Online Commerce, Inter-Regional Retail Trade, and the Evolution of Gravity Effects : Evidence from 20 Billion Transactions*

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Abstract

This paper investigates inter-regional retail trade linkages, and changes in the gravity effects between cities and regions arising from online commerce, as opposed to traditional point-of-sale commerce. We build original inter-regional retail trade measures from nearly 20 billion domestic consumer online and in-store transactions made through bank cards, in France 2018-19. We are able to study the mobility of individual bank card holders throughout France, their on-site purchases, and also the locations from which their online purchases were made. We find evidence that online consumer expenditure tends to be more heavily concentrated in the already-large regional economies. This result suggests that the increasing movement toward online purchasing may tend to increase the concentration of overall economic activity, and may have important implications for regional economic development.

Key words: Consumption expenditure, consumer mobility, gravity model, inter-regional trade, e-commerce.

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1 Introduction

Retail e-commerce is growing quickly and now represents a significant proportion of household final consumption expenditure; consumers worldwide spent 2.8 trillion US dollars online in 2018, according to Statista.[1] In the fourth quarter of 2019, the share of online commerce in total U.S. retail sales was 11.4 percent, up from 10.1 percent from the corresponding quarter in the previous year, for a total value of 158 billion U.S. dollars. In the UK, the third largest e-commerce market after China and the U.S., the share of e-commerce reached 16.5 percent of total sales in 2019.

Although online purchases have become an increasingly important share of aggregate consumption, relatively little is known about the ways in which consumer mobility and economic relations between regions (represented here by cities and, especially, départements)[2] have been modified by this new technology. The convenience of online commerce has indeed led consumers to prefer this mode of purchase for many goods, travelling less frequently to physical stores (Gentzkow, 2007; Pozzi, 2013). But geographical location still continues to play a key role in online commerce for a large number of physical goods because they need to be locally delivered by retailers, or because (particularly in the case of cross-border commerce) there may be information frictions (see for instance Rauch, 1999; Huang, 2007; Head and Mayer, 2014; Allen, 2014; Chaney, 2018).

The main objective of this paper is to study the ways in which economic relations between cities and regions may be modified or disrupted by online commerce. Traditional macroeconomic data sources do not contain precise, localized data on online consumption expenditures, and so are not suited to examining its effects. Nevertheless, the electronic recording of electronic purchases means that the data do exist with which to make detailed studies of online consumption behaviour and the possible effects on the economy. We use one of the richest data sets that has been made available to researchers, consisting of the set of card payments made on approximately 70 million bank cards in France, over the two-year period 2018-19, totaling nearly 20 billion transactions.[3] The detailed information on

[1] E-commerce worldwide - Statistics & Facts Published, Mar 12, 2019.

[2] Excluding the overseas territories, Metropolitan France is divided into 95 "départements". Départements are administrative divisions that correspond to the NUTS3 level (Nomenclature of Territorial Units for Statistics), the geocode standard for referencing the subdivisions of countries for statistical purposes regulated by the European Union.

[3] These data were made available thanks to a partnership with Groupement des Cartes Bancaires CB, and we exploit the card payments data in accordance with the EU General Data Protection Regulation, in

timing and location of the transaction, the nature of the merchant, and the type of purchase, i.e. online or off-line (i.e. point-of-sale transactions), allows us to contrast the patterns of consumption observable in each of these two classes of consumer payment.

We proceed as follows. We first build consumer mobility indicators; mobility is measured as the distance between two distinct geographical purchasing locations such as cities. Next, for each consumer we are able to estimate the number of distinct geographical locations visited, as well as the number and value of the cardholder's home (city or département) or away-from-home transactions. These measures are then used to construct inter-city or inter-département retail trade volume or value. Some measures of mobility or trade relations between geographical areas can be applied to off-line or online trade, since all retailers are geographically located. Although the consumer does not physically move in the course of an online transaction, the retailer is geographically located and certain goods are still delivered, or ordered online and consumed on site (e.g., hotel stays). With these measures of inter-regional retail trade, we estimate online and off-line gravity models. Gravity models, whether for trade among nations or within regions, have shown great stability over time; the economic sizes of regions and the distance between them have invariably been strong predictors of the extent of trade. We consider in this paper whether this pattern has been changed by the move toward online expenditures.

