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SUMMARY

The measured effect of national borders on trade seems too large to be explained by the apparently small border-related trade barriers. This puzzle was first presented by McCallum (1995) and has gone on to spawn a large and growing literature on so-called border effects.

There are three basic ways to solve the border effect puzzle. First, one might discover that border-related trade barriers are actually larger than they appear. This approach might emphasize unconventional barriers such as the absence of good information (Rauch, 2001 provides a comprehensive survey of this emerging literature). Second, it might be that there is a high elasticity of substitution between domestic and imported goods, leading to high responsiveness to modest barriers. Finally, the border effects may have been *mismeasured* in a way that leads to a systematic overstatement. This paper takes the third approach and argues that illusory border effects are created by the standard methods used for measuring distance between and within nations.

McCallum (1995) initial paper used a gravity equation combined with data on trade flows between Canadian provinces and American States to find that the average Canadian province traded in 1988 20 times more with another Canadian province than with an American state of equal size and distance. Wei (1996) showed how the gravity equation could be used to estimate border effects in the (most frequent) absence of data on trade flows by sub-national units. He measured “trade with self" as production minus exports to other countries. He then added a dummy variable that takes a value of one for the observations of trade with self and interpreted its coefficient as the border effect. This approach has been widely emulated. However, it only works if one measures distance within and between nations in an accurate and comparable manner. Most of the literature has used point-to-point measures for internal and external distances.

We argue in this paper that, because distances are always mismeasured in the existing literature, the border effects may have been mismeasured in a way that leads to a systematic overstatement. Our goal here is to develop a correct measure of distance that would be consistent for international as well as intra-national trade flows.

We call this new measure “effective distance”. It is calculated so as to ensure that trade between countries replicate trade between regions of those countries as a function of region-to-region distances.

We show how use of the existing methods for calculating distance leads to “illusory" border and adjacency effects. We then apply our methods to data on interstate trade in the United States and inter-member trade in the European Union. We find that our new distance measure reduces the estimated border and adjacency effects but does not eliminate them. Thus, while we do not solve the border effect puzzle, we do show a way to shrink it.

ABSTRACT

The measured effect of national borders on trade seems too large to be explained by the apparently small border-related trade barriers. This puzzle was first presented by McCallum (1995) and has gone on to spawn a large and growing literature on so-called border effects. We argue in this paper that, because distances are always mismeasured in the existing literature, the border effects may have been mismeasured in a way that leads to a systematic overstatement. Our goal here is to develop a correct measure of distance that would be consistent for international as well as intra-national trade flows. We show how use of the existing methods for calculating distance leads to “illusory" border and adjacency effects. We then apply our methods to data on interstate trade in the United States and inter-member trade in the European Union. We find that our new distance measure reduces the estimated border and adjacency effects but does not eliminate them. Thus, while we do not solve the border effect puzzle, we do show a way to shrink it.

JEL classification: F12, F15
Key words: Border effect, gravity equation, distance measurement.

La partie illusoire des effets frontières : la mesure de la distance surestime le biais domestique du commerce

Résumé

L'effet des frontières nationales sur les échanges commerciaux semble trop important pour pouvoir être expliqué par le faible niveau actuel des barrières aux échanges entre nations développées. Cette énigme a été révélée pour la première fois par McCallum (1995) et a entraîné une littérature importante cherchant à documenter et expliquer ces "effets frontières".

Il y a actuellement trois grands types d'explications apportées à cette énigme. Nous pourrions tout d'abord revenir sur notre croyance initiale concernant le faible niveau des barrières aux échanges internationaux. Cette approche met en avant l'existence de barrières au commerce non conventionnelles comme l'imperfection de l'information (Rauch, 2001 fournit une revue très complète de cette littérature émergente). Un deuxième élément d'explication pourrait également résulter du fait que, même en présence de barrières de faible ampleur, une élasticité de substitution importante entre biens domestiques et biens importés entraîne une réduction importante du volume du commerce. Enfin, les effets frontières pourraient avoir été systématiquement surestimé en raison de problèmes *d'erreurs de mesure*. Cet article choisit cette troisième voie d'exploration en tentant de montrer que des effets frontières sont créés de manière illusoire par les méthodes habituelles de mesure des distances internationales et intra-nationales.

La contribution originelle de McCallum (1995) utilisait un modèle de gravité et des données de commerce entre les provinces canadiennes et les Etats américains pour trouver qu'une province canadienne moyenne commerçait en 1988 environ 20 fois plus avec une autre province canadienne qu'avec un Etat américain de taille et distance canadienne. Wei (1996) a montré que le modèle de gravité pouvait être utilisé dans les cas (les plus fréquents) où l'on ne dispose pas de données de commerce entre régions intranationales. Il mesure le commerce "interne" à un pays comme la production de ce pays diminuée des exportations vers tous les autres pays. Il introduit alors une variable indicatrice des observations de commerce interne et interprète son coefficient comme l'effet frontière. Cette approche a été depuis très largement suivie. Néanmoins, cette approche n'est correcte que les auteurs mesurent les distances entre nations et internes aux nations de manière correcte et comparable.

Nous soutenons dans cet article que la littérature existante adopte des mesures de la distance inapropriées qui entraînent une surestimation systématique des effets frontières. Nous cherchons à développer une mesure de la distance qui serait cohérente à la fois entre pays différents et entre régions différentes d'un même pays.

Nous appelons cette nouvelle mesure " distance effective". Son mode de calcul assure que le commerce entre deux pays est bien égal à la somme des échanges bilatéraux entre les régions de ces deux pays, eux mêmes fonction de la distance entre ces régions.

Nous montrons d'abord analytiquement comment l'utilisation des mesures existantes entraîne des estimations d'effet frontières et d'effet d'adjacence "illusoires". Nous appliquons ensuite nos méthodes à deux échantillons : l'un portant sur des données d'échanges entre Etats américains, l'autre portant sur le commerce entre pays membres de l'Union Européenne. Nos résultats montrent que cette nouvelle mesure de la distance réduit significativement l'effet frontière estimé et l'effet d'adjacence, sans toutefois éliminer ces effets. Notre méthode n'offre pas de réponse définitive à l'énigme des effets frontières, mais permet de réduire substantiellement la "taille" de cette énigme.

RÉSUMÉ COURT

L'effet des frontières nationales sur les échanges commerciaux semble trop important pour pouvoir être expliqué par le faible niveau actuel des barrières aux échanges entre nations développées. Cette énigme a été révélée pour la première fois par McCallum (1995) et a entraîné une littérature importante cherchant à documenter et expliquer ces "effets frontières". Nous soutenons dans cet article que la littérature existante adopte des mesures de la distance inapropriées qui entraînent une surestimation systématique des effets frontières. Nous cherchons à développer une mesure de la distance qui serait cohérente à la fois entre pays différents et entre régions différentes d'un même pays. Ce faisant, nous montrons comment l'utilisation des mesures existantes entraîne des estimations d'effet frontières et d'effet d'adjacence "illusoires". Nous appliquons ensuite nos méthodes à deux échantillons : l'un portant sur des données d'échanges entre Etats américains, l'autre portant sur des données d'échanges entre pays membres de l'Union Européenne. Nos résultats montrent que notre nouvelle mesure de la distance réduit significativement l'effet frontière estimé et l'effet d'adjacence, sans toutefois éliminer ces effets. Notre méthode n'offre pas de réponse à l'énigme des effets frontières, mais permet de réduire substantiellement l'importance de cette énigme.

Classification *JEL* : F12, F15

Mots Clefs : effets frontières, gravité, mesure de la distance.

