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ABSTRACT

This paper deals with the effects of cross-border transport infrastructure in the presence of agglomeration economies. *Cross-border infrastructure is more likely to increase than to decrease inequalities between and within regions, and has not helped regional convergence in Europe. Under-investment due to spillovers, coordination failures, and the inadequacy of networks originally designed for national markets provide a role for supranational institutions. Hub-and-spoke networks tend to increase urban primacy while cross-border transport connections tend to reduce it. Improvements in transport and communication allow firms to separate innovation, management and production, increasing efficiency and urban interdependence.*

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Agglomeration and cross-border infrastructure

Diego Puga

1. Introduction

Economists have traditionally explained spatial differences in production, employment and income through differences in underlying characteristics. These characteristics include differences in natural endowments, as well as differences in the endowments of other factors that can only be changed slowly – the amount of capital accumulated over time, or the skills acquired by the workforce – and differences in the technology available at different locations. Such differences have much to explain when one compares regions and countries that are far away or have very different development levels. They also have relatively straightforward implications for cross-border infrastructure improvements: By facilitating trade, improvements in transport and communication across regions and countries will lead to increasing specialization in activities in which regions have a comparative advantage. Such specialization will typically generate aggregate gains in all regions involved, even if within each region there are both winners and losers from this process.

Comparative advantage considerations are not the main determinants of differences in production structures and patterns of trade across locations that are geographically close and similar in terms of underlying characteristics. Recent work in economic geography indicates that, in such a context, a key part of what makes a location particularly attractive for certain activities is the combination of localized increasing returns and how easy it is to access customers and suppliers from that location. This implies that regions with similar underlying characteristics can end up looking very different. The role of cross-border infrastructure in this context is also much more complex.

In this paper we begin in Section 2 by reviewing the literature that has often been called new economic geography, which tries to explain broad patterns of agglomeration extending across substantial parts of a region or even crossing regional boundaries. This literature puts a strong emphasis on transport costs and how they affect regional inequalities in production, employment, and income. We review the role of cross-border projects according to this work and also discuss the empirical evidence on their impact, drawing from a broad range of studies, especially for Europe. These studies include papers that are closely related to the new economic geography and others that are not, studies based on aggregate data as well as others using geographically detailed data on specific projects.

In Section 3 we turn to agglomerations at lower geographical levels, particularly those that operate at the level of individual cities. We study the role of transport infrastructure in either increasing the benefits or reducing the costs of large cities, how it affects the concentration of urban population in a country's largest city, and its role in facilitating the spatial separation of the various activities of firms and the growing interdependence of cities.

Throughout the paper we take a broad view of cross-border infrastructure, taking this to mean infrastructure that crosses the administrative boundaries of regions or countries, and therefore serves mostly to facilitate movement of goods and people across regions rather than within regions. A specific type of cross-border project is that which crosses national boundaries or the boundaries of regional jurisdictions with significant power to design and finance their own transport and communication infrastructure. These have distinguishing features that we also discuss. However, much of the paper deals with connections across regional borders more generally. We also discuss when the effects of cross-border projects are similar to local transport and commuting projects and when they are different.

2. Agglomeration, cross-border infrastructure, and regional inequalities

The new economic geography builds on two basic elements. First, large markets are disproportionately attractive for firms producing differentiated products under scale economies. Second, large markets are large partly because many firms and consumers choose to locate in them. The combination of market access and mobility creates a 'snowball' effect whereby a large market attracts more firms and people who will work for those firms, and the demand for intermediates by these firms and the demand for final goods by their workers make the market even larger, which in turn attracts even more firms and workers.

Let us look at these two key elements of new economic geography models, market access and mobility, in more detail. We will then explore their implications for cross-border infrastructure.

2.1 Market access

Large markets are disproportionately attractive for firms producing under increasing returns to scale because of the 'home market effect'.

Large markets are disproportionately attractive for firms producing with increasing returns to scale because, in imperfectly competitive industries where differentiated products are subject to transport costs, each firm typically has a larger market share close to its home location than far away. Consequently, firms with a larger home market have larger sales. With scale economies, larger sales allow firms to exploit economies of scale further, lowering their costs and increasing their profits. This in turn encourages existing firms to expand and attracts new firms into this market. As a result, if there were two regions in a relatively isolated country and one of them accounted for 60 percent of demand, it would produce more than 60 percent of the part of output that is characterised by scale economies. This is the 'home market effect' (Krugman 1980).

Defining the relevant size of demand in a market is straightforward in the benchmark theoretical model with only two regions: It is enough to look at demand from consumers, firms and government in the market itself. Furthermore, Head *et al.* (2002) show that, in the two-region context, the home market effect holds not only in static but also in dynamic terms: An increase in the share of demand that a market holds causes an even greater increase in its share of output characterised by scale economies. In reality, however, countries have many regions and are rarely isolated. As Head and Mayer (2004) point out, reformulating the home market effect in a multi-region, multi-country framework is not straightforward. The main difficulty is that, when there are more than two regions, the relevant size of demand in a market must combine demand from consumers, firms and government in the market itself with a measure of accessibility of consumers, firms and government in every other market. This is where cross-border infrastructure becomes key.

Behrens *et al.* (2004) extend Krugman's (1980) theoretical model to many regions allowing not only for differences in the size of demand in different regions but also for differences in the quality of transport links connecting them. They show that the attractiveness of a region for firms is a combination of three elements: Market size (attracting firms towards high-expenditure countries), accessibility (attracting firms towards countries that are centrally located or have good transport connections), and competition (driving firms away from markets easily served by many competitors). This raises three important issues for home market effects.