This paper contributes to several distinct economic literatures. First of all, a large literature analyses the ways in which geographic frictions reduce inter-regional trade. Wolf (2000) and Hillberry and Hummels (2008) for example have tested the impact of distance on interstate commerce in the United States using data from the Commodity Flow Survey of the US Census. They find evidence for instance that spatial frictions matter, and have the greatest impact over very short distances. Shipments destined for the same 5-digit zip code, that is within cities, are three times higher than those outside the zip code. McCallum (1995) uses Canadian and U.S. data to estimate the effect of national boundaries for each of the years 1984-1988 on shipments from each province to each other province, as well as shipments between each province and the rest of the world (imports and exports). He finds that national borders continue to matter. Anderson and van Wincoop (2003) also estimate a theoretical gravity equation and confirm that national borders reduce trade between industrialized countries. All of the aforementioned papers use aggregate and regional

application of Article 89. We use the abbreviation 'CB' to indicate the source of the card payments.

statistics on shipments between establishments, and the question arises whether similar results are also observed at the consumer level. The present paper proposes new and original inter-regional retail trade measures from massive and detailed consumer online and in-store transactions, and provides an answer to this question.

Secondly, a more recent literature analyses geographic patterns of trade between individuals using online transactions. Hortaçsu et al. (2009) use for instance a sample of within-US eBay transactions and gravity equations to show that the coefficient on distance is much smaller on eBay than for total trade flows. The study is however limited to the analysis of transactions between individuals, and to online auctions related to products that are mainly durables. Lendle et al. (2016) extend the previous work and also use a sample of cross-border eBay transactions but exclude all transactions that were concluded via auctions as well as those sold by consumers, so that the eBay data resemble off-line trade practices. The empirical analysis however is restricted to 40 product categories traded in international markets (61 countries). The present paper departs from both studies by focusing on inter-city and inter-regional retail trade in France on the entire basket of goods and services traded online and in-stores between consumers and retailers.

Thirdly, another recent literature investigates the local structure of consumption industries. Agarwal et al. (2019a) use detailed credit card transaction data and argue that consumer mobility influences the local structure of consumption industries. The authors find that consumer mobility varies substantially across sectors, and that where travel frictions are expected to matter relatively more, employment tends to be more highly concentrated, and establishments more dense. We also use consumer mobility, but with the aim of explaining inter-regional online and off-line trade. The estimation results also suggest that the nature of purchase, i.e. online as opposed to off-line, is related to more highly concentrated economic activity.

Our analysis of billions of payment card transactions leads us to a number of results. (1) Perhaps surprisingly, we find that a card 'travels' out of the home region on average less online than off-line; in each case there is a high degree of dispersion of the degree of mobility across individuals. Online transactions are on average more concentrated on a smaller number of cities and merchants. We also find that mobility is associated with greater consumer spending. (2) The distance between départements is a strongly negative predictor of off-line volume and value of trade. However, gravity relationships have been changed consequentially by the availability of the new technology; distance is a less strong predictor of online trade, although the effect is still negative. (3) Disaggregation by sector reveals further patterns; for instance, we find that the distance has no substantial effect in sectors where goods are delivered to consumers, such as appliances. By contrast, distance is as important as in off-line commerce within sectors such as lodging and transport where goods must be consumed in the same way regardless of whether the purchase is made online or on-site. As well (4), the size of the 'exporting' département's economy has a much larger effect with online than with traditional in-store sales. This result suggests that the increasing movement toward online purchasing may tend to increase the concentration of economic activity: that is, consumer expenditure moves further toward the already-large regional economies as online sales come to represent a larger fraction of total expenditure. This result may have important implications for regional economic development. Finally (5), at the level of cities, we find that distance and proximity effects in the gravity model are of lower magnitude than for départements, while nonetheless statistically significant. That is, proximity between cities is a much smaller factor in explaining online trading relationships than among départements or regions: the estimated parameter on the size of the economy from which the purchase is made is still positive but three times lower than that observed in the inter-départment analysis.

The remainder of the paper is structured in four sections. Section 2 describes the data, and the French payment card market, in detail. Section 3 describes geographical patterns at the level of the individual, including the nature of consumers' movements and purchases outside the home region. Section 4 uses aggregated data to examine trade links between regions of France, primarily using gravity models of inter-regional retail trade. The patterns observable in online and point-of-sale expenditures are compared and contrasted. Section 5 summarizes our conclusions and discusses further research directions to be pursued using data of this type.

