Barrier Effects of Borders: Implications for Border-Crossing Infrastructures

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Borders discourage spatial interaction. The present paper gives a typology of possible backgrounds of such barriers. Five distinct ways of measuring border effects are presented and empirical results are shown for various transport modes: car, bus (public transport), train, plane. Border effects tend to decline in Europe, but they remain substantial, reductions of up to 80% are observed. They lead among others to low supply of border crossing transport links. A social cost benefit analysis of investments in international corridors is given. We find that border effects due to low demand for cross- border transport will lead to low net benefits of such investments. But the common practice that benefits of foreign users are ignored in social cost benefit analysis deserves to be reconsidered. By interpreting an international project as a joint project the benefits of foreign users are no longer overlooked, thus reducing the risk of underinvestment in international links.

Keywords: borders, spatial interaction, infrastructure, Trans European Networks

1. Introduction

Spatial interaction depends on generalized costs, which include the financial and time related costs of transport, but also broader types of transaction costs (Williamson, 1994, Andersson and Wincoop, 2004). Borders play a special role here, since they often imply a sudden jump in these costs. They correlate with fiscal and institutional differences, but also with cultural and language differences. Fiscal differences can be changed relatively easily by amending fiscal laws. But other types of differences are much more difficult to change. Therefore it is important to investigate the impact of borders on spatial interaction, and more specifically the impact of efforts to reduce border effects in common markets such as NAFTA, EU and ASEAN[2] (Ratti and Reichman, 1993, Van Houtum, 1998, Geenhuizen and Ratti, 2001, Anderson and Wincoop, 2004). In the present paper I will focus on the European context. I will address the question of to what extent border effects remain after the process of EU integration which has emphasized the harmonization of fiscal and legal dimensions, and the deregulation of international transport.

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[2] These three common market areas are very different, both in terms of period of existence and in scope. The EU started already in the 1950's and has gradually implemented a strong process of harmonization of institutions. ASEAN and EU started later and with less ambitions.

The main effect of borders is that they *discourage* spatial interaction. This is what we find in our empirical research, and it is also what follows from the large majority of the literature. Nevertheless, there are some distinct cases where we find the opposite: borders may also *stimulate* interaction. These cases are important enough to be discussed separately, and this subject will be addressed at the end of section 2.

The theme of the nature and size of border effects in spatial interaction is of course related to the subject of the advantages and disadvantages of border regions. When spatial interaction would not be hampered by borders, border regions would hardly be a relevant subject to study. An important question is to what extent border regions are more strongly affected by border effects in spatial interaction compared with non-border regions. For a good number of cases border regions will indeed be more strongly affected, like with cross-border commuting, and other types of short distance interactions such as use of private and public facilities. Cross-border polycentric metropolitan regions will have difficulties to exploit agglomeration advantages as long as border effects hamper spatial interactions of workers and firms. For these themes cross- border cooperation of public and private actors may be of eminent importance (see for a survey on cooperation in some metropolitan regions in the western part of Europe, ESPON, 2010). Of special relevance are border regions where the construction of new infrastructure suddenly brings regions much closer than they used to be. Examples are the regions of Kent and Nord Pas-de-Calais in the case of the Channel Tunnel (Vickerman, 1993), and Copenhagen-Malmo in the case of the Oresund fixed link (Bygvra and Westlund, 2004, Hansen and Serin, 2007). Knowles and Matthiesen (2009) find for example that border related barriers explain why the use of the Oresund fixed link was underpredicted in the transport models.

The aim of this contribution is to investigate the nature of the barriers implied by borders. In addition, the paper wants to shed light on empirical aspects of border effects: to what extent do borders really discourage spatial interaction between regions? The focus will be on the implications of borders on the supply of border-crossing infrastructure. A third aim is to explore implications of border effects for social cost benefit analysis of international transport infrastructure projects.

This paper is organized as follows. In section 2 a typology of border related barriers will be discussed. In this section we will also shortly discuss the potential of borders to stimulate spatial interaction. In section 3 we will present various ways to measure border effects and some empirical results on barrier effects of borders for various types of infrastructure. In addition to commonly used indicators for border effects we will also develop and use an indicator for the effect of borders on the supply of links in road and rail networks. Section 4 addresses social cost benefit analysis of improvements in border crossing links, followed by some policy implications in section 5. Section 6 concludes.

2. Types of barrier effects of borders

Border related barriers can be defined to exist when the intensity of interaction in space suddenly drops at places where a border is crossed (see Figure 1).