First, high-quality transport connections and a central geographic position are a crucial part of what makes demand for firms located in a particular region large, allowing the region to attract a disproportionate share of tradable sectors producing with increasing returns to scale (henceforth 'industry'). Thus, it is more appropriate to think of this force of attraction as a 'market-access' as opposed to a pure 'home market' effect. This turns out to be very important empirically. Davis and Weinstein (1996), focusing exclusively on local demand, find little support for the hypothesis that a larger share of demand is associated with a disproportionate share of sectors characterised by scale economies. However, Davis and Weinstein (2003), using the same data for OECD countries but measuring the size of demand with a combination of local demand and accessibility, find very strong support for the hypothesis that a larger share of demand is associated with a disproportionate share of sectors characterised by scale economies. This underlines the importance of cross-border transport infrastructure as a determinant of location.

Second – and despite this finding, Behrens *et al*. (2004) show that a larger market and better accessibility do not always translate into more industry. In particular, a region with substantial local demand and good accessibility may be cast under a 'hub shadow' if it is located very close to another region with even greater demand and better accessibility. As a result, it may end up with less industry than a region with smaller demand or worse accessibility that is not as close to the dominant region and, hence is less exposed to competition from firms located there.

Third, when one moves away from the two-region abstraction to a multi-region world, the dynamic version of the home market effect no longer holds: An increase in demand in a region or a transport project that improves accessibility will not always cause a more than proportionate increase in industry and may even lead to a fall in the share of industry in the region. This will be the case when the dominant effect from increased accessibility is fiercer competition from firms located elsewhere.

Improving accessibility might fail to raise the share of industry in a region due to the 'hub shadow' and fiercer competition from outside.

2.2 Mobility

Starting from the premise that there are market size or market access effects, the new economic geography departs from earlier approaches by noting that market size itself should not be taken as exogenously given. Krugman (1991) makes this point by introducing labour mobility in the model of Krugman (1980). This apparently simple change opens the possibility of a snowball effect where even small differences in market size or market access quickly lead to substantial changes in production patterns and income.

Krugman's (1991) model, like that in Krugman (1980), considers two sectors, one producing under increasing returns and monopolistic competition, the other one producing under constant returns and perfect competition.[1] Crucially, workers in the increasing-returns sector are mobile across regions.[2] To highlight how the interaction between market access and mobility can open up large differences in production structures and income even across regions that are *a priori* very similar, the model assumes that regions are identical in every respect, including their endowment of immobile factors.

Given that regions are assumed to be *a priori* identical, it is natural to consider a benchmark situation where they have identical production structures. If one firm then decides to relocate, how does this affect the profitability of firms in the destination region? The arrival of an extra firm puts additional pressure on the product and labour markets, reducing profits and encouraging the newly arrived firm

1 Krugman's (1991) model relies on many special assumptions. However, subsequent work (see, for example, Ottaviano *et al.* 2002) has found its main conclusions to be robust.

2 Workers are, however, not mobile across sectors. Allowing for inter-sectoral worker mobility does not substantially change the results, as long as there is some immobile factor (*e.g.*, land). All that adding inter-sectoral mobility does is to strengthen the propensity of the increasing-returns sector to agglomerate by making labour supply to this sector more elastic (Puga 1998).

to go back. If there was no migration, this would keep regions identical in the absence of exogenous differences in endowments or technology. Migration can change this because the arrival of an extra firm means that more goods can be bought locally without incurring cross-border transportation. This, combined with the upward pressure on wages caused by the firm's arrival, encourages some workers to migrate towards the region to which the firm relocates. The arrival of migrants in turn causes an increase in local demand and at the same time eases pressure in the labour market. The increase in local demand, by virtue of a market size effect, may encourage other firms to relocate, which would lead to further migration, and thus a further increase in demand, and so on.

Whether or not such a chain reaction takes place depends crucially on how costly it is to transport goods across regions. When transport costs are very high, firms sell almost exclusively in their own location and all that matters then is exogenous differences in local demand. Without such differences there is no reason why sectors with increasing returns to scale should concentrate in a few locations.

As transport costs fall, it becomes easier for firms to sell in other regions. Because firms have a larger share of sales in their own market, a larger home market allows firms to exploit economies of scale further, placing them in a favourable position relative to firms with a smaller home market. The key difference introduced by worker mobility is that even tiny initial differences are enough to get a cumulative process started. Once trade costs are sufficiently low, just a few extra firms and the additional workers they bring along are enough to create a market size effect that will attract more firms and workers and amplify differences further.

When firms and workers are mobile, falling transport costs tend to spur agglomeration, increasing regional inequalities.

A first implication of models of this type for the effects of cross-border transport infrastructure connecting different regions is that, in evaluating such projects, it is important to consider their effects on the geographical distribution of economic activities. A second implication is that, in the presence of agglomeration effects, projects that result in small changes in transport costs can sometimes have large consequences. It may be tempting to see this as a further justification for using transport infrastructure improvements to reduce regional inequalities. However, a third implication of such models is that reductions in transport costs have a natural tendency to increase rather than reduce regional inequalities.

Introducing localized knowledge spillovers and growth in this type of model raises an important additional consideration: Policies targeted at reducing the regional inequalities generated and amplified by agglomeration come with efficiency losses (Martin 1999). Furthermore, for regions that lose industry as a consequence of increasing agglomeration in other areas, static losses from firm relocation are compensated, at least partly, by greater aggregate growth and efficiency (Martin and Ottaviano 1999).

Agglomeration in the model by Krugman (1991) relies on the assumption that when firms relocate towards a region, they are able to attract more workers on the basis of higher wages and better access to a broad range of goods, thereby increasing local demand and encouraging further relocation. In the United States, migration is indeed the main adjustment mechanism to changes in regional fortunes (Blanchard and Katz 1992). In Europe, however, the adjustment takes place mostly through labour-market participation decisions (Decressin and Fatàs 1995).