ILLUSORY BORDER EFFECTS : DISTANCE MISMEASUREMENT INFLATES ESTIMATES OF HOME BIAS IN TRADE[1]

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1. INTRODUCTION

The measured effect of national borders on trade seems too large to be explained by the apparently small border-related trade barriers. This puzzle was first presented by McCallum (1995) and has gone on to spawn a large and growing literature on so-called border effects. The original finding was that Canadian provinces traded over 20 times more with each other than they did with states in the US of the same size and distances. Subsequent studies of North American, European and OECD trade also found somewhat smaller but still very impressive border effects.[4] Obstfeld and Rogoff (2000) referred to the border effect as one of the "six major puzzles in international macroeconomics".

There are three basic ways to solve the border effect puzzle. First, one might discover that border-related trade barriers are actually larger than they appear. This approach might emphasize unconventional barriers such as the absence of good information.[5] Second, it might be that there is a high elasticity of substitution between domestic and imported goods, leading to high responsiveness to modest barriers.[6] Finally, the border effects may have been *mismeasured* in a way that leads to a systematic overstatement. This paper takes the third approach and argues that illusory border effects are created by the standard methods used for measuring distance between and within nations.

Hundreds of papers have estimated gravity equations to investigate the determinants of bilateral trade after controlling for the sizes of trading partners and the geographic distances separating them. The data used in these studies generally aggregate the trade conducted by individual actors residing within two economies. However, distances between economies are almost invariably measured from

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[4]Helliwell (1996), Anderson and Smith (2000), Hillberry further investigate province-state trade. Wei (1996) and Helliwell (1998) examine OECD trade. Nitsch (2000) looks at aggregate bilateral flows within the European Union while Head and Mayer (2000) examine industry level border effects in the EU. Wolf (1997 and 2000) also considered the case of trade between and within each American state.

[5]Rauch (forthcoming) provides a comprehensive survey of this emerging literature.

[6]Head and Ries (2001) estimate large (between 8 and 11) elasticities of substitution affecting Canada-US trade but still find barriers other than tariffs have the effect of at least a 27% tariff.

one point in a country to another point.
Wei (1996) showed how the gravity equation could be used to estimate border effects in the absence of data on trade flows by sub-national units. He measured “trade with self" as production minus exports to other countries. He then added a dummy variable that takes a value of one for the observations of trade with self and interpreted its coefficient as the border effect. This approach has been widely emulated. However, it only works if one measures distance within and between nations in an accurate and comparable manner. Most of the literature has used point-to-point measures for internal and external distances.
We are concerned in this paper with situations in which point-to-point distances may give misleading estimates of the relevant geographic distance between and within geographic units. Our goal here is to develop a correct measure distance for economies that are not dimensionless points. This measure differs from the average distance measures developed in Head and Mayer (2000) and Helliwell and Verdier (2001). We then show how use of the existing methods for calculating distance leads to “illusory" border and adjacency effects. We then apply our methods to data on interstate trade in the US and international trade in the EU. We find that our new distance measure reduces the estimated border and adjacency effects but does not eliminate them. Thus, while we do not solve the border effect puzzle, we do show a way to shrink it.[7]

2. PRIOR MEASURES OF DISTANCE

Here we review the different methods used in the literature for the calculation of distances between and within economies.

2.1. Between-unit distances

The gravity equation literature almost always calculates between country distances as the great-circle distance between country “centers." In practice the centers selected are usually capitals, largest cities, or occasionally a centrally located large city. In some cases, such as France, the same city accomplishes all three criteria. In a case like the United States, one could arguably choose Washington DC, New York City, or St. Louis but in practice most studies use Chicago. The selection of cities is not particularly important in cases where countries are small and/or far apart or alternatively if economic activity is very much concentrated in the city chosen. Then the variance due to city choice is probably swamped by the basic imprecision of using geographic distance as a proxy for a whole host of trade costs (freight, time, information transfer).
When countries are close together and economic actors within those countries are geographically dispersed, there is greater cause for concern with the practice of allocating a country’s entire population to a particular point. Most studies include a dummy variable indicating when two countries are adjacent. Since this variable is rarely of interest, many authors include it without an explanation, simply out of deference to common practice. However, it might be related to freight costs (adjacent

[7] In a recent paper, Anderson and van Wincoop (2001) propose a new gravity specification more closely linked to theory. They reduce *McCallum-type border effects* dramatically and interpret their results as “a solution to the border puzzle”. The approach we follow here proposes a way to reduce *Wei-type border effects*, that is the cases where internal bilateral trade flows are not observed but where the total volume of those flows are.

countries are directly connected via train and highway) or to political costs (there may be costs entailed every time one crosses a national border). However, neither argument really justifies an adjacency dummy. The freight costs argument suggests rather that the available modes of transport between two economies be interacted with the distance. The political argument suggests one should count the number of border crossings between two trade partners.

We argue later that adjacency will have tend to have a positive measured effect on trade because effective distance between nearby countries is systematically lower than average distance and on average it is lower than center-to-center distance as well.

2.2. Within-unit distances

There has been remarkably little consensus on the appropriate measure of internal distance. Those discrepancies are a particular source of concern in the border effects literature as the level of internal distance chosen directly affects the estimated border effect. As described below, the border effect measures the “excessive” trade volumes observed within a nation compared with what would be expected from a gravity equation : this is interpreted as a negative impact of the existence of the border on international trade flows. Recalling that gravity relates negatively trade flows with distance, the border effect is crucially dependent on how distances within a country and between countries are measured. More precisely, an overestimate of internal distance with respect to international distance will mechanically inflate the border effect which will compensate for the large volumes of trade observed within a nation not accounted for by the low distance between producers and consumers inside a country.[8]

In this section we survey the literature on this topic. Our central argument is that most measures of internal distances overestimate internal distances with respect to international distances because they try to calculate average distances between consumers and producers without taking into account the fact that, inside countries, goods tend to travel over smaller distances.

1. The initial papers in the literature employed fractions of distances to the centers of *neighbor* countries. Nitsch (2000a,b) vigorously criticizes this approach and so far as we know there is no defense other than it represented a first attempt at solving an intrinsically difficult problem.
   (a) Wei (1996) proposes $d_{ii} = .25 \min_j d_{ij}$, i.e. one quarter the distance to the nearest neighbor country, with distance d_{ij} between two countries between two counties being calculated with the great circle formula.
   (b) Wolf (1997, 2000) used measures similar to Wei’s except for multiplying the neighbor distance by one half instead of one fourth and Wolf (1997) averaged over all neighbors rather than taking only the nearest one.
2. A second strand in the literature use *area*-based measures. Those try to capture an average distance between producers and consumers located on a given territory. They therefore require an assumption on the shape of a country and on the spatial distribution of buyers and sellers. Their advantage is that they can be calculate with only a single, readily available datum, the region’s area.

[8] An important caveat is provided in the empirical section. If use of overestimated internal distances results in lower estimated coefficients on distance then it is not clear what the final impact on estimated border effects will be.

(a) Leamer (1997) and Nitsch (2000a) use the radius of a hypothetical disk, i.e. $\sqrt{\text{area}/\pi}$. Both authors assert that this is a good approximation of the average distance between two points in a population uniformly distributed across a disk.[9]

(b) Redding and Venables (2000) state "we link intra-country transport costs to the area of the country, by using the formula $d_{ii} = .33\sqrt{\text{area}/\pi}$, to give the average distance between two points in a circular country." Keeble et al (1988) relied on the same formula and said they were following Rich (1980). However, Rich refers to even earlier work to argue that the multiplier of the radius should be 0.5 under a uniform distribution but something less if consumers are more concentrated at the center of the disk.

(c) Head and Mayer (2000) assumes that production in sub-national regions is concentrated in a single point at the center of the disk and that consumers are uniformly distributed across the disk. As will be demonstrated later, this can be shown analytically to lead to the following distance formula : $d_{ii} = .67\sqrt{\text{area}/\pi}$.

