the economic activities translate into more metropolitan functions. Metropolitan areas located in countries further along in the European integration process also seem to perform well. Europeanisation and integration benefits thus seem to translate into the accumulation of metropolitan functions. However, intra- and inter-polycentricity do not impact the index of metropolitan functions.

In column (2), the potential nonlinear effects of the EU history variable are accounted for. It appears that metropolitan areas located in new EU member States (which joined the EU in the period 2004-2007) benefit most from EU integration. In this specification, the effects of the other variables are not significantly different from the baseline model.

In column (3), potential cross-border effects are scrutinized. The coefficient associated with the border setting variable is not significant, suggesting that borders do not have a clear and direct impact *per se* on the accumulation of metropolitan functions.

Finally, column (4) investigates a potential differentiation of the effects of the border depending on the stage of European integration: the border may indeed act as a barrier or as an interface depending on the openness of this border. The introduction of an interaction variable for border setting and EU history reveals an interesting distinction: the border seems to act as a resource, but the positive effect of the border diminishes with the stage in the European integration process. In other words, border metropolitan areas located in countries outside the EU or recently included in the EU benefit most from their position. This specific effect is probably related to several dimensions of the border, as evidenced in the previous sections, and

the Nested Tobit and endogenous-class Tobit models will further try to disentangle the multi-dimensional effects[5].

Table 4. *Estimation results for Model 1 (Tobit model)*

	(1) Baseline model	(2) Nonlinear effects of EU history	(3) Potential cross-border effects	(4) Joint effects of EU history and borders
Population	4.58***	4.68***	4.71***	4.70***
	(6.58)	*(6.74)*	*(6.86)*	*(7.03)*
GDP per capita	0.40***	0.48***	0.48***	0.52***
	(4.95)	*(3.37)*	*(3.47)*	*(3.82)*
Diversification	5.27*	6.41*	6.40*	6.53*
	(1.65)	*(1.82)*	*(1.78)*	*(1.75)*
Capital and international city	10.20***	9.45***	9.39***	9.29***
	(4.84)	*(4.37)*	*(4.31)*	*(4.57)*
Federal State	2.42	3.11*	2.89*	2.96*
	(1.63)	*(1.90)*	*(1.65)*	*(1.76)*
EU history	2.27**			
	(2.50)			
Non EU and EFTA members		*Ref.*	*Ref.*	*Ref.*
EFTA member States		0.12	0.01	-2.58
		(0.02)	*(0.00)*	*(-0.42)*
New EU member States (2004-2007)		8.09**	8.01**	8.58**
		(2.44)	*(2.48)*	*(2.52)*
EU member States (1973-1995)		5.76	5.87	6.68
		(1.14)	*(1.17)*	*(1.32)*
EU old member States (1957)		7.67	7.77	9.31*
		(1.50)	*(1.52)*	*(1.76)*
Intra- polycentricity	0.30	0.64	0.39	1.16
	(0.16)	*(0.35)*	*(0.20)*	*(0.62)*
Inter- polycentricity	0.17	0.32	0.32	-0.23
	(0.11)	*(0.20)*	*(0.20)*	*(-0.14)*
Border setting			1.14	14.77***
			(0.45)	*(2.70)*
EU history * Border setting				-3.67***
				(-2.81)
Constant	-25.10***	-25.32***	-25.53***	-27.24***
	(-4.91)	*(-5.07)*	*(-5.13)*	*(-5.30)*
Pseudo R^2	0.2020	0.2049	0.2054	0.2140
Nb obs.	124	124	124	124

Note: Bootstrapped z-statistics reported in parentheses. *** denotes significance at the 1% level, ** significance at 5% and * significance at 10%.

5.2. Tobit model with specific border-related variables

The results of the estimations of the Tobit model with specific border-related variables are presented in Table 5. The baseline model (column 1) includes the metropolitan-related variables and the border-related variables. Regarding the metropolitan-related variables, the significant coefficients are the same as in Model 1 except for the diversification index, which is no longer significant. Regarding the border-related variables, the physical proximity of the main urban agglomeration to a border has, as expected, a negative effect on the level of

metropolitan functions. This barrier effect points to constraints exerted by the border on urban development. Among the differentiation factors, the differences in currencies and the unemployment rate differentials positively impact the index of metropolitan functions. The remaining border-related variables are not significant.

These results are confirmed with the stepwise model (column 2). The principal difference concerns the variable debordering, which becomes significant, although not as expected. All things equal, the opening of borders has a negative impact on the level of metropolitan functions. Cities located in close vicinity to borders that have opened for more than 20 years do not benefit from it.