Does this imply that when, as in Europe, there is limited interregional migration, production structures are determined mostly by traditional comparative advantage considerations? It does not because there are other sources of agglomeration economies that do not rely on labour mobility.

A key alternative source of agglomeration operates through mobile demand for intermediates by firms rather than through mobile demand for final goods by consumers.[3] Venables (1996) and Krugman and Venables (1995) model this in a way that closely resembles Krugman's (1991) framework. In Krugman (1991), a relocation by a few firms increases demand in the destination region through the expenditure of workers attracted from other regions. In Krugman and Venables (1995) there is no interregional mobility, so workers must be drawn from other sectors instead, and the higher demand comes from the expenditure on intermediates by the newly arrived firms. In addition to this demand linkage, in Krugman and Venables (1995) there is a cost linkage because firms in a region with a larger industrial base can purchase a larger share of their intermediates free of interregional transport costs.

Despite the many similarities between the frameworks of Krugman (1991) and Krugman and Venables (1995), their different assumptions about labour mobility have crucial implications for the consequences of cross-border transport improvements. Puga (1999) explores these differences using a framework in which both interregional migration and input-output linkages may drive agglomeration.[4] Limited labour mobility weakens the propensity of sectors with increasing returns to agglomerate but tends to create wider regional income disparities. It also complicates the relationship between transport improvements and agglomeration.

Wages tend to increase in areas attracting firm relocations. Yet firms often do not necessarily move to low wage areas, because in doing so they would forego the benefits of proximity to suppliers of intermediate goods and to their customers. If workers move in response to the wage differences opened by agglomeration, this amplifies differences in market size further and encourages more agglomeration but it also mitigates income differences across areas. It should be no surprise, therefore, that the United States has both greater concentration of economic activity and smaller income differences across areas than Europe where worker mobility is much lower (Puga 1999).

Another, perhaps more surprising implication of limited labour mobility is that transport improvements are not necessarily associated with growing concentrations of industry. Clearly, when transport costs are very large, firms avoid shipping their output by spreading out production. A firm's location is then mostly determined by local access to immobile demand, such as demand from farmers and resource-based activities. For intermediate values of transport costs, it becomes feasible to supply markets from distance, and places with a nascent advantage in terms of market size are able to build on it and attract a growing share of industry from other places. Thus, as is also the case with labour mobility, reductions in transport costs initially increase the geographic concentration of production. However, further transport cost reductions, when there is limited worker mobility, may lead industry to spread out to take advantage of lower wages in regions with fewer firms.

When workers are immobile, falling transport costs first lead to agglomeration, too, but firms might eventually spread out.

It may be tempting to see this as an indication that, due to low interregional labour mobility, European integration and improvements in transport infrastructure will cause regional convergence both in terms of real wages and of production structures. However, the ability of poorer regions to catch up in this context relies on very large reductions in transport costs, on similar endowments in terms of skills, and on a flexible response of interregional wage differentials to changes in the location of production. Regarding transport cost levels, Head and Mayer (2004) estimate the model

3 In Section 3 we discuss alternative motives for agglomeration at smaller geographical scales such as cities or neighbourhoods.

4 The framework also allows agglomeration to cause differences in wages across regions, which is important to understand the relationship between transport costs and regional inequalities.

by Puga (1999) for various sectors using European and North-American data and suggest that most sectors are in the part of parameter space where reductions in transport costs will induce more rather than less agglomeration. Regarding interregional wage differentials, Puga (1999) suggests that the combination of minimal interregional migration with wage setting at the national sector level may help understand the rise in income inequalities between European regions within each country over the last 20 years at the same time as inequalities between countries have fallen. If agglomeration is not reflected in wage differences, it may be reflected instead in differences in unemployment rates. Since clusters of activity may extend across several administrative units, this can result in clusters of high and low unemployment extending across regional and even national borders, as documented by Overman and Puga (2002).

2.3 Transport and the evolution of regional inequalities

The cumulative causation that is at the core of new economic geography models, whereby additional demand attracts more production, which in turn creates even more demand, implies that modest changes in transport costs can sometimes have large effects. Casual readers of this literature may conclude from this that there is even greater rationale than traditionally thought for using transport infrastructure investment as a key instrument to reduce regional inequalities. However, if anything, these models suggest the contrary. Whether there is strong labour mobility (as in the United States), or whether there is weak mobility, large differences in skills, and constrained flexibility of wage differentials across regions within each country (as in Europe), reductions in transport costs will tend to increase, not decrease, regional inequalities.

When immobility combines with wage inflexibility, infrastructure improvements favour regions with better initial conditions.

Clearly, cross-border infrastructure projects connecting lagging regions with key markets make it easier for firms in those lagging regions to reach new customers. However, as stressed by Puga (2002), roads and rail lines have lanes and tracks going both ways. Thus, improvements in cross-border communication also make firms in lagging regions subject to stronger competition from firms in more developed areas. New economic geography models indicate that, when there is a combination of weak interregional migration and institutional constraints on wage differences across locations, the latter effect is likely to dominate and, hence improvements in communication encourage firm location in regions with better initial conditions.

The above conclusion has particularly important implications for Europe. Rodríguez-Pose and Fratesi (2004) study the allocation of the European Structural Funds across different spending categories and find that investment in transport infrastructure has not been accompanied by investment of comparable magnitude targeted, for instance, at improving workforce skills or research and innovation. While regional policies have grown from about one tenth to over one third of the EU budget, their focus has become increasingly biased towards infrastructure, especially transport networks. The majority of the European Structural Funds is spent on promoting the development and structural adjustment of regions whose development is lagging behind – called 'Objective 1' regions, mostly those with a GDP per capita below 75 percent of the EU average. About one half of Structural Funds expenditure in Objective 1 regions during the period 1994–1999 was allocated to investment in infrastructure, transport, and the environment – a proportion that rises to 70 percent in the case of Spanish regions, and to 90 percent in that of Portuguese regions. Such improvements in transport connections alone are unlikely to trigger the takeoff of lagging regions.