(d) Helliwell and Verdier (2001) consider internal distances of cities which are represented as square grids. Calculating distances between any two points on the grid, they report that the internal distance is $d_{ii} \approx .52\sqrt{\text{area}}$.

3. Rather than working with geometric approximations, one can use actual data on the spatial distribution of economic activity with nations. These *sub-unit based weighted averages* require more geographically disaggregated data on activity, area, longitude and latitude.

(a) In addition to the fractions of neighbor distances mentioned earlier, Wolf (1997) also used the distance between the two largest cities, which we shall denote $d_{i:12}$, to calculate internal distance of American states. This is akin to estimating the average distance with a single draw. It ignores intra-city trade. Wolf (2000) amends the earlier formula by adding a weight for the share of the population in the top two cities accounted for by the smaller city, $w_{i:2}$. He sets $d_{ii} = 2w_{i:2}d_{i:12}$, which forces the internal distance to lie between zero (if the entire population were concentrated in the largest city) and $d_{i:12}$ if the cities were equally sized.[10]

(b) Head and Mayer (2000) use a simple weighted arithmetic average over *all* region-to-region distances inside a country. They used GDP shares as the weights, w_j. With R denoting the number of regions, country i's distance to itself is given by

$$d_{ii} = \sum_{j=1}^{R} w_j (\sum_{k=1}^{R} w_k d_{jk}).$$

[9] Indeed, with 20000 points distributed uniformly on a disk of radius 1, we find that the average distance between any two of those points is about 0.9.

[10] Note that Zipf's law, described in Fujita et al (1999), suggests that the second largest city in a country will have half the population of the largest city. This implies $w_{i:2} = 1/3$. If $d_{i:12}$ is an unbiased estimate of the distance between randomly selected individuals, then Wolf's measure is about 67% of that representative distance. Indeed, Wolf (2000) reports an average value of 95 for his d_{ii} which is 62% of the average 153 miles separating first and second cities in the Continental 48 states.

For regions' distances to themselves Head and Mayer used the area approximation described above.

(c) For internal distances of Canadian provinces, Helliwell and Verdier (2001) use urban agglomerations and two or three rural areas as their sub-provincial geographic units. Their internal distance is given by a "weighted average of intra-city distances, inter-city distances, the average distance between cities and rural areas, and the average distance from one rural area to another." Although their algebraic expression for obtaining average distances is more complicated than the one displayed in the previous item, we believe it to be essentially the same, except for using population weights instead of GDP shares.

We conclude from this review of the literature that the desired measure of internal distance has been some form of "average" distance between internal trading partners. It may be calculated directly using sub-national data on the geographic distribution of activity or by making various simplifying geometric assumptions. Nitsch (2000b) compares the two methods and concludes that the area-based approximations may be good enough indicators of the averages of sub-national distances.[11]

We will argue that average distances are not the appropriate measures of distance within or between geographically dispersed economies. Rather we argue for a constant elasticity of substitution aggregation that takes into account that desired trade between two actors is inversely related to the distance between them.

3. Effective Distances between "States"

Trade is measured between "states" where we denote the exporting state with i and the importing state with j. In the empirical section states correspond to either the States that comprise the United States or the nation-states that comprise the European Union. Each state consists of geographic sub-units that we will refer to as districts. This will correspond to counties in the United States. For the EU nation-states, counties will correspond to NUTS1 regions for most countries except Portugal where we use NUTS2 and Ireland where we use NUTS3 (these smaller countries are single NUTS1 regions).

Trade flows between and within districts are presumed to be unmeasured by official data collecting agencies. Of course the degree of geographic disaggregation for trade data is a decision variable of statistical agencies and varies across jurisdictions and time. The key idea is that a "state" is defined here as the smallest unit for which trade flows are measured. Districts are defined as a smaller unit for which only basic geographic information (area, longitude and latitude of the center) and economic size (gross product or population) are available.

We identify exporting and importing districts respectively with the indexes k and ℓ. Thus trade flows from district k to district ℓ are given by $x_{k\ell}$. Therefore state to state trade is given by

$$x_{ij} = \sum_{k\in i}\sum_{\ell\in j} x_{k\ell}.$$

[11] He also warns that center-to-center distances are very fragile for countries that are near each other and illustrates with the example of Germany and Austria.

Suppose $x_{k\ell}$ is a function, $f_{k\ell}(\cdot)$ of distance between districts, $d_{k\ell}$. We define effective distance between states i and j as the solution to the following equation :

$$f_{ij}(d_{ij}) = \sum_{k\in i}\sum_{\ell\in j} f_{k\ell}(d_{k\ell}). \tag{1}$$

Thus, effective distances between two states replicate the sum of trade as a function of district-to-district distances.

For the purposes of deriving the effective distance measure between states i and j, we will assume trade between districts is governed by a simple gravity equation :

$$x_{k\ell} = G y_k y_\ell d_{k\ell}^{\theta}, \tag{2}$$

where the y variables represent the total income (or GDP) of each district, the d represents distance between districts, and θ is a parameter that we expect to be negative. The parameter G is a "gravitational constant." While it used to be said that gravity equation lacked theoretical foundations, there are now about a half dozen papers establishing conditions for equations that closely resemble (2). As a general rule, however, G must be replaced with more complex terms that vary across exporters and importers. In the derivation that follows we are assuming that those indexes terms do not vary much.

Using the gravity equation formula we find

$$x_{ij} = \sum_{k\in i}\sum_{\ell\in j} G y_k y_\ell d_{k\ell}^{\theta} = G\sum_{k\in i} y_k y_j d_{kj}^{\theta},$$

where $y_j = \sum_{\ell\in j} y_\ell$ and $d_{kj} = \left(\sum_{\ell\in j}(y_\ell/y_j)d_{k\ell}^{\theta}\right)^{1/\theta}$. Thus the distance from district k to state j is a constant elasticity of substitution (CES) index of the distance to each individual district in state j. In mathematics, this function is also referred to as a "general mean." It takes the weighted arithmetic mean as a special case when $\theta = 1$ and the harmonic mean as a special case when $\theta = -1$ and each district is of equal size.

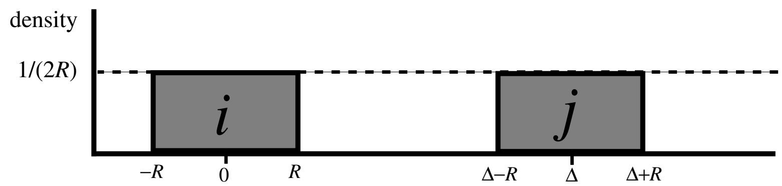
Continuing, we find $x_{ij} = G y_i y_j d_{ij}^{\theta}$, where d_{ij}, the effective distance is given by

$$d_{ij} = \left(\sum_{k\in i}(y_k/y_i)\sum_{\ell\in j}(y_\ell/y_j)d_{k\ell}^{\theta}\right)^{1/\theta}. \tag{3}$$

This formula satisfies our definition of effective distance. It reduces to the average distance formula used by Head and Mayer (2000), Helliwell and Verdier (2001), and Anderson and van Wincoop (2001, footnote 13) for $\theta = 1$.[12] Unfortunately for that formula, there are hundreds of gravity equation estimates of θ that show it is not equal to one. Rather our review of recent papers suggests that in most cases $\theta \approx -1$. Since the harmonic mean is known to be less than the arithmetic mean whenever there is variation, this implies that arithmetic mean distances overstate effective distances.

[12] All three papers appear to have arrived at this measure independently.

FIG. 1 – Two states on a line



4. GEOMETRIC EXAMPLES

We now consider a few concrete, highly stylized, but analytically tractable, examples. These will allow us to illustrate the differences between our effective distance and other possible metrics.