Column 3 accounts for potential interaction effects of the variable debordering. Among the metropolisation-related variables, the only significant change with the two first model specifications is the significance of the variable diversification, which has positive effects on metropolitan functions. For the border-related variables, the proximity and the opening of borders have a negative effect, whereas the existence of a market potential, difference in currencies and differentials in corporate taxes have a positive impact on the accumulation of metropolitan functions. At the cross-border scale, the transaction costs associated with different currencies seem to be outweighed by exchange rate benefits. Two significant interaction effects moderate the aforementioned estimation results. First, the contiguity between an urban agglomeration and a border induces a negative effect that diminishes with the duration of opening of the border. Second, the roles of scale and agglomeration economies associated with a bigger market potential diminish over time when the border is open. Some disadvantages as well as some advantages linked to the border appear to reduce within a debordering dynamic.

Finally, the stepwise specification including interaction effects presented in column 4 converges with the previous estimation results.

Table 5. *Estimation results for Model 2 (Nested Tobit model)*

	(1) All variables	(2) Stepwise model	(3) With interaction effects	(4) Stepwise, with interaction effects
Population	4.62***	4.57***	4.62***	4.54***
	(7.53)	*(7.90)*	*(7.62)*	*(7.99)*
GDP per capita	0.37***	0.34***	0.37***	0.33***
	(5.49)	*(5.44)*	*(5.54)*	*(5.45)*
Diversification	5.30	*n.s.*	6.23*	*n.s.*
	(1.49)		*(1.73)*	
Capital and international city	10.50***	9.64****	10.86***	10.11***
	(5.63)	*(4.94)*	*(5.48)*	*(5.09)*
Federal State	1.82	*n.s.*	1.70	*n.s.*
	(1.22)		*(1.13)*	
EU history	3.05**	2.82**	3.12***	3.13***
	(3.52)	*(3.16)*	*(3.56)*	*(3.33)*
Intra- polycentricity	0.32	*n.s.*	0.78	*n.s.*
	(0.16)		*(0.38)*	
Inter- polycentricity	0.21	*n.s.*	0.31	*n.s.*
	(0.14)		*(0.20)*	
Proximity	-2.68*	-3.49*	-14.05***	-12.29***
	(-1.87)	(-2.05)	(-3.43)	(-3.11)
Rebordering	-1.39	*n.s.*	-1.92	*n.s.*
	(-0.29)		(-0.50)	
Debordering	-0.65	-0.67*	-3.35***	-1.44**
	(-0.57)	(-1.87)	(-2.90)	(-1.98)
Market potential	0.00	*n.s.*	0.04**	0.07*
	(0.38)		(2.16)	(1.92)
Language	0.03	*n.s.*	-0.58	*n.s.*
	(0.03)		(-0.69)	
Currency difference	7.82**	7.29***	7.58***	7.60***
	(2.56)	(3.83)	(2.63)	(4.25)
GDP differential	-3.41	*n.s.*	-2.17	*n.s.*
	(-1.16)		(-0.94)	
Unemployment rate differential	0.34*	0.64**	0.38	*n.s.*
	(1.83)	(1.95)	(1.52)	
Corporate tax differential	0.23	*n.s.*	0.64**	0.41**
	(0.98)		(2.59)	(2.04)
CB branding	-1.08	*n.s.*	-6.26	*n.s.*
	(-0.27)		(-1.65)	
Proximity * Debordering			7.59***	4.47**
			(4.07)	(2.56)
Market potential * Debordering			-0.03**	-0.02*
			(-2.41)	(-1.86)
Constant	-27.73***	-22.36***	-28.89***	-23.23***
	(-5.66)	*(-5.35)*	*(-5.59)*	*(-5.32)*
Pseudo R^2	0.2127	0.2070	0.2165	0.2097
Nb obs.	124	124	124	124

Note: Heteroscedasticity-robust z-statistics reported in parentheses. *** denotes significance at the 1% level, ** significance at 5% and * significance at 10%. *n.s.* (not significant) stands for variables rejected from the stepwise procedure.

5.3. Tobit model with endogenous determination of classes

The results of the estimation of the endogenous-class Tobit model are reported in Table 6. The results for the metropolisation-related variables are very similar to those yielded in the previous models.