Various reasons of the existence of barrier effects of borders can be distinguished (Nijkamp et al., 1990, Linders, 2005, Helliwell, 1996). Table 1 describes five main reasons. They derive from the following main domains governing spatial interactions: preferences, public sector policies, institutions (both formal and informal), information and infrastructure related costs (see for example Button, 2009, Rietveld and Stough, 2006). Given the fact that these domains are very different in

nature, it is not surprising that some of them are broader than others. As we will demonstrate below, the framework of Table 1 will also be helpful to interpret some specific cases where borders stimulate cross-border transport.
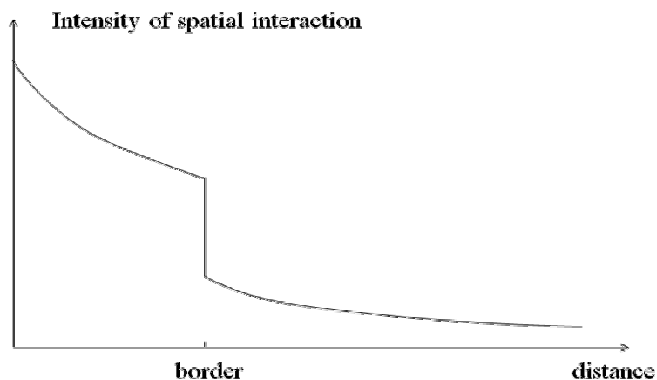

Figure 1. Discontinous effect of border on spatial interaction

The first group of barrier effects concerns *preferences* of consumers and producers for domestic interactions compared with international interactions. Such a preference may be based on taste: for example in food consumption one can observe clear differences in national habits, leading to a disincentive for the international trade in certain food products. Language, ethnical and cultural differences can lead to a strong preference for trade or communication partners from the own country compared with other countries. This does not only hold true for consumers, but also for firms. As indicated by Hofstede (1980), there are substantial cultural differences between certain groups of countries which makes cooperation between firms in different countries difficult. Another example is found with governments in their role of final consumer which may give priority to producers from the own country in the procurement of equipment, weapons, business services, etc.

Table 1. Barrier effects of borders

Preferences	Preferences of consumers for domestic rather than foreign products and destinations
Public sector regulation	Taxes or other limitations on cross-border trade and transport imposed by national states
Institutions	Differences in institutions at both sides of border
Information	Lack of information on foreign countries
Transport costs	Weak or expensive infrastructure services in transport and communication for international links

The second group of border related barrier effects concerns *public sector regulation*: taxes and other limitations on cross-border trade and transport (Anderson and Wincoop, 2004). Such limitations concern import duties, quota systems for international trade, differences in tax levels (cf. fuel taxes), visa requirements, etc. These interventions can have both a monetary and a time effect on spatial interaction. Examples of monetary effects are the costs of getting a visa or special taxes levied on people crossing the border. Examples of time costs concern the waste of time for getting visa, waiting at customs offices, waiting at borders etc. Avoidance of border delays is very important for

firms working with a just-in-time concept. It may induce the selection of domestic rather than international suppliers. To these time losses must be added the time needed for extra paperwork in the case of international trade. It is on this type of trade barriers that most common markets have focused.

A third category concerns *institutional differences* between countries Institutional differences in labour markets between countries may imply a clear disincentive for cross-border commuting (Houtum and Van der Velde, 2004). The same holds true for differences in social laws and practices, health care, elderly care, education systems. For the introduction of particular new products in a country firms have to follow certification procedures. If each country has its own procedure this will lead to additional costs and possibility of delays. A related problem is that countries often differ in the specification of the requirements certain products must satisfy. This leads to the need to adapt products to particular national standards which obviously has a cost increasing effect. A well known example is the difference between the UK and other European countries in the choice of which side of the road is used leading to differences in automobile design. As indicated by Strassoldo (1998), differences in organization, language, attitudes and values probably have a strong impact on cross-border flows, an impact that has a longer lasting effect than the physical constraints such as infrastructure that may be easier to remove in the short to medium term.

The fourth reason for the existence of barriers relates to *lack of information on foreign destinations*. Lack of information always plays a role in the intensity of spatial interaction, but in border-crossing interactions it is more severe. For example many newspapers, data banks and information systems have a clear national orientation. Acquiring additional information is possible, but it gives rise to costs in terms of money and time. Personal information networks also often have a domestic bias. The information people have is strongly influenced by interaction patterns in the past. Thus, information related barriers to international interactions depend on the other types of barriers mentioned above (Cappelin and Batey, 1993). They can be said to reinforce them. Since the stock of information is built gradually, the historical component of barrier effects may be expected to be substantial.

The last type of border related barrier effect concerns the *supply of transport and communication services* (Vickerman, 1993). This effect expresses itself in the form of various types of costs. If one would compute generalized costs, one would observe a discontinuity in these costs when a border is crossed. The generalized costs consist of two main components: monetary expenditures and time related costs.

An example where there is an extra *monetary* burden related to international transport compared with domestic transport is in the railway market. In international rail transport the lack of cooperation between national railway companies leads to relatively high international tariffs. In telecommunication a similar tendency can be observed: international tariffs are often much higher than long distance domestic tariffs, even though the distance between the communication partners may be very much the same.

Most cases of supply related transport costs of borders concern the *time* component. Take as an example railway infrastructure, where one observes that high speed rail developments usually start with domestic links (France, Germany, Spain). Only at a later stage international links are added. This means that the speed of services between major links in the same country is faster than between comparable links in different countries.