2 Bank card data

2.1 An overview of bank card transactions data

Transactions data from bank cards have been used for a number of purposes in the existing literature, exploiting several key characteristics not present in official statistical agency data: in particular, the fact that they are available at a higher frequency or granularity (at least a daily aggregate, and often at the level of individual transactions), and more rapidly (possibly the next business day following a transaction, as opposed to weeks or as much as two months for official data). Such data have for example facilitated the study of financial innovation and consumer choice of payment method (Agarwal et al., 2019a,b; Lendle et al., 2016; Bounie and Camara, 2019; Wang and Wolman, 2016), the response of consumption to income shocks or other exogenous events (Agarwal and Qian, 2014; Galbraith and Tkacz, 2013)), and near-real-time economic monitoring (Galbraith and Tkacz, 2018; Carlsen and Storgaard, 2010).

Transactions data are typically recorded with a very high degree of accuracy[4] as well as detail. With respect to real-time monitoring of the economy, they suffer from the disadvantage of omitting some elements of national income; there is little coverage of investment, government expenditure, or exports. However, from the point of view of the study of consumption and consumer behaviour, this difficulty is largely absent, except to the extent that cash transactions may differ in character from card payments.

The latter is the focus of the present study, and for this purpose the bank card data used here are very well adapted. This data set is exceptional in the literature in a number of ways: it offers very wide coverage of consumers throughout France, leading to the sample of observed transactions of about 20 billion, substantially larger than the sample size in almost any comparable study (a rare exception being Dolfen et al. (2019)). In the next subsections we describe the features of these data.

2.2 The *Cartes Bancaires CB* data and French payment card market

France is a country with a mature bank card (carte bancaire) market. Cartes Bancaires CB is the leading domestic scheme, created by the French banks in 1984, which by 2019 had more than 100 members (Payment Service Providers, banks and e-money institutions).

As of 2018 there were 70.4 million CB cards in use in the CB system, and 1.77 million CB affiliated merchants (CB, 2018). CB cards can be immediate-debit cards, but also deferred-debit cards (‘charge cards’ that require the balance to be paid in full each month),

[4] Galbraith and Tkacz (2018) compared interbank payments sent and received by major banks in approximately 75 million transactions over more than 10 years of data aggregated to the daily frequency, and found no discrepancies.

or credit cards (cards with a credit line). A peculiarity of the French card market is that merchants who accept CB cards will make no distinction between debit cards and the other types.

Our sample comprises 9.2 and 10.7 billion transactions on CB cards in 2018 and 2019 respectively, for a total value of about €376 and €427 billion, i.e. 340 transactions, or €13,530, per second in 2019. In the rest of this paper, we focus on this representative set of transactions. We observe each of these transactions very precisely. A transaction is characterized by its value, the date of the transaction (we have two dates; actual transaction date and settlement date), the time of day recorded to the second, the type of payment card (debit / credit / prepaid), the geographical location of the merchant, the statistical classification of the type of purchase, and the type of purchasing channel used during the transaction, i.e. off-line or online. Note that the geographical location of online merchants is self-reported, and may be the location of a head office or major warehouse.

A summary of descriptive statistics is provided in Table 1.

Table 1: Summary of descriptive statistics

	Mean	**Q1**	**Median**	**Q3**	**St.Dev.**	**Obs. (billion)**	**Sum (billion €)**
PANEL A: Transaction values in 2018							
All	41	10	22	45	96	9.21	376.35
Off-line	38	10	21	42	79	7.98	299.30
Online	62	10	25	59	168	1.23	77.05
Share of Online (%)						*13.4%*	*20.5%*
PANEL B: Transaction values in 2019							
All	40	10	20	43	96	10.72	426.79
Off-line	36	10	20	41	78	9.20	334.09
Online	61	10	24	57	167	1.52	92.70
Share of Online (%)						*14.2%*	*21.7%*

Notes: This table reports the summary of descriptive statistics of card transaction values in 2018 and 2019. Q1, Median and Q3 represent the first, second and third quartiles of transaction values (in euro).

This data set is exceptional in its coverage, allowing us to capture a significant proportion of consumer expenditure in France. To appreciate the richness of the data set, consider a few comparisons with national statistics provided by the National Institute of Statistics and Economic Studies (INSEE). GDP in France in 2018[5] was estimated as €2,350 billion,

[5]We use 2018 national statistics because 2019 statistics are not yet available.

with € 1,221 billion (52 percent of GDP) representing household consumption expenditure. Excluding fixed charges (rents, financial services, insurances) from household consumption expenditure, as these are typically paid by direct debits and credit transfers, the remaining part of consumer expenditure amounts to € 802 billion (34 percent of GDP). Comparing these figures with total CB card payments (€ 376 billion), the value of CB card payments represents 16 percent of the French GDP, 31 percent of the total household consumption expenditure, and finally 47 percent of total household consumption expenditure excluding fixed charges.