4.1. States along a line

Suppose there are two identical states comprising a continuum of districts with uniformly distributed incomes. State i is centered at the origin and extends from $-R$ to R whereas state j begins at $\Delta - R$ and extends to $\Delta + R$. The density of income in each state is given by $1/(2R)$. Center-to-center distance is Δ. This geography is illustrated in Figure 1.
Let us first consider state-to-state distance. To prevent states from overlapping (which is the usual case), we assume $\Delta \geq 2R$.

$$d_{ij} = \left(\int_{-R}^{R} (1/(2R)) \int_{\Delta-R}^{\Delta+R} (1/(2R))(\ell - k)^{\theta} d\ell dk \right)^{1/\theta}.$$

Solving the double integral we obtain

$$d_{ij} = \left(\frac{(\Delta - 2R)^{\theta+2} + (\Delta + 2R)^{\theta+2} - 2\Delta^{\theta+2}}{(\theta+1)(\theta+2)(2R)^2} \right)^{1/\theta}.$$

Let us now express the ratio of center-to-center distance (Δ, which is also the average distance, as can be checked when setting θ equal to one) to effective distance as

$$\Delta/d_{ij} = \lambda \left(\frac{(\lambda - 1)^{\theta+2} + (\lambda + 1)^{\theta+2} - 2\lambda^{\theta+2}}{(\theta+1)(\theta+2)} \right)^{-1/\theta},$$

where $\lambda \equiv \Delta/(2R)$. This equation shows the factor by which center-to-center distances inflate effective state-to-state distances. While the expression is fairly compact, it is not easy to analyze directly. Evaluating it numerically for the case of $\theta = -1.0001$ (trade is inversely proportionate to distance as is commonly observed in the data) and $\lambda = 1$ (adjacent states), we find that center-to-center distances (which equal average distances in this case) overstate effective distance by 39%. As λ increases, the inflation declines quickly and for $\lambda > 2$, distance inflation lies under 5%.

Let us now consider intra-state distance. States, generally, totally overlap, in the sense that they have a continuous geography. In that case, following the state-to-state method, we find state i's distance from self is given by

$$d_{ii} = \left(\int_{-R}^{R} (1/(2R)) \int_{-R}^{k} (1/(2R))(k-\ell)^{\theta} d\ell + \int_{k}^{R} (1/(2R))(\ell - k)^{\theta} d\ell dk \right)^{1/\theta}.$$

Integrating, we obtain

$$d_{ii} = R \left(\frac{2^{\theta+1}}{(\theta+1)(\theta+2)} \right)^{1/\theta}.$$

The average distance in this case is then equal to $\frac{2}{3}R$. The ratio of average to effective distance is thus now much higher than in the inter-state distance. Indeed, for $\theta = -0.99$, we obtain an inflation factor of 69 here against 1.38 for inter-state. The overestimate of existing measures of distance (like the average distance, which we chose here because it is one of the most sophisticated) is thus much higher for internal distances. As emphasized first by Wei (1996) and as will be apparent formally in the next section, an overestimate of internal distance relative to the external one will mechanically translate into an overestimate of the border effect.

4.2. States on plane

Locating states along a line allows us to compute effective distance by evaluating a double integral. However, real states occupy (at least) two dimensions. We first consider a simplified case that is analytically feasible before considering a few numerical examples. Suppose state i consists of single point located at the center of a disk of radius R. Let state j consist of economic activity that is uniformly distributed across that disk. Thus, $y_\ell/y_j = (2\pi d_{i\ell})/(\pi R^2)$. We denote $d_{i\ell}$ as r. The distance of state i to state j is given by

$$d_{ij} = \left(\int_{0}^{R} [(2\pi r)/(\pi R^2)] r^{\theta} \right)^{(1/\theta)} = (2/(\theta+2))^{1/\theta} R.$$

Substituting $\theta = 1$, we obtain the arithmetic average distance of $(2/3)R$. Using $\theta = -1$ we obtain $d_{ij} = (1/2)R$. Note that this implies that average distances inflate the effective distance by a factor $4/3$ or 33%.

Now let us compare average and effective *within* state distances for some two-dimensional geometric representations of an economy. Table 1 shows the ratio of average to effective distance for different distance-decay parameters, θ. The first two columns work with disk-shaped economies and the second two use rectangles. Column (1) works with analytical results from the previous section for the case of a core point at the center of the disk trading with a set of actors uniformly distributed across the rest of the disk.[13] Column (2) contains results of simulations of 2500 actors randomly dis-

[13]Note that we could also think of this as one half the effective distance between any two points on the disk if we restricted all transport to pass through the center point.

TAB. 1 – Average Distance relative to Effective (CES) distance in Two Dimensions

Method :	(1)	(2)	(3)	(4)
Shape :	Disk		Rectangle	
Distribution :	Core-Periphery	2500 draws	50X50 Grid	90X30 Grid
avg/CES ($\theta = -0.5$)	1.186	1.305	1.302	1.436
avg/CES ($\theta = -1.0$)	1.333	1.545	1.513	1.730
avg/CES ($\theta = -1.5$)	1.679	2.133	1.8445	2.184
avg/$\sqrt{\text{area}}$	0.376	0.514	0.522	0.642

tributed across the disk.[14] Column (3) follows Helliwell and Verdier in considering a grid. Column (4) changes the dimensions of the grid so that it is three times as long as it is wide.[15]

Comparisons for given θ show that the nature of the geometric approximation does matter for determining average and effective distances. In particular, concentration of producers in column (1) gives rise to low distances while the elongated rectangle of column (4) gives larger distances. Squares and disks are approximately the same. For any given geometry, smaller values of θ, i.e. greater trade impeding effects of distance, causes lower effective distances. The reasoning is that the more distance lowers trade, the more the individuals will concentrate their trading activity locally. The implication is that the more negative is true θ the more average distances will overstate effective distances.

5. ESTIMATING BORDER EFFECTS

The simplest form of the gravity equation is useful for determining the appropriate method of creating a distance index for trade between and within states that are geographically dispersed aggregates of smaller units. However, as emphasized by Anderson and van Wincoop (2001), the simple gravity equation is not a reliable tool for estimating border effects. In that paper the authors carefully develop a theoretically consistent method for identifying national border effects when one has data on sub-national units. Using similar but somewhat more general assumptions we develop an alternate method that appears to have two advantages. First, it is appropriate for aggregate and industry-level trade flows. Second, it can be estimated using ordinary least squares.

Denote quantity consumed of variety v originating in state i by an representative consumer in state j as c_{vij}. Following virtually all derivations of bilateral trade equations we assume that import volumes are determined through the maximization of a CES utility function subject to a budget constraint. We use a utility function that is general enough to nest the Dixit-Stiglitz approach taken by Krugman (1980) and its descendants as well as Anderson (1979) and related papers by Deardorff (1998) and Anderson and van Wincoop (2001). We follow the notation of the latter paper whenever

[14]The program used was ⟨http://economics.ca/keith/border/disksimu.do⟩.
[15]The program used was ⟨http://economics.ca/keith/border/gridsimu.do⟩.

appropriate. We represent the utility of the representative consumer from country j as and

$$U_j = \left(\sum_i \sum_{v=1}^{n_j} (s_{ij} c_{vij})^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{4}$$

The s_{ij} can be thought of as the consumer j's assessment of the quality of varieties from country i, measured in “services" per unit consumed. The budget constraint is given by

$$y_j = \sum_i \sum_{v=1}^{n_j} p_{ij} c_{vij}.$$

The Anderson approach assumes a single variety (or good, depending on interpretation) per state, i.e. $n_j = 1$, that is perceived the same by all consumers, i.e. $s_{ij} = s_i$. The Krugman approach identifies varieties with symmetric firms and sets $s_{ij} = 1$.