The above examples concern time related barrier effects due to the absence of a sufficient infrastructure. A somewhat different barrier effect is due to the way infrastructure is used. For

example, train services at international links usually have lower frequencies than at comparable national links. This means that international travelers face higher inter-arrival times which lead to higher waiting times or a less efficient use of time abroad. A similar case holds true for international airline services. Rail transport provides other examples of barrier effects. Technical incompatibility in railway systems due to differences in gauge (for example between Spain and France) or voltage (for example between Germany and The Netherlands) lead to time losses when passing the border because one has to change carriages and/or locomotives.

The border effects discussed above will have impacts on both passenger and freight transport. Their relative impact will vary among both domains in transport. Particularly, institutional differences have led to strong disincentives for international passenger trip making in for example the domains of work (cross-border commuting) and health care. Also delays related to borders during cross-border trips probably affect passengers more than freight. Plat and Raux (1998) find for the border effect that cross-border traffic in Western Europe is reduced with about 79% compared by similar traffic that does not cross a border. For freight traffic a reduction of about 50% is obtained. This provides clear evidence that borders affect passenger transport more strongly than freight transport[3].

The above discussion of border effects focused on negative effects of borders on spatial interaction. In some cases, borders may also *stimulate* spatial interaction. This relates mainly to the first three of the five dimensions mentioned in table 1. Some consumers have a strong preference for variety and this will stimulate cross-border shopping and tourism. Differences in taxes may stimulate cross-border interactions (Hansen, 1977, Kanbur and Keen, 1993), and the same holds true for differences in the fees for university education. Further, when countries are keen on protecting domestic suppliers of transport services by imposing barriers to entry on foreign suppliers, the result may well be that domestic transport is more expensive than international transport. For example, before the abolition of the 'tour-de-role' in domestic inland water transport in The Netherlands, domestic prices were higher than international prices. Along similar lines, cabotage is the reason that domestic sea transport from the capital Jakarta to the various regional ports in Indonesia is more expensive than international transport between Jakarta and the port of Singapore. Further, institutional differences in the regulation of opening times of shops may stimulate cross-border shopping during for example Saturday afternoons or Sundays. Some of these interaction enhancing effects are clearly asymmetric: tax difference stimulates transport in one direction, but variety seeking may go in both directions. Nevertheless, as we will see in the next section, the overwhelming aggregate effect of borders is that they discourage spatial interaction.

The theme of border effects on transport flows is of course related to the subject of the specific position of border regions. In Europe, the 20th century witnessed a reinforcement of the position of nation states (Maddison, 2006). This had a strong impact on the meaning of borders and hence made the position of border regions more pronounced. This was further reinforced by the increasing share of the public sector with its inherent domestic orientation. A special case was the creation of the iron curtain which implied a strong decrease in possibility of cross-border traffic. The issue of the disadvantages of border regions as places with low opportunities for interaction gradually was recognized (for an early study see Strassoldo (1970). Hansen (1977, 1981) placed the theme on the agenda of economists, both in a European and North American context. The Journal of Borderland studies was launched in 1986. The steps taken by the European Community towards the Maastricht

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[3] An opposing factor is that distances in freight transport tend to be longer than in passenger transport. Hence, the share of freight trips that will be affected by borders is larger than with passenger trips. However, given that a potential interaction would cross a border, the Plat and Raux result shows that the border effect is larger for passenger transport than for freight transport.

treaty of 1992 led to a strong boost of research on the topic. Multidisciplinary studies appeared such as Ratti and Reichman, 1993, Cappelin and Batey, 1993, Martinez, 1994, Geenhuizen and Ratti 2001). Outside Europe the creation of NAFTA in 1994 clearly boosted interest in the theme of border effects and border regions. One of the current themes with border regions concerns the possibility to create and exploit agglomeration advantages in a cross-border polycentric context (ESPON, 2010).

3. Measuring border effects on spatial interaction

In this section we will discuss some alternative ways of measuring border effects on spatial interaction and transport infrastructure. We will focus on the effects of borders on flows, service frequencies and infrastructure densities. This means that we will not explicitly go into most of the underlying factors introduced in section 2. Thus, differences in densities at both sides of borders, physical barriers that may be related with borders (mountain ridges, rivers) and cultural and institutional differences that correlate with borders are not addressed explicitly. Their impact will be measured, but the precise mechanism will remain implicit.

There is a large literature on international trade that addresses the impact of borders on trade (Rauch, 1999, Evans, 2003, Anderson and Wincoop, 2004). The typical model adopted here is the gravity model for bilateral trade flows. The first factor hampering trade is of course direct transport costs and this is usually dealt with in a rather superficial way by means of the distances between centroids of countries. The next factor consists of a range of factors related to the border effects mentioned above, such as trade barriers, differences in language, institutions, culture. Studies like Linders (2005) show that these factors have a large impact on international trade flows.

These studies certainly shed light on border effects, but not yet to the full extent. Consider two countries like Canada and the USA, that have identical languages and rather similar institutions. Helliwell (1996) found a *'mistery of missing trade'*, implying that trade between a pair of regions in one of the countries is much larger than trade between a similar pair of regions, but now located at different sides of the USA-Canada border. He observes a border effect of no less than 80%. For the analysis of the border effect one needs data on trade or other types of spatial interaction that is measured at the regional level and where border crossing flows are incorporated. Data quality with this combination of regional and international is generally poor.