A first indication that vast spending in infrastructure is not helping poor regions to catch up is the fact that income convergence across European regions came to a halt in the late 1970s (see, amongst others, Marcet 1994; de la Fuente and Vives 1995; Neven and Gouyette 1995; and López-Bazo *et al.* 1999). In recent years, if anything, regional income inequalities have increased, especially inequalities within individual countries (Esteban 1999, Rodríguez-Pose 1999, Duro 2004, Rodríguez-Pose and Fratesi 2004). Overman and Puga (2002) show that regional inequalities have also increased in terms of unemployment. Regions with high or low unemployment in the mid 1980s have seen little change, while regions with intermediate unemployment have moved towards more extreme values. During this process, regions have experienced similar outcomes to their neighbours, a process largely driven by similar changes in labour demand, partly due to agglomerations that extend across regional and national boundaries.

One could still argue that perhaps there are underlying forces pushing for regional divergence, and that investment in transport and communication infrastructure prevents even stronger divergence. However, the evidence indicates that even this more optimistic view of the effects of recent infrastructure spending on regional inequalities is not justified.

The claim that transport infrastructure investment prevented an even stronger rise in inequalities is not justified.

A first approach to empirically studying the effects of transport infrastructure on the economy is to use aggregate regional data to estimate an aggregate production function. The underlying motivation is the view of transport infrastructure as an input into the production process. Early exercises of this sort (Aschauer 1989) found implausibly large returns to government capital. Part of the problem with these early estimates is that they, to a large extent, capture common time trends: In the United States and other industrialized countries the rate of public investment in infrastructure and the rate of productivity growth were both unusually large in the 1950s and 1960s. Subsequent studies tackle this by using regional data and find much smaller returns (Garcia-Milà and McGuire 1992). There is an additional potential endogeneity problem with these studies, common in productivity estimations, because inputs are correlated with unobservable region-specific productivity shocks. One way to tackle this problem is to use regional panel data with region-specific fixed effects. Using this approach, Holtz-Eakin (1994) and Garcia-Milà, *et al.* (1996) find minuscule or even zero output effects from public investment. Fernald (1999) differentiates between industries that are vehicle-intensive and those that are not to further address the endogeneity problem and once again finds very small effects, at least for additional improvements. As he notes (p. 619), "the interstate system was highly productive, but a second one would not be."

A related literature studies the effects of transport and communication infrastructure more specifically on regional inequalities by regressing regional growth rates on initial income and various regional characteristics, including regional infrastructure investment. Using this approach and detailed data on the allocation of the European Structural Funds across regions and investment categories, Rodríguez-Pose and Fratesi (2004) show that regions that have benefited from greater investment in infrastructure, whether individually targeted at the region or cross-border in nature, have not fared better in terms of income growth and convergence.

Recent empirical studies, using very geographically detailed data on actual and planned road improvements, provide further support for the idea that recent infrastructure investment in Europe is not helping convergence. Combes and Lafourcade (2005) carefully measure the evolution of transport costs in France over the 20-year period 1978–1998. They find that total transport costs (in real euros per kilometre) declined by 38.5 percent over this period. Surprisingly, improvements in infrastructure accounted for only 3.2 percentage points, with the bulk of the cost reduction due to lower tyre and truck maintenance costs, improved fuel economy, efficiency gains from logistics, and deregulation in the transport industry.

While infrastructure improvements played only a minor role in lowering average transport costs in France since the late 1970s, they mattered for relative changes. This is yet another reason why infrastructure improvements may have much smaller effects than expected: If the bulk of the change in transport costs is driven by other considerations common to all connections, relative accessibility will not change much. Combes and Lafourcade (2007) use the detailed transport data in Combes and Lafourcade (2005) to structurally estimate a new economic geography model for France. They conclude that relative accessibility and the agglomeration processes at the core of the new economic geography can account for much of the distribution of firms across France. Teixeira (2006) applies the same methodology to study the effects of transport infrastructure investment in Portugal in 1985–1998, which represented 1.9 percent of GDP over this period. He compares the actual size of sectors at different locations in 1985 with the size predicted by the model under the assumption of transport costs equivalent to their 1998 level. The model result is greater geographic concentration of activity than was actually observed in 1985 but less than the actual concentration in 1998. He concludes that road improvements not only failed to reduce spatial concentration but in fact increased it, a process which was amplified by economic growth. However, he also suggests that further improvements could take Portugal far enough that they would be associated with the final dispersion phase predicted by certain new economic geography models during an integration process. Garcia-Milà and Montalvo (2007) compare new business locations close to major Spanish roads that were improved in 1980–2000 with locations close to major roads that were not improved (but that *a priori* were equally likely to have been improved, on the basis of observable characteristics). They find that road improvements had no significant effect on new business location decisions.

Infrastructure investment in Europe has greatly improved core-periphery links but exacerbated differences in relative accessibility.

Part of the reason why there have not been greater effects from the vast improvements in infrastructure in Europe over the last decades may be that relative rather than absolute accessibility drives location decisions. As the European Commission notes, "[i]n transport policy, cohesion countries stand to gain in absolute terms from trans-European networks but not necessarily in relative terms" (Commission of the European Communities 1996, p. 8). Gutiérrez and Urbano (1996) study the changes in accessibility (measured as a GDP-weighted sum of travel times to network nodes) that result from the implementation of the trans-European road network. They show that, while most European regions gain better access to the main activity centres and lagging regions experience some of the largest changes in absolute terms, the gap in relative accessibility between the areas with the best and the worst initial accessibility increases as a result of the network. Similar conclusions emerge from an analysis of high-speed rail. Vickerman *et al.* (1999) show that, while there will be large changes in accessibility throughout Europe as a result of new high-speed rail lines, large and centrally-located European cities will gain the most accessibility in relative terms.