In each specification of the endogenous-class Tobit model, the same optimal number of classes (4) and also the same composition within those groups is reached (Table 7). Group 1 is composed of four border metropolitan areas where the centre is located in Switzerland. This location implies that these cases are similar in their relationship with the other side of the border (France, Germany or Italy): outside the EU but experiencing a recent opening in the goods and labour markets, with a difference in currency as well as significant GDP, unemployment and corporate tax differentials in favour of the centre (Switzerland). All in all, it appears that the four cases benefit the most from their cross-border positioning. This is in line with the results reached with the Nested Tobit model: a recent opening of the border as a new contact factor and significant differentiation factors (currency, unemployment and corporate tax differentials benefitting the centre) are relevant dimensions of the borders for accumulating metropolitan functions.

Group 2 includes eleven border and cross-border metropolitan areas. Apart from Vilnius, those cases all include an internal border within the EU, but the opening of the border is rather recent in most cases (except for Groningen and Nice). Being a member of this group is associated with a slightly higher index of metropolitan functions in our model. This is in line with the results reached in the previous subsection: the second group mostly includes cases that experienced a recent reduction of borders' impediments.

On the contrary, Group 3 includes 8 metropolitan areas belonging to countries within the EU, with borders open for some time. Apart from Copenhagen-Malmö, all these cases share a common currency (the euro) across their border. Most of these metropolitan areas (except Luxembourg, Eindhoven and Gent) also exhibit limited differentials across the borders in terms of GDP per capita, unemployment rates and/or corporate tax differentials. The differentiation dimension, at least as measured in our empirical framework, does not seem to be relevant for most of these cases. However, it has to be stressed that many metropolitan areas belonging to this group exhibit a high index of metropolitan functions, mainly related to important population and GDP per capita. However, their border location does not seem to contribute to their good performances.

Finally, Group 4 comprises only three cases (Nicosia, Skopje and Zagreb) outside the EU, with controlled borders. Here, the separation dimension related to the border location seems to be mitigated by significant differentiation factors (mainly a different currency and unemployment rate differentials). All in all, being a member of this fourth group does not translate into significantly higher or lower metropolitan performances.

Table 6. *Estimation results for Model 3 (Tobit model with endogenous classes)*

	(1) Baseline model	(2) Stepwise model	(3) Nonlinear effects of EU history	(4) Stepwise, with nonlinear effects
Population	4.63***	4.49***	4.61***	4.57***
	(7.57)	*(7.79)*	*(7.64)*	*(7.53)*
GDP per capita	0.36***	0.31***	0.57***	0.66***
	(5.53)	*(4.89)*	*(4.43)*	*(6.54)*
Specialisation	5.45	*n.s.*	7.18**	7.03**
	(1.56)		*(2.12)*	*(2.30)*
Capital and international city	10.85***	10.42***	10.00***	9.37***
	(5.52)	*(5.14)*	*(5.09)*	*(5.34)*
Federal State	1.32	*n.s.*	2.47	3.03**
	(0.87)		*(1.54)*	*(2.03)*
EU history	3.02***	3.06***		
	(3.41)	*(3.28)*		
Non EU and EFTA members			*Ref.*	*Ref.*
EFTA member States			-9.57	-15.41***
			(-1.52)	*(-3.94)*
New EU member States (2004-2007)			7.07**	5.66***
			(2.41)	*(3.07)*
EU member States (1973-1995)			4.01	*Ref.*
			(0.89)	
EU old member States (1957)			6.71	3.26**
			(1.46)	*(2.02)*
Intra- polycentricity	0.87	*n.s.*	1.34	*n.s.*
	(0.46)		*(0.74)*	
Inter- polycentricity	-0.03	*n.s.*	-0.32	*n.s.*
	(-0.02)		*(-0.20)*	
Class 1	9.80**	10.26**	15.07***	15.90***
	(2.23)	*(2.54)*	*(3.25)*	*(3.39)*
Class 2	2.46*	2.40*	1.38*	1.42*
	(1.81)	*(1.88)*	*(1.92)*	*(1.90)*
Class 3	-4.02*	-4.11**	-3.98*	-3.43**
	(-1.89)	*(-2.33)*	*(-1.96)*	*(-2.04)*
Class 4	1.93	*n.s.*	0.76	*n.s.*
	(0.66)		*(0.19)*	
Constant	-27.62***	-22.00***	-26.39***	-24.92***
	(-5.58)	*(-5.27)*	*(-5.82)*	*(-5.91)*
Pseudo R^2	0.2105	0.2056	0.2159	0.2135
Nb obs.	124	124	124	124

Note: Bootstrapped z-statistics reported in parentheses. *** denotes significance at the 1% level, ** significance at 5% and * significance at 10%.