The present paper presents some results by using various types of data and various measures of border effects. The first concerns the full estimation of spatial interaction models where formulations on distance decay are enriched with border related factors. A simple example for trade T between region i and region k would be:

$$T_{ik} = a. P_i. P_k. Dist^{\delta}_{ik}. (1-B1_{ik})$$

where P stands for the masses of the two regions, Dist is distance, and B1 reflects the impact of a border in case the two regions would be separated by a border; δ represents the distance elasticity of bilateral trade. In the absence of a border between i and k, B1 would be equal to zero, in other cases we expect the border effect to have a dampening effect on trade. A broader discussion of the gravity model can be found in Anderson and Wincoop, 2004). It is important to note that many applications of the model are on the basis of national trade data, but when the focus is on border effects, the data should be at the regional level, and data on cross-border flows should be available. Examples of work based on this specification can be found in Brocker and Rohweder (1990), Brocker (1998) and Plat and Raux (1998).

A second approach is based on control groups (see for example Knowles and Matthiesen, 2009; Neusser, 1985). The control group approach is based on the idea that observations with treatment are compared with similar observations without treatment. In the present context treatment relates to the existence of a border. Similarity has to be checked for the variables that are relevant determinants of the phenomenon under study, such as population and distance as determinants of spatial interaction between regions. A special feature of the present context is that the units of observations are not regions themselves, but pairs of regions. A pair of regions is determined, both located in the same country. A similar pair is then identified, but separated by a border. With similarity we mean that the sizes of the regions are similar, and also their distances. By this approach we control for the main explanatory variables in spatial interaction models. Then the border effect is reflected by the ratio of the flows between both pairs. More precisely, the border effect B is defined as the relative decrease in spatial interaction due to passing a border. So when T_{ik}(domestic) is the spatial interaction between regions within a country, and T_{jl} (international) is the interaction between a similar pair separated by a border, then the border effect is defined as:

B2 = 1 - {T_{ik}(domestic) / T_{jl} (international)}

A third approach focuses on the ratio of traffic intensities on a certain international link j *at* the border and the intensity *close to* the border, denoted as T_j (at border) and T_j (close to border), respectively. The easiest way to illustrate the meaning of these terms is to consider an international highway with distinct exits. The flow 'close to' the border is observed just before the last exit before one passes the border; the flow 'at' the border is observed on the border line itself. In this case the border effect, relating to traffic on a certain link is measured as:

B3 = 1- {T_j (at border) / T_j (close to border)}

This can both be applied to public transport services and to road transport. A typical example for traffic densities is illustrated in Figure 2. This figure does not reflect data on a specific international link, but a tendency that one may expect on a cross-border corridor connecting two cities. The general tendency is that flows on borders are much smaller than they are at some distance from the border. Major express ways linking large cities with neighbor countries display large differences in traffic intensities: near the large city they are very high, on the border they are much smaller. Indeed the major difficulties in so called hinterland connections of large cities usually do not appear near the border, but near the cities themselves. Of course the large difference in intensity depends considerably on the high population density around the large cities leading to a high demand there. In order to identify a border effect it is therefore better to compare traffic intensities on borders with intensities near borders (say some 10 km away), as done in the B3 indicator.

The last approach is to compare the density of border crossing infrastructure at the border (for example: the Netherlands with a border length with Belgium and Germany of about 500 km has 6 international railway lines crossing the border. This implies a density of one railway line per 83 km). Drawing an arbitrary straight line within the country would yield a considerably higher density. The latter can be approximated by the ratio of the length of the railway system in a country and its surface. For the Netherlands this would lead to a score of about 1 railway per 14 km. The corresponding border effect can be defined as 1 minus the ratio between infrastructure density on the border ID (border) and infrastructure density within the country ID (domestic):