Behind this relative advantage of more central locations is the 'hub effect' (Krugman 1993; Puga and Venables 1997). When major cities get connected through roads or high-speed rail lines, cities located more centrally get better access to nearly everywhere whereas in more peripheral locations the improvement is felt mostly in the access to nearby locations. This increases demand in larger and more central locations relative to peripheral ones, and through a market size or market access effect encourages relocation towards those locations that already had an initial advantage. In the case of high-speed rail this hub effect is amplified by the strong nodal aspect of the network: High-speed rail lines have few stops and this greatly increases differences in relative accessibility between locations where the train stops and those where it does not. A consequence of this may be that, paradoxically, the main effect of cross-border infrastructure is on intraregional rather than interregional differences in production. Looking at the case of Spain using detailed spatial data, Holl (2004a) finds that indeed new production establishments are significantly more likely to locate in the immediate proximity of a major road. Holl (2004b) reaches a similar conclusion for Portugal.

2.4 Peculiarities of cross-border infrastructure

The above analysis refers to cross-border communication infrastructure defined as infrastructure connecting different regions – as opposed to infrastructure facilitating internal distribution and commuting. We have seen that, unlike improvements in local infrastructure (bound to help the region carrying out the improvements), cross-border projects linking different regions have more ambiguous effects in the sense that they may harm rather than help the investing peripheral regions (Martin and Rogers 1995).

Nevertheless, the distinction between the two types of projects is not as clear as it may seem. For instance, Venables and Gasiorek (1999) calibrate a new economic geography model with data for European regions in order to evaluate the impact of several road projects financed by the Cohesion Fund. Their analysis shows that sometimes infrastructure built in a single region has strong effects elsewhere. This is the case of the completion of the M-40 ring road around Madrid. Since it acts as a central link for Spain's radial motorway network, it has strong spillover effects throughout Spain and Portugal. On the other hand, the new Tagus crossing in Lisbon improves mainly local transport and its effects are highly concentrated in the Lisbon region.

Thus, the defining characteristic of cross-border communication infrastructure projects – as opposed to local projects – is not that investment is split among several regions, but that it mainly affects the cost of moving goods and people across regions rather than within regions.

In the EU national borders make within-country trade six times larger than international trade.

National transport and communication networks were often designed with a view to facilitating trade within a country. For example, travelling within France from Toulouse to Bordeaux (210 km apart measured as the crow flies) takes just over two hours by either road or train. Travelling from Toulouse to Barcelona (260 km apart) takes four hours by road and six hours by train despite there being no customs or passport controls. A large literature documents significant border effects – discontinuities in trade as one crosses the border. McCallum (1995) estimates that in 1988 the average Canadian province traded twenty-two times more with another Canadian province than with an American state of equal size and distance. Anderson and van Wincoop (2003) show that the border effect is much lower once the average multilateral trade barriers faced by both countries are taken into account. They estimate that the border can explain Canadian inter-province trade being six times as high as trade between Canadian provinces and US states. Since the United States has a much larger economy than Canada,[5] it experiences a much smaller border effect with US interstate trade being only 25 percent higher than US-state–Canadian-province trade. In the European Union, the border effect makes within-country trade six times larger than international trade for a comparable distance and country size, according to Chen (2004).

The measured border effect may be so high because even in the closed economy, activity is not distributed evenly across the territory but gets less dense near the border. Firms respond to networks designed for the national market by agglomerating within countries in clusters that rarely extend close to, let alone across, national borders. As a result, even if trade barriers are eliminated and transport networks adapted to facilitate international shipments, an important border effect will remain as long as earlier patterns of agglomeration persist. Hillberry and Hummels (2003), using data on actual distances of shipments within the US, find a substantial amount of the border effect to be driven by the fact that sectors do not spread out within countries proportionately to population.

5 Since the US economy is eight times larger than the Canadian economy, an increase in trade barriers raises the price of a smaller fraction of goods in the United States (where more goods are produced domestically) than in Canada.

Another defining characteristic of cross-border infrastructure is that it crosses political boundaries. Since its effects spill over beyond the boundaries of the region or regions where the infrastructure is built (and thus beyond the political constituency of the corresponding government), there is a natural tendency for individual governments to under-invest in cross-border infrastructure.

In addition, because cross-border infrastructure typically extends over a number of regions, this also raises coordination problems since a connection built or improved by one government up to the border will be of little use if the project does not continue on the other side – a problem that will be aggravated if the project has particularly asymmetric effects.

Rodríguez-Pose and Fratesi (2004) study the effectiveness of both cross-regional and intraregional transport projects financed with structural funds in promoting growth in Objective 1 regions. They find that more investment on either cross-regional or intraregional projects is not correlated with higher growth. However, since few border regions are classified Objective 1 regions, this is best interpreted as evidence of the ineffectiveness of the large infrastructure investment of the structural funds rather than as evidence of the relative effectiveness of cross-border and national infrastructure investment.

Cross-border infrastructure can address the inadequacy of national networks but lack of coordination and under-investment need tackling.

Taken together, the small effects from the vast improvements in infrastructure in Europe over the last decades and the three features discussed above – networks designed for the national market becoming inadequate with growing integration, under-investment due to spillovers, and coordination failures – suggest that it may be best for supra-national institutions to concentrate on cross-border infrastructure where they have a distinct role that national governments cannot play. Regarding the adaptation of transport networks to cross-border trade, this will be particularly effective when there are clusters with potential input-output linkages at different sides of the border. Hanson (1996) finds evidence of these cross-border clusters following trade liberalization between the United States and Mexico. Local employment has grown more in those border areas that have more agglomeration of industries with strong buyer-supplier relationships. Regarding spillovers and coordination failures, the role of supra-national institutions will be particularly important when the distribution of the investment that must be made at each side of the border differs substantially from the distribution of expected benefits.