The solution to the utility maximization problem specifies the value of exports from i to j as

$$x_{ij} = \frac{n_i (p_{ij}/s_{ij})^{1-\sigma}}{\sum_h n_h (p_{hj}/s_{hj})^{1-\sigma}} y_j. \tag{5}$$

Thus, the fraction of income, y_j spent on goods from i depends on the number of varieties produced there and their price per unit of services compared to an index of varieties and quality-adjusted prices in alternative sources.

The next step is to relate delivered prices and service levels to those in the state of origin. Again following standard practice we assume a combined transport and tariff cost that is proportional to value, that is $p_{ij} = t_{ij} p_i$. We further allow for an analogous effect of trade on perceived quality. In particular the services offered by a good delivered to state j are lower than those offered in the origin i by a proportional decay parameter $\gamma_{ij} \geq 1$. The decay may be attributed to damage caused by the voyage (for instance if a fraction $\gamma - 1$ of the products shipped break or spoil due to excessive motion or heat in the vessel) or to time costs or even to more exotic factors such as cultural differences or communication costs. We expect pairs of states that speak different languages to have higher values γ_{ij}. Combining both types of trade cost we obtain

$$p_{ij}/s_{ij} = (t_{ij}\gamma_{ij})(p_i/s_i).$$

We now follow Baldwin et al. (2001) in defining a new term, ϕ, that measures the “free-ness," or phi-ness as a mnemonic, as $\phi_{ij} = (t_{ij}\gamma_{ij})^{1-\sigma}$. The parameter ϕ is conceptually appealing because it ranges from zero (trade is prohibitively costly) to one (trade is completely free). Note that ϕ depends on both the magnitude of trade costs (through t and γ) and the responsiveness of trade patterns (through σ). Baldwin et al. show that it is a crucial parameter in core-periphery models. When ϕ exceeds a critical value, manufacturing activity agglomerates entirely in one region.

After making the substitutions into equation (5), we obtain

$$x_{ij} = \frac{n_i (p_i/s_i)^{1-\sigma} \phi_{ij}}{\sum_h n_h (p_h/s_h)^{1-\sigma} \phi_{hj}} y_j. \tag{6}$$

Since our goal is determine (and then decompose) the ϕ_{ij} parameters, the term $n_i(p_i/s_i)^{1-\sigma}$ is simply a nuisance. The number of varieties in each country and their qualities are unobservable and good cross-sectional price information is difficult to obtain. Hence, we would like to use theory to eliminate these parameters and obtain a relationship between exports and ϕ_{ij} that does not depend on unobservables.

Anderson and van Wincoop accomplish this by imposing a “market-clearing" condition and assuming symmetric trade costs. Formally, this means first setting income in the importing country equal to the sum of its exports to all markets (including itself) ; making i the importer this means $y_i = \sum_j x_{ij}$. Second, it means $\phi_{ij} = \phi_{ji}$. Applying both assumptions, Anderson and van Wincoop obtain

$$x_{ij} = \frac{y_i y_j}{y_w} \frac{\phi_{ij}}{(P_i P_j)^{1-\sigma}},$$

where y_w is world income and the P terms are referred to as the multilateral trade resistance of each country and given by the solution to $P_j^{1-\sigma} = \sum_i (y_i/y_w)\phi_{ij} P_i^{\sigma-1}$.

This solution is compact and intuitively appealing and relates closely to the simple gravity equation. However, it has two drawbacks. First, the market clearing assumption sets GDP (y_i) equal to the sum of all trade flows from i. This balanced trade equation is not appropriate for industry-level data where we expect states with high numbers of varieties of low quality-adjusted prices to be net exporters.[16] A second drawback of the Anderson and van Wincoop specification is the non-linear specification of the resistance terms necessitates the use of non-linear least squares.

We now develop a method to calculate ϕ_{ij} directly and then ordinary least squares can decompose the ϕ_{ij} into parameters corresponding to distance and border effects. This method is simply a many-country generalization of the method introduced in Head and Ries (2001). The basic idea is combine the odds of buying domestic relative to foreign in country i, x_{ii}/x_{ji}, with the corresponding odds in the other country, x_{jj}/x_{ij}. Our “nuisance" term, $n_i(p_i/s_i)^{1-\sigma}$, will cancel out as it appears in the numerator of the odds term for country i and the denominator for country j. Define Ξ_{ij} as the geometric mean of the two odds-ratios. It relates to ϕ_{ij} as follows :

$$\Xi_{ij} \equiv \sqrt{\frac{x_{ii}}{x_{ji}} \frac{x_{jj}}{x_{ij}}} = \frac{\sqrt{\phi_{ii}\phi_{jj}}}{\phi_{ij}}. \tag{7}$$

In the standard core-periphery, trade within regions is costless. Thus, the free-ness of trade in this case is given by $\phi_{ij} = 1/\Xi_{ij}$.

We decompose the determinants of the free-ness of trade into distance and border-related components :

$$\phi_{ij} = (\mu \xi_{ij})^{-B_{ij}} d_{ij}^{\theta},$$

where $B_{ij} = 1$ if $i \neq j$ and zero otherwise. The ξ_{ij} reflect log-normal variation in the border effect

[16] Even for aggregate data, the market-clearing assumption must be used cautiously since GDP (the measure for y_i) includes services and sums value-added flows whereas most trade flows comprise gross shipments of merchandise.

around a central tendency of μ.

$$\Xi_{ij} = \mu \xi_{ij} \left(\frac{d_{ij}}{\sqrt{d_{ii} d_{jj}}} \right)^{-\theta}. \tag{8}$$

Taking logs we obtain our regression equation :

$$\ln \Xi_{ij} = \ln \mu - \theta \ln \left(\frac{d_{ij}}{\sqrt{d_{ii} d_{jj}}} \right) + \ln \xi_{xj}. \tag{9}$$

We will refer to $\ln \Xi_{ij}$ using the term "friction" as it represents the barriers to external trade which are zero when both distance and borders do not matter for trade patterns ($\mu = 1$ and $\theta = 0$). The [mean] border effect, μ is obtained by exponentiating the constant term in the regression. One may determine the ad valorem tariff equivalent of the trade costs due to the border, denoted $b - 1$ by Anderson and van Wincoop, by raising the estimate of μ to the power of $1/(\sigma - 1)$ (which has to be taken from another source, as σ cannot be identified in the present setting) and subtracting 1.

This method for calculating ϕ and estimating border effects is easy to use and imposes relatively few assumptions. To review, we need CES preferences and trade costs that are (i) multiplicative, (ii) power functions of distance, and (iii) symmetric between trade partners. As with all studies based on Wei (1996) our method does require data on exports to self, x_{ii}, and accurate estimates of the internal distances, d_{ii}.