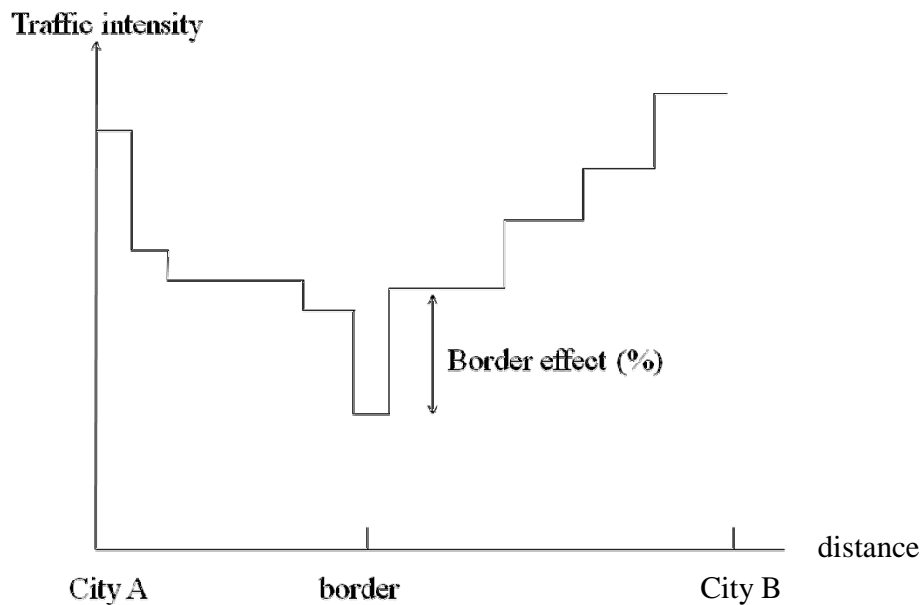B4 = 1- {ID (border) / ID (domestic)}

Figure 2. Border effect measured by means of traffic intensities at an international link between city A and city B

Note that infrastructure density ID (border) is measured as number of crossings per km, so that the dimension is 1/km. Further, ID (domestic) is measured in terms of kms of infrastructure divided by the surface in km². Hence ID (domestic) is also measured in 1/km, so that the resulting indicator B4 is a dimensionless index as it should be. The advantage of this approach is that one does not need a demarcation of a border region. It just suffices to measure the number of border crossings of an infrastructure network. Further, indicator B4 does not take into account differences in population density. When border regions have population densities that are much lower than the average population density, one would also expect a lower infrastructure density on the border. It would be possible to refine the definition of B4 via standardization by means of population densities. The ideal refinement would be to also take into account the elasticity of infrastructure supply with respect to population, but that would be beyond the scope of the present paper. Given the relationship between infrastructure density and population density, indicator B4 should be interpreted with care.

Indicators B1 and B2 are essentially identical. Both are based on origin destination (OD) flow data; the difference between them is that the first one is based on a complete model estimation, while the second one is based on a control group approach. Indicator B3 is different since the data used are just flows on a link; no OD flow data are needed. Indicator B4 is different again, since it is not based on flows, but on infrastructure supply.

We now turn to an application of these measures in the context of European transport. An example of the first approach is given in De Jong et al. (2011) for cross-border commuting in this EJTIR issue. In this paper we present some results for the other approaches. Concerning B2, we present some results for rail. In this case T is measured as the number of trains between two cities. We compare for example the difference in frequency between Cologne and Mannheim (both German) with that between Cologne and Utrecht (Germany and Netherlands). The border effect in 1992 between these

two city pairs equals 64%, in 1999 it has decreased to 55%. For a larger set of cities (described in Rietveld, 2001) we find a decrease of the border effect of some 56% in 1992 to about 50% in 2009. Thus, we conclude that there is a substantial border effect, and this effect is decreasing. Further it is found that the border effect is larger for countries where a different language is spoken compared with countries where the same language is spoken.

For the B3 measure we present as an example the cases of the A1 and A16 international highways linking the Netherlands with Germany and Belgium, respectively. The results are shown in table 2. Thus, the traffic intensities at the international highways are about 30 % lower on the border than they are some 10 kms away from the border. This underlines the discontinuity shown in Fig 2. A similar approach has been applied to bus frequencies on the border, and at some distance from the border. Here, the border effect is considerably stronger: about 58% for a sample of border crossing bus services in The Netherlands. This is slightly lower than the 60-65% observed in 1992 (Rietveld, 2001).

Table 2. Border effects on international highways, measured by means of B3

	Border effect 1996	Border effect 2008
A1 (NL-DE)	35%	30%
A16 (NL-BE)	37%	31%

Source: AVV (1994, 2008)

Table 3. Border effects (B4) for rail and highways based on infrastructure densities

Border between countries	Border effect based on infrastructure densities on borderline relative to border area	
	Railway	Highway
Belgium- The Netherlands	0.90	0.79
Belgium-France	0.80	0.71
Germany-The Netherlands	0.88	0.69
Germany-Belgium	0.75	0.64
Germany-France	0.82	0.78
Switzerland-Austria	0.71	1.00
Switzerland-France	0.77	0.69
Italy-France	0.88	0.84
Italy-Switzerland	0.84	0.89

The last border effect index (B4) focuses on the supply of infrastructure on borders compared with density in reference regions. Table 3 reports results on network densities for rail and road on borderlines, where we take density in border regions as a point of reference (Rietveld, 1993). As explained above, index B4 results from comparing the density of border crossings per km with the average density of infrastructure measured as infrastructure km per km². We find very high border effects of .83 for rail and .78 for highways for the countries considered. Thus, this table reveals a very strong effect of borders on infrastructure supply in border regions. Part of this effect may be related to the lower population densities in border regions compared with the average population density in a country, but it is clear that the countries considered here have large cities close to borders. To

mention a few: Antwerp, Enschede, Maastricht, Luxemburg, Lille, Strasbourg, Basle, Geneva. Thus, the gap between average population density and density in border regions will be limited, which means that the barrier effect shown in the table is really substantial.