3. Infrastructure improvements and growing urban interdependence

3.1 Transport and the urban trade-off

The previous section studied the relationship between communication infrastructure and agglomerations over large geographical areas, such as those that extend across substantial parts of a region or even cross regional boundaries. We now turn to agglomerations at smaller geographical levels, particularly those that operate at the level of individual cities.

Firms and workers are much more productive in large cities than in other locations. It is also in large cities where the vast majority of substantial innovations emerge. The productivity advantages of cities and urban clusters with a high density of firms and workers have been known for a long time. The first influential modern study, by Sveikauskas (1975), regressed log output per worker in a cross-section of city-industries on log city population and found that a doubling of population increases output per worker by about 6 percent.

A problem raised by this and other early estimates of the magnitude of agglomeration economies is that higher output per worker may not be so much a consequence of a higher local employment but its cause, *i.e.*, if a location has an underlying productive advantage it will tend to attract more firms and workers. Ciccone and Hall (1996) were the first to tackle this issue, by instrumenting for local employment. Their main finding is that reverse causality on this matter is only a minor issue. This conclusion was confirmed by much of the subsequent literature (Combes *et al.* 2007). Another issue is that output per worker may not be the best measure of productivity. The literature has addressed this by using a wide variety of productivity measures: Estimated total factor productivity, wages, and proxies like local rates of firm creation and employment growth (see Rosenthal and Strange 2004 for a discussion). The current consensus is that a doubling of city size increases productivity by between 3 and 8 percent for a large range of city sizes.

Urban agglomerations are more productive than other places.

Despite the broad agreement on the magnitude of agglomeration economies at the urban level, the literature has been far less successful at distinguishing between its possible sources. There is a large theoretical literature that builds three broad classes of mechanisms to explain the existence of urban agglomeration economies (Duranton and Puga 2004). First, a larger market allows for a more efficient sharing of indivisible facilities (*e.g.*, local infrastructure), a variety of intermediate input suppliers, or a pool of workers with similar skills. Second, a larger market also allows for a better matching between employers and employees, buyers and suppliers, or business partners. This better matching can take the form of improved chances of finding a suitable match, a higher quality of matches, or a combination of both. Finally, a larger market can also facilitate learning, for instance promoting the development and widespread adoption of new technologies and business practices.

Distinguishing between these mechanisms in practice has proven difficult, although there has been recent progress (see Rosenthal and Strange 2004 for a review). Most of these mechanisms operate over very small distances and are thus not particularly sensitive to long-distance transport infrastructure (Rosenthal and Strange 2001; Henderson, 2003a). An important exception is agglomeration in order to share a variety of intermediate suppliers. Overman and Puga (2008) show that spending a large fraction of costs on intermediate inputs alone does not make a sector more likely to agglomerate. Firms agglomerate to share a variety of intermediate suppliers only if the suppliers of a sector's key intermediates are themselves agglomerated. In this case final producers tend to cluster within reasonable distance of their intermediate suppliers and long-distance infrastructure allows the benefits of such an agglomeration to be reaped further away.

While there are clear advantages to having a larger population and more employment in specific activities in a city, there are also disadvantages. Larger cities have more expensive residential and commercial land and involve lengthier average commutes. Following from the work of Henderson (1974), models of systems of cities characterize city size as the result of a trade-off between the benefits of agglomeration economies on the one hand and congestion costs on the other. The relationship between city size and the net urban benefits resulting from aggregating agglomeration and congestion costs is thus typically concave, with net benefits first increasing and then decreasing with city size.

From a policy perspective, there is a tendency to focus on promoting the benefits, in particular through cluster policies. However, the case for such cluster policies is weak (see Duranton 2008 for a thorough discussion). The existence of both benefits and costs to greater clustering implies that, unless there is a clear reason to believe that the decisions of private agents will deliver suboptimal clustering, many cluster policies may be, if not harmful, at least wasteful. Of course, there are typically inefficiencies associated with agglomeration economies. However, the inefficiencies created by different agglomeration mechanisms and the policies required to address them are quite distinct. And when such policies are in place, the danger of capture by interest groups is great.

Addressing urban congestion costs is more effective than cluster policies.

Addressing urban congestion costs, while also complex is plagued by fewer problems and can also be more effective. There are also greater public checks on such policies, since bad transport or housing policies are more easily perceived by a city's population. This would in principle point to transport infrastructure for commuting as a way to improve the trade-off between agglomeration and congestion costs delivered by cities. However, interregional transport infrastructure also plays an important role because it is often widely used for commuting. When a highway connecting two cities is built or improved, people commuting between the suburbs and the centre of each city account for much of the traffic in the first 15 to 20 kilometres at either end of the highway. As a result, highways affect the housing choices of people living in a city by facilitating commuting. Baum-Snow (2007) shows that an additional highway crossing an average US city doubles the number of people relocating from the city centre to the suburbs.

Reductions in commuting and local transport costs following the construction or improvement of highways also make a city more attractive relative to other locations. Recent empirical work finds that, as a result, highways have a positive and significant effect on urban population growth. Duranton and Turner (2008) address the issue of reverse causation – faster growth possibly leading to more roads – by instrumenting US roads with the 1947 interstate plan.[6] They find that a 10 percent increase in roads increases a city's population and employment by an extra 2 percent over the following 20 years. Addressing the reverse causality problem thereby increases the estimated effect of roads on city growth by a factor of five. This indicates that road building is endogenous to urban growth, but with more roads being built in cities with slow growth than in cities with fast growth. Duranton and Turner (2008) show that there were more roads built between 1980 and 1990 in cities experiencing a negative population shock during the previous decade. These new roads built in response to a local downturn tend to have much smaller effects on urban growth than the average new road.