Table 7. *Composition of the 4 classes generated within the Tobit model with endogenous classes*

Class 1	4 cross-border metropolitan areas: Basel; Geneva; Lausanne; Zürich
Class 2	11 cross-border metropolitan areas: Brno; Dresden; Graz; Groningen; Innsbruck; Linz; Ljubljana; Nice; Salzburg; Vilnius; Vienna-Bratislava
Class 3	8 cross-border metropolitan areas: Eindhoven; Gent; Copenhagen-Malmö; Lille; Luxembourg; Aachen-Maastricht-Liège; Karlsruhe; Strasbourg
Class 4	3 cross-border metropolitan areas: Nicosia; Skopje; Zagreb

6. Conclusions

This article examines the multifarious and ambivalent effects of state borders on the level of metropolitan functions of European cities. To achieve this, a multi-dimensional conceptualization of the border is articulated with an empirical validation to identify statistically significant causal effects.

Regarding the extent to which border metropolitan areas benefit from or are penalized by their proximity to a border, the results suggest that it is the cases located outside the EU or recently integrated into the EU that enjoy their border setting. Cross-border metropolitan areas in Rhineland Europe (excluding Swiss cases), Benelux and Northern Europe do not seem to benefit from the opening of intra-EU borders (at least not anymore). Regarding which aspects of borders are an advantage or a constraint, the results of the different models suggest that it is the border differentials that constitute the main resource. Differentials in unemployment rates and corporate taxes as well as currency differences seem to instigate a process of 'value capture'. It is interesting to note that the opening of borders *per se* does not constitute an advantage. It has also been shown that the immediate vicinity of a border is to be considered an obstacle that penalizes the development of the city and thus the level of its metropolitan functions. This negative effect related to such a separation factor is, however, diminished when the border is open. Finally, the existence of a potential for cross-border interaction (i.e., a cross-border market area) leading to economies of scale and agglomeration has a positive impact on the development of metropolitan functions. This impact, however, tends to decrease as the borders open. For other variables tested such as language differences or cross-border branding initiatives, no significant effects could be highlighted.

The multiple and contrasting results highlight the relevance of disentangling the different intrinsic dimensions of borders and considering their ambivalent effects on the development of metropolitan areas. The impact of the variable debordering also emphasizes the process-based character of the border. More than the current institutional status of borders and their greater or lesser permeability, it is their historical trajectory, the evolution of their functions over time, that matters. If the temporal context plays a key role in explaining the level of metropolitan functions of border urban areas, it is the same for the spatial context. Beyond the control of the more or less proximity of the borders, the issue of the spatial distribution of gains and costs induced by borders remains an open question. Indeed, insofar as the unit of analysis includes areas located on either side of a border, cross-border disparities remain hidden. One way to continue and complete the work begun in this article would be to find out who are the 'winners' and the 'losers' of the opening of state borders within cross-border metropolitan areas.

Finally, this analysis offers new insights into the supposed role and effects of cross-border metropolitan areas in Europe. The idea that cross-border metropolitan areas constitute new growth poles beneficial to, or at least compatible with, the strengthening of the territorial dimension of the EU cohesion policy, that is, a socio-economic convergence between regions within and either sides of States, has been discussed in the circles of European regional policy (see notably ESPON, 2010). However, the results suggest that metropolitan areas that 'outperform' their metropolitan functions thanks to the border are those where cross-border differentials are most pronounced. To the extent that these cross-border differentials are emerging as the primary resource from the borders, it seems that the performance of cross-

border metropolitan areas is in favour of the reproduction of cross-border disparities rather than lessening them.

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Notes

[1] In this paper, the term 'border metropolitan areas' includes metropolitan areas that extend beyond state borders and can therefore be conceived of as 'cross-border'.

[2] The case of Frankfurt-Hahn has been dismissed given the absence of any metropolitan functions except the airport run by a low-cost company.

[3] The reference year of the different indicators varies with the variables used, from 2003 to 2009 (see BBSR 2011 for details). Because the date is the same for all metropolitan areas for a defined indicator, the risk of data mismatch between cases is limited.

[4] Potential heteroskedasticity in the residuals of the Tobit model is also tested and accounted for using White's correction.

[5] This effect cannot be compared to a kind of "catching-up" or "convergence" effect (as evidenced in the economic growth literature on countries or regions) because our dependent variable is a 'stock' indicator (i.e., the accumulation of metropolitan functions) rather than a 'flow' measurement (as the annual growth rate of GDP per capita).