The border effects in tables 2 and 3 are not independent from each other. The first table shows a rather modest border effect, whereas the latter displays a very high effect. The point is that when there is a very small number of border crossing links as reflected by B4, this implies that border crossing flows are forced to make use of the small number of links available. This implies a concentration of international flows on the links, so that one may expect a relatively high share of cross-border traffic on these international corridors, as reflected by B3. Thus, B3 and B4 will be negatively correlated. An implication of this funnel effect is that detours in international transport tend to be larger than detours in domestic transport. Clearly, for border crossing trips between regions further away from the borders the detour effect will most probably be mild, but for short distance trips between regions separated by a border, the detour effect may be substantial.

The figures we presented above mainly concern the supply side of infrastructure and transport services. Part of the data refer to frequencies of local public transport and trains. For another part is it on the supply of physical infrastructure. Bringing these results together we find that there are still substantial border effects ranging from about .50 to about .80. The effects tend to be larger for rail and public transport compared with road transport. In all cases a tendency towards smaller barrier effects can be observed. The lowest border effect (.35) is found for B3, but as indicated above, this value may be expected to be low when there is a lack of border crossing infrastructure due to the funnel effect.

In the next section discuss the low supply of border crossing infrastructure using a cost benefit perspective.

4. A welfare analysis of the supply of border crossing infrastructure

In this section we discuss the implications of borders on the supply of infrastructure from a social cost benefit analytical perspective. For this purpose we consider an international corridor with four nodes (A to D) in a two country setting as represented in Figure 3. The distances between neighbouring nodes are equal, and the border is in the middle between nodes B and C. The network consists of two domestic links (A-B, C-D) and one international link (B-C). The network is not congested. Note that this international corridor implies a serial network with two governments taking decisions on the quality of the links they are controlling. The quality indicator used here is speed. By improving the design of roads governments can increase the speeds on a link.
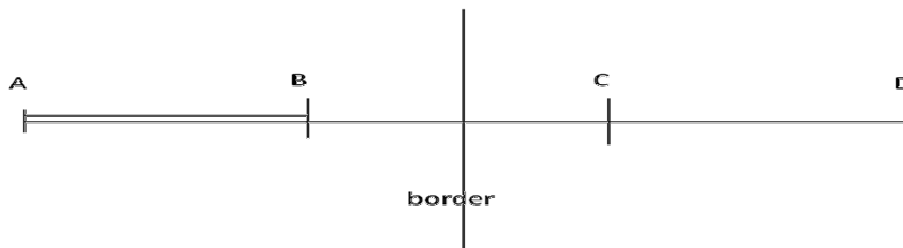

Figure 3. International corridor with four nodes and three links; improvement considered on A-B link

Twelve transport markets can be distinguished on this corridor: AB, AC,… up to DC. The domestic link AB serves 6 of the 12 markets (AB, AC, AD; BA, CA, DA), while the international link BC serves 8 of the markets in this network (AC, AD, BC, CD, and vice versa). Assume that the four cities are of equal size and that speeds are equal everywhere in the initial network. Let d be the distance between neighbouring nodes and let speed in the initial network be uniform at the level s. Then travel time t between neighbouring nodes equals d/s. We assume that transport demand between nodes i and j (i ≠j) can be specified as follows:

$q_{ij} = c.[|i-j|d/s]^{\lambda}(1-b.d_{ij})$,

where i, j are indicators of nodes A B C D, In this equation, c represents a constant, λ is the travel time elasticity, b (0≤b≤1) is the size of the border effect, and d_{ij} is a dummy with a value 1 when i and j are separated by a border, else d_{ij}=0. Thus, when i and j are separated by a border, demand decreases with a factor b. We assume the travel time elasticity λ to be equal to -1[4].

We take as a benchmark the situation that borders do not play a role as a determinant of travel demand (b=0). Then, Table 4 shows that when a border effect would apply of (assume) 70%, demand on the domestic link AB is reduced by about 32%. In the present network the impact of border effects on a domestic link is substantial since domestic links are located close to the border. Further, demand on the international link would –of course- be reduced by 70%.

Table 4. Travel demand effects of investing in domestic versus international links, with and without border effects

	Without border effect on travel demand			With border effect on travel demand		
	Travel demand before investment	Travel demand after investment	Change in travel demand	Travel demand before investment	Travel demand after investment	Change in travel demand
Investment in domestic link AB	1000	1081	+81	682	749	+67
Investment in international link BC	1272	1368	+96	382	410	+28

Note: travel demand has been scaled such that demand at the domestic link equals 1000 in the absence of border effects.

Table 4 also shows that when border effects would not play a role, initial demand at the international link is higher than at the domestic link, the reason being that in this case BC has a more central position in the corridor. Thus, absent border effects, BC would be a more promising link to be improved compared with AB. This will be explored in more detail in a welfare analysis further in this section. However, with a border effect of 70% this initial favorable position of the international link no longer holds, since demand at international links is more strongly affected by the border effect than demand on domestic links.

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[4] This value of the elasticity would follow from the constant travel time property (see for example Mokhtarian and Chen, 2004).