We now return to the issue of distance measurement. Let us define $\bar{d}_{ij}$ as the average distance, or equation (3) evaluated at $\theta = 1$. The corresponding estimate of the border effect will be called $\bar{\mu}$. For simplicity, take the case of symmetric countries, i.e. where $d_{ii} = d_{jj}$. Using equation (8), we define the *illusory border effect*, or the magnitude of border inflation due to distance mismeasurement, as

$$\bar{\mu}/\mu = \left(\frac{\bar{d}_{ij}/\bar{d}_{ii}}{d_{ij}/d_{ii}} \right)^{\theta}. \tag{10}$$

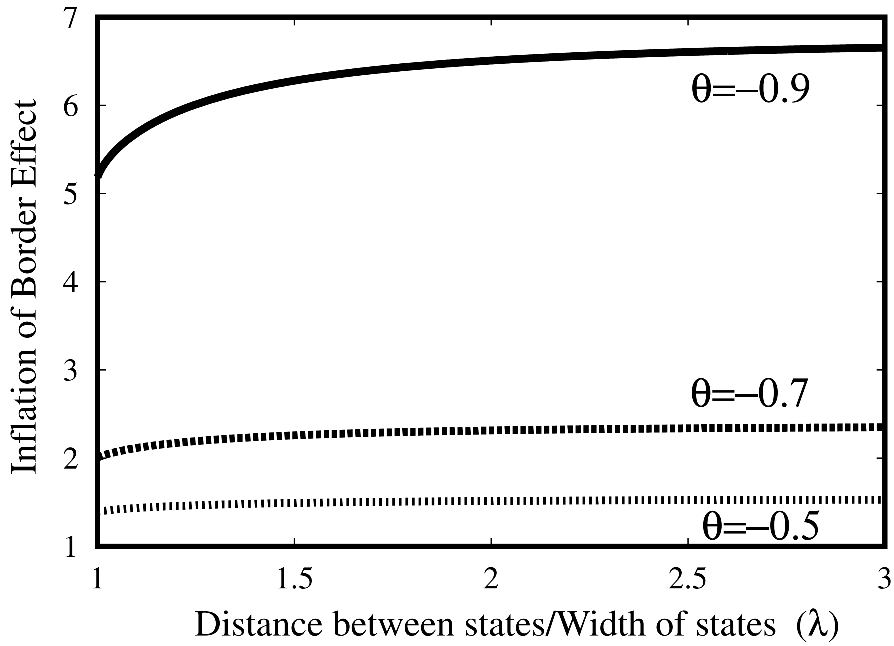
Consider again the relatively simple case of two states that are identical except for their position along a line. In that case we can obtain an analytic solution for border inflation as a function of λ, the ratio of the distance between county centers over the distance within a country from border to border.

$$\bar{\mu}/\mu = \frac{2(3\lambda)^{\theta}}{(\lambda - 1)^{\theta+2} + (\lambda + 1)^{\theta+2} - 2\lambda^{\theta+2}}. \tag{11}$$

We plot this function for cases of θ equal to -0.9, -0.7, and -0.5 in Figure 2. We see that use of average distance causes substantial inflation of the estimated border effects. The illusory border arises because average distances under-measure internal distance to a much greater extent than they under-measure external distance. The inflation factor is smallest for adjacent states. This is because average distance also substantially underestimates distance to nearby states.

In summary, use of average distances (or similar methods) instead of effective distances will lead to biased upwards border effects. Furthermore the more negative is θ, the distance-decay parameter for trade, the greater the bias.

FIG. 2 – Distance mismeasurement causes border inflation in “Lineland"



6. EMPIRICAL APPLICATIONS

We apply our new measure of state-to-state distances to two distinct data sets that have recently been subject to empirical analysis in the literature on border effects. The first sample uses trade flows between American States as used by Wolf (1997 and 2000) except that he used 1993 data at the aggregate level and we use industry-level 1997 data. The second one focuses on trade between and within European nations between 1993 and 1995 (Head and Mayer, 2000). The two data sets use quite different sources of information for trade flows : transportation data (the 1997 Commodity Flow Survey) for the US sample and more traditional trade data from customs declarations for the EU sample.[17]

In each case we present first the results of the estimated equation (9). Our focus is here to see how the estimated border effect vary according to the measure of distance used in the regressions. We use various measures of distance that are precisely defined in section 2. : For the US sample, we use the method initiated by Wolf (which we will note WOLFD) which provides a natural benchmark as the samples used here and in Wolf (2000) are very comparable. We also use the disk-area based measure (which we will note AREA) where $d_i i = .67\sqrt{\text{area}/\pi}$. For the EU sample, we choose to take the AREA distance as a benchmark. For both samples, we compare those distances with two versions of the key distance measure developed in this paper : $d_{ij} = \left(\sum_{k\in i}(y_k/y_i)\sum_{\ell\in j}(y_\ell/y_j)d_{k\ell}^{\theta}\right)^{1/\theta}$. A first version sets $\theta = 1$, which is the arithmetic weighted average distance (noted AVGD) use in Head and Mayer (2000). A second version sets $\theta = -1$, which appears to be a very frequent finding of the gravity equations run in the literature. This is the distance measure we will focus on as the previous sections showed that its use should reveal the illusory part of the border effect.

To keep results comparable to previous papers and as a robustness check, we also present results of "standard gravity equations" in each case. We regress then imports of a destination economy on its total consumption, the production of the origin economy[18], our various measures of distance, and a dummy indicating when the origin and destination are the same, i.e. when trade takes place *within borders*. Those regressions also include industry fixed effects

In both the friction and gravity type regressions, we add controls for adjacency, same Census Division (US data only), and same language (EU data only). We define these last three dummy variables so that they *only take values of one on inter-economy trade*. This means that the border effect is interpreted as the extra propensity to trade within borders relative to trade with an economy that is not adjacent, in the same Division, or sharing the same language. This is a different specification from that employed by Wei and Wolf. It is the one advocated by Helliwell (1998). Near the bottom of the results tables we provide McCallum-style border effects for both types of dummy specification. We emphasize that the issue is one of interpretation, not estimation.

[17] The US data can be downloaded easily from ⟨www.bts.gov/ntda/cfs/cfs97od.html⟩. The EU trade data comes from the COMEXT database provided by Eurostat but requires much more manipulation to reach the form used in our estimation (see Head and Mayer, 2000, for more information).

[18] For the EU data, production data is directly available at the industry level considered which enables to compute industry level production and consumption. For the US data, we use the sum of flows departing from a state (including with destination is own state) as its production for the considered industry and the total inflows (including from self) as its consumption.

6.1. The impact of "borders" within the United States.

Wolf (2000) points out that if border effects were caused exclusively by real border-related trade barriers then they should not operate on state-to-state trade. The reason is that the US constitution expressly prohibits barriers to inter-state commerce. There are no tariffs, no customs formalities, or other visible frontier controls. Nevertheless Wolf finds significant border effects, albeit smaller than those reported for province-state trade by McCallum and Helliwell's studies. That is, state borders give a case of a political border that should have no economic significance based on trade barriers. Furthermore, even informal barriers due to cultural difference or imperfect information seem unlikely to apply. These factors might enter into the effect of distance but we would expect no discontinuities at the border.

Could the border effects estimated by Wolf be "illusory"—the consequence of improper distance measures ? Table 3 investigates this hypothesis. The main results are obtained by comparing columns (5) and (6). We find that effective distances sharply reduce the estimated border effect relative to average distances (the fall is about one third of the initial border effect, going from 9.3 to 6.3, compared to the distance measure used by Wolf, the border effect is roughly divided by 2[19]). Furthermore adjacency effects decline as well. This is just as predicted. However, these effects do not disappear. Furthermore, we find small but statistically significant effects for trade within Census Divisions. These are nine regional groups of states that have no political significance. The results in this table suggest that there are positive neighborhood effects on trade that are just not being captured by distances, even our preferred effective distances.

The standard gravity specification yields qualitatively similar results. Border effects fall by 36% when using our preferred measure of distance instead of the arithmetic average one as can be seen in the two last columns of table 3.

6.2. The impact of borders within the European Union.

Head and Mayer (2000) and Nitsch (2000a) found results on the extent of border effects for the European Union that revealed that the level of fragmentation was still quite high within the European Union despite the progressive removal of formal and informal barriers to trade during the economic integration process. We now draw on the same data used in Head and Mayer (2000) to investigate the extent to which the impact of borders was in fact inflated by average distance measures used. In order to get most comparable results possible with the US data set, we restrict the sample to the three years of data we have post 1992 (1993–1995). We chose those years because the Single Market Programme was

[19] Surprisingly, the magnitude of our border effects seems quite larger than in the results reported by Wolf (2000). This seems to come from the fact that we are using a different year of the CFS data. Robustness checks not reported here show that in a regression of trade flows using exactly the same variables as the first column of its table 1 page 559, we get extremely close results for all coefficients except the border coefficient which is 1.48 in his study for 1993 and 2.13 here for 1997. While it is indeed troubling that this coefficient could rise over time, it does not affect our principal focus here which is not the magnitude of the border effect per se, but its variation with different distance measures.