3.2 Transport, trade, and urban primacy

Various types of transport infrastructure differ in their effects on urban concentration. We have already discussed the hub effect created by radial transport networks. This implies that transport networks that connect different regions with radial links through a hub city (typically the capital or the largest city) will tend to increase concentration in that city. In an urban context this will tend to increase urban primacy, *i.e.*, the share of a country's urban population that is in its largest city. Henderson (2003b) documents that many countries have excessive urban primacy. This means that the largest city has grown to a point at which additional agglomeration creates more congestion costs than benefits. However, Henderson (2003b) also finds several countries with suboptimal primacy in 1990 – mostly European countries, such as Belgium, Netherlands, Switzerland, and West Germany. He estimates optimal urban primacy by using cross-country data to calculate the relationship between a quadratic function of urban primacy and productivity growth, after controlling for other determinants of growth and allowing for variations with country size. He then shows that deviations from optimal primacy reduce economic growth substantially. Henderson (2002) documents an additional cost: Excessive primacy not only implies very large commuting and

6 The argument is that highways in the 1947 interstate plan were designed to interconnect major US cities and to connect them with Canada and Mexico, not to improve local transportation. Therefore, they are a possible cause but not a consequence of suburbanization or population growth in particular cities. This is the same instrumentation strategy as that used by Baum-Snow (2007) to study the role of roads in suburbanization, although in the latter case addressing reverse causality makes little difference to the results.

housing costs in the biggest city but strains the whole urban system by diverting resources from other cities to contain congestion and environmental costs in the biggest city.

While transport infrastructure that connects national trade through a hub city favours primacy, cross-border infrastructure that facilitates trade with the outside world will tend to reduce primacy. Krugman and Livas Elizondo (1996) develop a model that shows this effect, motivated by the case of Mexico. In a closed economy accessing demand is equivalent to accessing the local market, which is often concentrated in the main city. Opening up to international trade, whether it is through tariff reductions or improved cross-border infrastructure, increases the importance of the international market relative to the national market. When access to the international market does not take place mainly through the largest city (as would be the case if it had to go through its port), this reduces urban primacy. Ades and Glaeser (1995) document that, in practice, countries more open to international trade tend to have less primacy. Hanson (1997) looks at the case of Mexico empirically and finds that bilateral trade liberalization with the United States has shifted Mexican industry away from Mexico City and towards states with good access to the US market. This is reflected in interregional wage differentials, which after integration are less related to distance from Mexico City and more related to distance from the border.

Cross-border infrastructure can reduce excessive urban primacy.

3.3 The growing interdependence of cities

Urban economists have long debated whether specialized or diverse cities are more conducive to growth (Glaeser *et al.* 1992; Henderson *et al.* 1995; Combes 2000). Duranton and Puga (2001) argue that both diversity and specialization are important but at different stages of a product's life cycle. Cities that are narrowly specialized in a few sectors create greater economies of agglomeration, thus a firm's productivity increases with proximity to similar firms. At the same time a diverse mix of activities makes cities more likely to grow, particularly in new sectors.

There is a tendency to think of clusters of similar firms as the best environment for innovation. Recent studies of innovation and technology adoption show instead that diverse metropolises encourage the development of new products and processes. Feldman and Audretsch (1999) find that local diversity has a strong positive effect – and narrow specialisation a negative one – on the development of new products reported by trade journals in the United States. Technology adoption is also facilitated by local diversity. For example, the adoption of computer-controlled machinery for cutting metals has been much faster at locations where there is a coexistence of firms (ranging from furnace manufacturers to aircraft producers) with similar technical needs, but not directly competing with each other (Harrison *et al.* 1996; Kelley and Helper 1999; No 2003). In the model developed by Duranton and Puga (2001), an entrepreneur with a new business project may not know all the details of the product to be made, which components to use and where to source them, which workers to hire, and how to finance the venture. Being close to different firms in different sectors makes it easier to experiment with several possibilities in the same location. Thus diverse cities facilitate learning and experimentation, important at early stages.

For firms in more standardized or mature industries, however, urban specialization is more important. These firms typically benefit less from the flexibility that urban diversity affords, and by locating in a specialized environment they can better reap the benefits of urban agglomeration economies. For example, automobile producers can substantially lower their costs by sharing suppliers of car parts with other producers, and garment manufacturers benefit from thick labour markets that facilitate the movement of workers across factories as the whims of fashion increase demand for some producers while simultaneously lowering demand for others (Rosenthal and Strange 2001; Overman and Puga 2008).

Studies of firm location indicate that new production establishments choose to locate disproportionately in more diverse cities (Lainé and Rieu 1999; Holl 2004b). However, over time many of these establishments relocate away from diverse cities towards more specialized environments (Duranton and Puga 2001). The pattern is particularly strong for firms for which innovating and being close to similar firms are particularly important (such as electronics producers). When such relocations take place, establishments tend to move to locations that are more specialized but still easily accessible from their previous location. In other cases exploiting the advantages of diversity early in a product's life cycle and the advantages of specialization later on does not involve relocation of a production facility but relocation of production across two facilities. For instance, Fujita and Ishii (1998) document that the major Japanese electronic firms produce prototypes in trial plants that are located in metropolitan areas, which are known to be particularly diversified. At the same time their mass-production plants are almost always located in more specialised cities. As Duranton and Puga (2001) put it, for manufacturing and services, unlike for agriculture, 'sowing' and 'reaping' can take place in different locations. A 'balanced' urban system is not one where all cities are similarly specialized or diversified but one where both diversified and specialized cities co-exist.

Transport infrastructure helps achieve a balanced urban system with specialized and diversified cities.