Table 4 also shows the effects of an investment on specific links AB and BC. It is assumed that after the investment, speed is 10% higher on the link. The table shows that without border effects, an improvement of the international link induces the largest travel demand increase on that link (+96 on a scale with a reference value of 1000). Border effects lead to a large reduction of this increase to only +28. The border impact is much smaller on the domestic link (from +81 to +67). The evident lesson of Table 4 is that borders lead to less traffic, in particular on border-crossing infrastructure. Investment will be less effective to raise demand in this case. Hence, a low supply of border crossing infrastructures as found in section 3 is not necessarily a sign of undersupply: there is just less need for investment here.

There is, however, another issue related to border crossing infrastructure that influences decision making: national governments do not consider positive spill-overs on foreign citizens in the cost benefit analysis of investment projects (Eijgenraam et al., 2000). The point is that investments are usually financed via domestic tax payers and then it makes sense that only benefits to domestic users are taken into account. As we will see this has strong detrimental effects on border-crossing infrastructure in this model. We will examine this by means of social cost benefit analysis of investment in the domestic (AB) versus the international (BC) link. The interference with the border effect will be taken into account by comparing the case with and without border effects. Hence we arrive at the 8 different cases presented in Table 5.

Table 5 shows that without border effects, with a co-operative approach of both governments the international project BC yields the higher increase in consumer surplus as the result of the investment (1269) versus an increase resulting from improving the domestic link (1000). In the case that a government only considers domestic benefits, the rank order of the two alternatives is reversed (777 versus 635), Considering the case that a government only improves the part of the link on its own territory up to the border will not really change this effect. It would imply that the speed of the cross-border trip between B and C is not reduced with 10% but only with 5%. This would about halve both the consumer surplus and the costs of the investment. We find that a zero weight assigned to foreign beneficiaries makes international links tumble on priority rankings of investment projects.

Table 5. Change in consumer surplus owing to investment in domestic versus international link; with and without border effects in transport demand

| | Change in consumer surplus: | | | |
	Without border effect; Without discounting of foreign welfare effects	Without border effect; With discounting of foreign welfare effects	With border effect; Without discounting of foreign welfare effects	With border effect; With discounting of foreign welfare effects
10% speed increase on domestic link AB	1000	777	687	620
10% speed increase on international link BC	1269	635	381	190

Note: change in consumer surplus has been scaled such that surplus change owing to a 10% speed increase on the domestic link equals 1000 in the absence of border effects.

These findings are entirely in line with the literature on capacity choice in a serial road network with governmental competition (De Borger et al. 2007, Ubbels and Verhoef, 2008, Mun and Nagakawa

2008, 2010). This literature shows that non-cooperative behavior of governments controlling different parts of a corridor has substantial negative effects on total welfare compared with the first best case of cooperative behavior. The standard practice of ignoring external benefits in cost benefit analysis is a clear example of non-cooperative behavior.

The case discussed by Ubbels and Verhoef (2008) is on policy competition between two regions where transport demand is not influenced by the existence of the border between the two regions. This is typically the case with regions within the same country. The additional consequences of the border effect on the performance of investing in AB versus BC are shown in the right hand part of Table 5. There we find that welfare on the international link BC is much more strongly affected by the border effect than welfare on the domestic link AB, so that the domestic link easily reaches the top in the ranking. This would even be stronger when welfare gains of foreigners are ignored (the initial ranking of change in consumer surplus in AB versus BC of 1000 versus 1269 is reversed into 620 versus 190).

 Table 5 presents the effects of two entirely different factors explaining the low supply of international links that we observed in section 3 with border effects of about 0.8: lack of demand for international transport, and lack of political weight given to consumer surplus of foreigners. From a welfare viewpoint, the two forces hampering the development of international infrastructure must be valued differently, however. The reduction in demand due to border effects is indeed a valid element that deserves to be accounted for in cost benefit analysis of both domestic and international projects. Low supply of border crossing infrastructure due to low demand just follows the logic of economics based cost benefit analysis. The possible claim that international infrastructure links would deserve priority because of their 'strategic importance' compared with domestic links is not valid from this viewpoint (see Exel et al. 2002). This is different with the second factor that hampers cross-national infrastructure, i.e., the rule that cost benefit analysis ignores welfare effects accruing to foreigners. From an overall welfare perspective the latter factor would lead to a misallocation of domestic versus international projects.

5. Policy implications

What are the policy implications of this analysis? A first implication is that social cost benefit analysis of projects with an international dimension should present results of a sensitivity analysis, where in addition to the base line approach sketched above also a variant is shown where foreign benefits are represented. This is a helpful tool to detect international projects with positive net benefits.