TAB. 2 – Border Effects for Inter-State commerce, 1997

	Dependent Variable : Ln Ξ (friction)					
Model :		(WOLFD)		(AREA)	(AVGD)	(CESD)
Cross Border	2.14*	2.56*	2.62*	2.32*	2.23*	1.85*
	(0.02)	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)
Ln Distance (see note)	0.65*	0.47*	0.45*	0.54*	0.63*	0.55*
	(0.01)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
Adjacent States		-0.62*	-0.53*	-0.47*	-0.42*	-0.41*
		(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
States in same Census Division			-0.25*	-0.14*	-0.20*	-0.17*
			(0.03)	(0.03)	(0.03)	(0.03)
Border Effect†	8.5–8.5	6.9–12.9	6.3–13.7	5.5–10.2	5–9.3	3.6–6.3
N	5841	5841	5841	5841	5841	5841
R^2	0.325	0.37	0.377	0.364	0.386	0.38
RMSE	.817	.79	.785	.793	.78	.783

Note : Standard errors in parentheses with * denoting significance at the 1% level. Distances are calculated using two major cities in columns (1) through (3) (WOLFD), area-based internal distances in (4) (AREA), average distance in columns (5) (AVGD), effective distance (CESD) in column (6).
† : The first border effect is imports from home relative to imports from an adjacent state in same census division. The second is relative to a non-adjacent state in a different division.

TAB. 3 – Border Effects for Inter-State Commerce, 1997

	Dependent Variable : Ln Shipments					
Model :		(WOLFD)		(AREA)	(AVGD)	(CESD)
Ln Origin Production	0.79*	0.81*	0.81*	0.81*	0.82*	0.82*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Ln Destination Consumption	0.75*	0.76*	0.76*	0.76*	0.77*	0.77*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Ln Distance (see note)	-0.73*	-0.51*	-0.47*	-0.48*	-0.56*	-0.54*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Within State (home)	2.35*	2.94*	3.05*	2.96*	2.85*	2.40*
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)
Adjacent States		0.80*	0.72*	0.70*	0.68*	0.61*
		(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
States in same Census Div.			0.28*	0.27*	0.29*	0.27*
			(0.02)	(0.02)	(0.02)	(0.02)
Border Effect†	10.4–10.4	8.4–19	7.7–21.1	7.3–29.6	7.5–17.2	4.5–11
N	21394	21394	21394	21394	21394	21394
R^2	0.716	0.735	0.738	0.738	0.741	0.742
RMSE	.908	.876	.872	.872	.866	.865

Note : Standard errors in parentheses with * denoting significance at the 1% level. Distances are calculated using two major cities in columns (1) through (3) (WOLFD), area-based internal distances in (4) (AREA), average distance in columns (5) (AVGD), effective distance (CESD) in column (6).
† : The first border effect is imports from home relative to imports from an adjacent state in same census division. The second is relative to a non-adjacent state in a different division.

supposed to be fully implemented and therefore the border effects should not reflect any tariff (since 1968) or non-tariff (since January 1st 1993) barriers to trade.

TAB. 4 – Border Effects for the EU after 1992

	Dependent Variable : Ln Ξ (friction)		
Model :	(AREA)	(AVGD)	(CESD)
Cross Border	3.35*	2.64*	1.44*
	(0.18)	(0.21)	(0.25)
Ln Distance	1.05*	1.38*	1.27*
	(0.05)	(0.08)	(0.07)
Share Language	-0.72*	-0.92*	-0.74*
	(0.14)	(0.13)	(0.14)
Adjacency	-0.70*	-0.48*	-0.40*
	(0.07)	(0.08)	(0.07)
Border Effect†	6.8–28	3.4–14	1.3–4.2
N	7213	7213	7213
R^2	0.265	0.258	0.276
RMSE	1.685	1.694	1.672

Note : Standard errors in parentheses with * denoting significance at the 1% level. Distances are calculated using the area approximation in columns (1) (AREA), the arithmetic weighted average in columns (2) (AVGD), the CES aggregator in column (3) (CESD). Standard errors are robust to correlated industry residuals.
† : The first border effect is imports from home relative to imports from an adjacent country speaking the same language. The second is relative to a non-adjacent country speaking a different language.

The most important result of those regressions estimating border effects in the EU is the fall in the estimated effect of borders when adopting our improved measure of effective distance. The border effect estimated in the friction specification (table 4) goes from $\exp(2.64) = 14$ to $\exp(1.44) = 4.2$ when passing from simple arithmetic average distance (AVGD) to effective distance (CESD). Compared to a more traditional area-based distance measure (AREA), the impact of distance measurement is even more impressive, the impact of the border being divided by 6.6 and adjacency being also drastically less important in trade patterns. The traditional gravity equation results are almost identical in both the estimated magnitudes and falls of the considered coefficients. While we just showed that our effective distance measure can help to understand how the effect of borders is globally overestimated because of the mis-measurement in distance, there is still some evidence of significant border effects in our sample. We will now see that the differences in border ef-

TAB. 5 – Border Effects for the EU after 1992

	Dependent Variable : Ln Imports					
Model :	(AREA)	(AVGD)	(CESD)	(AREA)	(AVGD)	(CESD)
Ln Importer's Consumption	0.53*	0.60*	0.59*	1	1	1
	(0.03)	(0.03)	(0.03)			
Ln Exporter's Production	0.89*	0.98*	0.96*	1	1	1
	(0.05)	(0.05)	(0.06)			
Ln Distance	-0.94*	-1.20*	-1.17*	-0.74*	-1.07*	-1.01*
	(0.04)	(0.05)	(0.05)	(0.04)	(0.05)	(0.05)
Share Language	0.66*	0.55*	0.55*	1.13*	0.88*	0.90*
	(0.07)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)
Adjacency	0.72*	0.54*	0.39*	0.60*	0.40*	0.28*
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Within Border	3.34*	2.72*	1.45*	3.56*	2.82*	1.71*
	(0.15)	(0.16)	(0.17)	(0.16)	(0.16)	(0.18)
Mills Ratio	1.76	3.06	2.58	5.74*	5.26*	5.28*
	(1.65)	(1.58)	(1.56)	(0.73)	(0.67)	(0.65)
N	20376	20376	20376	20376	20376	20376
R^2	0.777	0.779	0.782	0.671	0.681	0.684
RMSE	1.381	1.373	1.364	1.477	1.453	1.447

Note : Standard errors in parentheses with * denoting significance at the 1% level. Distances are calculated using the area approximation in columns (1) and (4) (AREA), the arithmetic weighted average in columns (2) and (5) (AVGD), the CES aggregator in columns (3) and (6) (CESD). In columns (4)-(6) a unit elasticity is imposed on exporter production and importer consumption by passing them to the left hand of the regression equation. Standard errors are robust to correlated industry residuals.

† : The first border effect is imports from home relative to imports from an adjacent country speaking the same language. The second is relative to a non-adjacent country speaking a different language.

fects among industries can also be explained by the same reasoning we used in deriving our effective distance measure, that is a systematic overstatement of border effects in goods that are difficult to ship compared to others.