Such a balanced urban system is greatly facilitated by good transport connections across cities. It also has important implications for where more local infrastructure projects are developed. Since this growing urban interdependence manifests itself in plant relocations away from large diverse cities, governments may be tempted to take resources for infrastructure investment away from them. This would kill the goose that lays the golden eggs, since such relocations to smaller specialized cities are just a later part of a life-cycle of firms to whom large diverse cities helped give birth.

There is a second dimension of urban interdependence highlighted by Duranton and Puga (2005), for which transport and communication infrastructure matters even more as it may actually be the driving force. Just as product development and mass production increasingly take place at different locations, so do management and production activities. Half a century ago the difficulties associated with managing businesses from far away made most firms keep their headquarters and management offices close to their factories.

The extra cost of coordinating and monitoring firms with facilities at multiple locations relative to integrated firms has decreased dramatically following key technological developments in transport and communication technologies as well as new management practices (Chandler 1977, Kim 1999). The cost of transporting goods, people and ideas has declined dramatically over the last century. For instance, maritime freight in 1990 was only one third as costly as in 1920, revenue per passenger-mile in air-travel in 1990 was one sixth of what it was in 1930, and the cost of a three-minute telephone conversation between New York and London fell by 98.7 percent between 1930 and 1990 (Jones 1997).

Such falls in transport and communication costs have greatly facilitated managing production from a distance. As a result, many firms have spatially separated their management and production activities, searching for the best possible conditions for each. For headquarters this means locations with other headquarters where they can, for example, share legal services or advertising agencies; for production facilities, it means places with other production plants. Headquarters are usually in bigger cities, because professional services tend to exhibit greater economies of agglomeration, are less land-intensive and employ highly educated employees willing to pay for big-city amenities. The ensuing increase in land prices prompts production establishments to relocate to smaller, more specialized towns and cities.

In addition to modelling this process, Duranton and Puga (2005) illustrate it with data from the United States. In 1950 the ratio of managers to production workers was similar across cities of different sizes. By 1990, however, cities with between 75 and 250 thousand people had 20 percent fewer managers per production worker than the national average whereas cities with between 1.5 and 5 million people had 20 percent more managers per production worker. Cities larger than 5 million people were 50 percent above the national average. A similar trend can be seen in other countries such as France and Germany (Bade *et al.* 2003). Aarland *et al.* (2007) use establishment-level data for the United States to study the determinants of the spatial separation between management and production. They find that good accessibility between central administration offices and production plants is crucial. Of the firms that separate management and production at least partially, 75 percent locate their stand-alone central administrative office within the same county as one of their production facilities. Those that do not operate in this way tend to be firms with production plants that are particularly dispersed or located in small cities, and prefer to have their central administrative office in a large city from which there is good access to its different plants.

R&D and management tend to locate in big diversified cities, large-scale production in specialized cities.

Overall, cities are becoming increasingly interdependent places. Firms split innovation and early production from more mature manufacturing, or management facilities from production plants. Good transport and communication infrastructure is an essential element that makes it possible for firms to find the optimal environment for each activity. Whereas we have paid particular attention to roads throughout this paper, in this case other types of transport and communication infrastructure are key. High-speed rail, while rarely used to transport goods, greatly facilitates visits by managers to production plants within the same country. In France it has been suggested that the construction of the Paris-Lyon high-speed rail line led to the relocation of headquarters from Lyon to Paris while in Spain there are concerns that the Madrid-Barcelona high-speed rail line may reinforce the process of headquarter relocation towards the capital (Puga 2002; Vives 2001). Internationally, non-stop air travel is a crucial determinant of the location of headquarters (Bel and Fageda 2008).

4. Conclusions

Recent work in economic geography and urban economics highlights the importance of agglomeration economies as a determinant of where firms and people locate. In the presence of agglomeration economies, productivity increases with the size of an activity in a location. This is both good news and bad news for places with poor initial conditions. It is good news because it means that a firm's location is not as constrained by physical geography and natural endowments as traditional theories based on comparative advantage imply. A place with poor endowments can nevertheless sustain a large concentration of activity with most firms staying because they prefer to be where the other firms and consumers are. It is also bad news because the circle created by market access and mobility causes great persistence. Once some places are sufficiently far ahead it is very difficult for lagging areas to catch up.

Cross-border infrastructure projects connecting lagging regions with key markets make it easier for firms in lagging regions to reach new customers but also expose them to fiercer competition from firms in more developed areas. Whether there is strong labour mobility (as in the United States) or whether there is weak mobility, large differences in skills, and constraints on wage differentials across regions within each country (as in Europe), improvements in transport infrastructure connecting regions are more likely to increase than to decrease regional inequalities. Nonetheless, they have an important role in facilitating increased efficiency and growth – partly as a result precisely of spatial concentration – and wider gains from trade.

Supra-national institutions should help overcome cross-border coordination failures and under-investment.

Cross-border projects can have large effects that extend well beyond the boundaries of the national or regional administration designing and funding them. They require coordination to ensure there is no underinvestment and to prevent coordination failures. They are also important to replace infrastructure designed with the national market in mind with one more adequate for an integrated world with growing trade flows. All this creates an important role for supra-national institutions.

Agglomeration is also important at smaller spatial scales and is the main justification for the very existence of cities. Transport infrastructure can increase certain benefits of large cities. In particular, it can reduce the costs associated with them. An excessive concentration of a country's urban population can be costly. Different types of transport infrastructure have very different effects on such concentration. Hub-and-spoke networks tend to increase urban primacy while cross-border transport connections facilitating international trade tend to reduce it. Transport and communication infrastructure plays a key role in allowing firms to separate innovation and early production from more mature manufacturing, or management facilities from production plants. This process, which has advanced rapidly in developed countries, increases efficiency and urban interdependence. The most relevant bits of infrastructure in this respect include high-speed rail, airports with frequent non-stop flights, and communication technologies.

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