A second implication is that by interpreting an international link as a joint project both countries may gain from its implementation. This would call for cooperation. Game theory makes clear that there is no unique solution, since there are many ways in which costs and benefits of a project can be shared. For example, in the case of the international project with investment cost equal to 300, any distribution of these costs within the range of 110 to 190 would yield a positive result for both countries. A 'fair' solution would be a 50-50 distribution of costs, but that is not necessarily what would be the final result of negotiations. Just consider the case where the border is not in the middle of cities B and C, but much closer to city B so that 20% of the construction would take place in country 1 and 80% in country 2, leading to costs of 240 versus 60. If costs would just be distributed according to the length of the trajectory in both countries it is clear that country 2 would not participate: since its costs would fall outside the range of 110 to 190. This will lead to (Coasian) negotiations between the two countries on the level of subsidy flowing from country 1 to country 2.

Lack of trust and high transaction costs may make the joint construction of such projects a difficult matter. What one sometimes observes is that a supranational authority such as the EU may provide some support by an extra subsidy for trans-European networks (TEN-T). However, Sichelschmidt (1999) emphasizes the experience with TENT-T projects that the risks of strategic behaviour of member states to present mainly domestic projects as 'trans European' are substantial. Therefore the policy of bilateral cooperation between neighbor countries may in the end be a better way to deal with cross-border surpluses than involving supranational bodies.

An interesting case of a subsidy is the Emslandlinie in the Western part of Germany, close to the German border The point is that the express way is entirely located in Germany, but that it is also useful for Dutch car drivers for certain origin-destination combinations with the country. The German and Dutch governments agreed that the express way would be built with a contribution of about 10% in the construction costs by Dutch national and regional governments.

Another interesting example concerns the connection between the port of Antwerp and the North Sea via the West Scheldt river. The point is that the port of Antwerp, located in Belgium is a strong competitor of the Dutch port of Rotterdam. For its connection with the sea, the ships have to pass Dutch territory. There has been a long history of distrust between the two countries originating in the Westphalia peace treaty (1648) that allowed the Netherlands the blockage of water transport to Antwerp for about 150 years. Given the lack of interest of the Netherlands to keep the West Scheldt River navigable for large sea vessels, the two countries agreed that the entire dredging costs of the Dutch river will be borne by Belgium. This is almost the opposite of the Emslandlinie case because here the contribution of the foreign party is only 10 versus 100% in the West Scheldt case.

These cases illustrate that negotiations on sharing costs of cross-border links may well lead to solutions where both parties agree to contribute. But it is clear that in addition to the two handicaps of cross-border projects mentioned above, transaction costs are a potential additional bottleneck.

Another range of policy implications concerns the relevance of border effects in the valuation of international projects. Proost et al. (2011) find that only 12 out of 22 TEN-T projects adopted by the EU have a social rate of return of 5% or above, thus including all international benefits. A wide range of factors may play a role here. The performance of a project depends of course strongly on network structures and more in particular on the existence of well performing alternatives of the TEN-T projects. An explanation from an entirely different domain concerns political economy based pork barrel strategies of lobby groups and national governments to let international parties contribute to the costs of projects. But an important part of the explanation no doubt concerns the barrier effects of borders that lead to low demand for the projects. A related finding of Proost et al. (2011) is that the international share of the benefits of the 22 TEN-T is not as high as one might expect (the median value is about 10% only). This shows that what is presented as an international project in order to get access to additional funding opportunities may is not always as international as is claimed.

These experiences underline the importance of the use of social cost benefit analysis as a tool for the valuation of both domestic and international projects. When cost benefit analysis is carried out along the lines sketched above it may well contribute to picking the really most beneficial projects by avoiding overinvestment in cross-border links due to underestimation of barrier effects of borders, and underinvestment due to ignoring international benefits of such projects.

6. Conclusions

The creation of the common market and the Maastricht treaty have led to a reduction of border related barriers to European transport. But these barriers continue to exist and are still of considerable size. This is no surprise given the various economic and non-economic dimensions of the barriers surveyed in section 2. Depending on the type of infrastructure and transport mode (road, rail, bus)we find that there are still substantial border effects ranging from .30 to about .70. The overall tendency during the past 15 years is a gradual –though modest- decline of the border effect.

Our analysis of cross-border transport services by various modes of collective transport reveals a double effect of borders. The first effect concerns the demand side: because demand for cross- border interaction is lower than for other destinations, the supply frequencies are lower as well. This supply effect will have an additional negative effect on cross-border interaction because of the lower frequencies. Thus, we observe the phenomenon that (demand related) barriers to cross-border transport flows create additional (supply related) barriers. Note that from a social welfare viewpoint, the low supply of capacity on infrastructure links is natural result: the optimal level of supply will follow the level of demand.

Our paper identified another reason why international links tend to perform less favourably than domestic links in cost benefit analysis of projects. Standard rules of social cost benefit analysis imply that benefits accruing to foreign actors may be ignored since they do not contribute to the finance of the project as tax payers (except in the case of toll roads). Our analysis reveals that this will easily provide a serious handicap for international projects implying a reduction in net benefits of up to 50%.

International cooperation between border countries and active supranational parties such as the EU may help to overcome the latter bottleneck. However, transaction costs may be high implying slow progress on international projects. Nevertheless, with the decreasing sensitivity of cross-border traffic to the existence of borders, the benefits of transnational cooperation tend to increase and this also means that we may expect an increasing number of transnational links to be completed.

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