6.3. Transportability.

The additional cost needed to transport an item varies greatly across goods. We have just seen that accounting for the fact that distance matters inside countries too considerably alters the magnitude of global border effects. A related question is how does it matter across industries. Authors that have been able to work at the industry level on this topic have systematically found that industries as oil refining, construction materials, wooden products, clay, metal containers were characterized by very high border effects, despite industry specific distance variables (an example is Chen, 2001, finding a very clear positive relationship between the border effect of an industry and the weight to value ratio of trade in that industry) . Table 6 reflects this tendency. The 10 highest border effects expressed as McCallum's ratio are shown industry by industry for the two samples. Those products appearing in the top list of border effects are also the ones that are presumably the harder to transport over long distances as it appears in the last column of the table. This last column shows the ratio of the average distance covered by the considered good over the same distance for the whole manufacturing industry (the precise construction of this variable is described below). As expected, those ratios are well below one, except for one of those industries. Typical examples are cement, concrete and soft drinks, all those products covering very low distances (between 10 and 15% of the average manufacturing product) and having a very high border effect.

TAB. 6 – High Border Effects Industries

US		EU		
Industry	Border effect	Industry	Border effect	Miles
Coal	498,3	Tobacco	2870,3	0,5
Natural sands	277,43	Cement	960,78	0,15
Gravel and crushed stone	243,38	Oil refining	730,31	0,24
Logs and other rough wood	49,76	Carpentry	718,76	0,66
Alcoholic beverages	32,21	Wooden containers	284,37	1,67
Coal and petroleum, n.e.c.	32,14	Food n.e.s	235,18	0,34
Other agric. prod.	30,61	Concrete	213,68	0,15
Gasoline and aviation fuel	21,49	Soft drinks	164,36	0,1
Mixed freight	18,47	Wood-sawing	153,05	0,34
Wood products	17,19	Grain milling	112,83	0,25

This result is very confusing at first sight. In industry by industry regressions, goods that are difficult and / or expensive to transport over long distances like cement or carpentry should simply exhibit larger negative effects of distance and therefore transportability should not affect border effects. The development of our improved measure of distance clarifies the link between transportability and borer effect and explains why those goods for which transportability is very low will exhibit border effects that are very much biased upwards. Indeed, the θ should be very high (in absolute value) for those industries which will cause internal distances of countries to be even more overestimated than for other goods because products in those industries cover very low distances in reality.

In order to test for this conjecture, we would ideally want to collect an independent estimate of θ for each industry and use it to calculate effective distance shown in equation (3). We would then expect the link between transportability and the border effect to disappear. We are unfortunately unable to do that because our model does not enable to get a prior estimate of θ before distance calculations.

We therefore proceed in a indirect way by using separate information that gives us the average distance covered by goods in different industries. This data comes from the CFS data used in the above section and we match the industries used in that data set to our NACE industries in the EU data. We therefore suppose that distance covered by a particular good within the United States is roughly similar to distance covered in the European Union for that same good. This does not appear to us as a highly unrealistic assumption, especially since the important aspect is the *relative* transportability of goods and how it affects the estimated border effect.

We calculate a transportability variable that uses the average mileage covered by goods in each industry. We divide that figure by the average mileage for aggregated flows to get a relative transportability index ranging from .10 for soft drinks (lowest transportability) to 2.6 for clocks (highest transportability). We plug in this variable in the regression and also interact it with the distance variable and the adjacency variable.

The results presented in table 7 show that transportability indeed strongly affect border effects as expected. This is true for all distance measurements but specially strong in the case of our effective distance. The resulting mean border effect is $\exp(1.14) = 3.12$, which falls to $\exp(1.14 - 1.22 \ln(1.5)) = 1.9$ for an industry with a transportability index 50% higher than average. For the most easily transportable good, the border effect is about nil and even slightly negative ($\exp(1.14 - 1.22 \ln(2.6)) = .97$). Note also that the adjacency effect vanishes for this industry ($\exp(-0.32 + 0.33 \ln(2.6)) = .99$). Transportability issues and the way it affects distance mis-measurement therefore seem totally crucial in the estimation of the impact of the borders on trade flows. With an appropriate measure of distance, it seems that European markets were, in those years following the completion of the Single Market Program, only marginally fragmented with a border effect of 3.12.

TAB. 7 – How Transportability Influences Distance, Adjacency, and Border Effects

	Dependent Variable : Ln Ξ (friction)					
Model :	(AREA)		(AVGD)		(CESD)	
Cross Border	3.35*	3.06*	2.64*	2.33*	1.44*	1.14*
	(0.18)	(0.17)	(0.21)	(0.17)	(0.25)	(0.21)
Ln Distance	1.05*	1.07*	1.38*	1.41*	1.27*	1.29*
	(0.05)	(0.05)	(0.08)	(0.08)	(0.07)	(0.06)
Share Language	-0.72*	-0.83*	-0.92*	-1.01*	-0.74*	-0.84*
	(0.14)	(0.14)	(0.13)	(0.13)	(0.14)	(0.14)
Adjacency	-0.70*	-0.63*	-0.48*	-0.40*	-0.40*	-0.32*
	(0.07)	(0.06)	(0.08)	(0.07)	(0.07)	(0.06)
Transportability		-1.00*		-1.22*		-1.22*
		(0.16)		(0.17)		(0.21)
Ln Distance X Transportability		0.08		$0.20^{\sim}$		0.12
		(0.05)		(0.09)		(0.06)
Adjacency X Transportability		0.27*		0.38*		0.33*
		(0.07)		(0.09)		(0.08)
N	7213	7213	7213	7213	7213	7213
R^2	0.265	0.38	0.258	0.371	0.276	0.39
RMSE	1.685	1.548	1.694	1.56	1.672	1.536

Note : Standard errors in parentheses with * denoting significance at the 1% level. Distances are calculated using the area approximation in columns (1) and (2) (AREA), the arithmetic weighted average in columns (3) and (4) (AVGD), the CES aggregator in columns (5) and (6) (CESD). Standard errors are robust to correlated industry residuals.

7. CONCLUSION

Statistical institutes report trade flows at a geographical level (usually the national level) that is far more aggregated than the level at which trade flows actually take place.

We develop in this paper a new measure of "effective" distance between and within geographical units for which we can observe trade flows that takes into account underlying trade patterns at a more disaggregated level. More precisely, it is calculated so as to ensures that bilateral trade flows between geographical units like nations are equal to the sum of bilateral trade flows between their sub-units. Our major finding is that the existing measures used in the literature overestimate effective distances and that this distance inflation is stronger the closer the two nations are to each other.

One important consequence of this finding has to do with border effects. Since conventional methods overestimate internal distances more than external distances, the negative impact of borders will be magnified in regressions trying to explain why trade is so "local." Following the same idea, adjacency effects are also very likely to be overestimated. We show that those two problems are most severe for goods that are costly to ship over long distances.

We investigate empirically these findings using trade flows between States in the US for the year 1997 and between countries in the EU during the years 1993-1995. Those two samples offer the advantage of being free of any effect of formal border-related barriers to trade. We thus want to see if the estimated impact of borders on trade flows can be totally brought to zero by the use of our improved distance measurement, that is if border effects of those samples are totally "illusory".

The use of the effective distance leads to smaller estimates of border effects and adjacency effects in the two samples, the reductions in the estimates are particularly important in the EU sample where the border effect is divided by more than 6 when using effective distance over a standard measurement. However it does not eliminate these effects. Thus the use of average and area-based measures of internal distance in the previous literature caused inflated border effect estimates but not illusory borders.

We finally investigate our conjecture about how the mismeasurement of distance causes easily transportable goods to have low border effects and goods like cement to have very large ones. Transportability issues and the way it affects distance mismeasurement indeed seem central in the estimation of the impact of the borders on trade flows. With our measure of distance, we find that post-single market Europe in 1992-1995 was only marginally fragmented with a border effect of 3.12. The most easily transportable industries have no border effect nor positive effect of adjacency.

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