In comparison with previous studies such as that of Agarwal et al. (2019a), our data set reflects to a greater degree the current use of the internet for consumers' transactions. As illustrated in Table 1, the share of online consumer spending in 2019 amounted to 14.2% by volume (number of transactions) and 21.7% by value, an increase of about 0.8 (volume) and 1.2 (value) percentage points with respect to 2018. These figures are in line with recent US studies that estimate the online share of overall retail sales at 10% (Dolfen et al., 2019). The proportion of cards that make at least one online transaction during the calendar year is 66% in 2018 data, and 67% in 2019, while 17% of merchants report making online sales in each of these years. Given the rapid increase in online activities, we compare off-line and online transactions throughout the present study.

A visual comparison of the aggregate values of these activities is given in Figure 1, which displays the distribution by city of aggregate online and off-line transaction values, as proportions of total transaction value. We observe that online transaction values are much more concentrated in certain départements, especially around Paris, compared with off-line transaction values which are widely dispersed. We will return to this point below.

(a) Off-line (b) Online

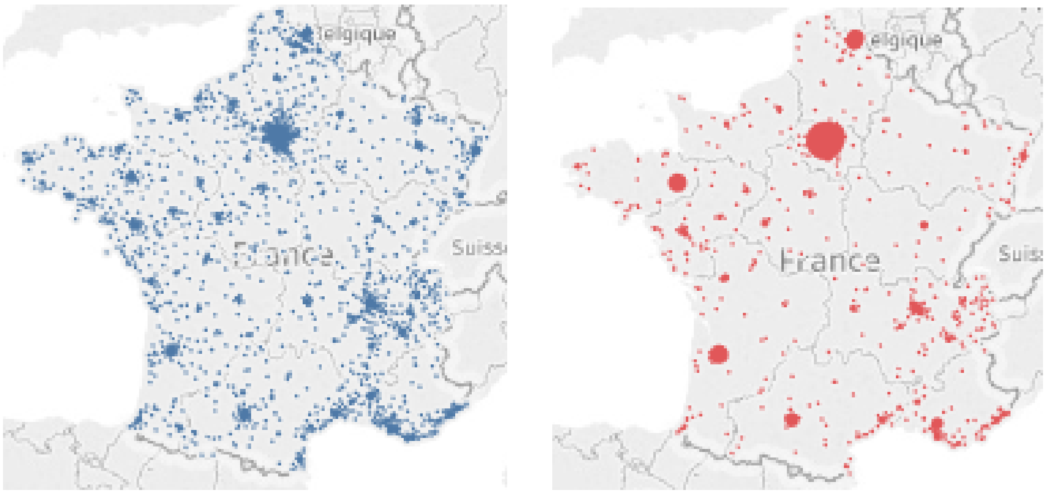

Figure 1: Spatial distribution of aggregate off-line and online transaction values, as shares of total transacted value, by city

3 Consumer mobility and external transactions

In this section, we examine consumer mobility and expenditure outside the home city or département, whether online or off-line. We begin by measuring the distance in kilometres that each card travels between cities in the course of point-of-sale transactions. We then study consumer mobility across cities and départements via the locations of point-of-sale transactions, characterize the relationship between consumer spending and measures of mobility, and analyze home-département and external ('away') expenditure patterns, both off-line and online.

3.1 Consumer mobility across cities and départements

A simple way to estimate consumer mobility is to calculate, for each card, the total distance traveled between payments made at locations in different administrative divisions such as cities and départements. This measure requires more information than that documented by Agarwal et al. (2019a); in particular, we need precise information on merchants' locations. Fortunately, each transaction in our data contains a merchant identification number, a code which gives the precise postal address of the merchant including the postal code, which we use at the five-digit level.

For each card, we measure the geographical distance between two point-of-sale payments carried out in different cities, using the Haversine distance formula.[6] Let i index transactions on card j, and let c_i be the location of the centroid of the city where transaction i took place, so that we can define $d(c_i, c_{i+1})$ as the Haversine distance between the city centres for two consecutive transactions; if these take place in the same city then $d(c_i, c_{i+1}) = 0$. To compute this distance, we use the longitude and latitude coordinates.[7] Finally the annual inter-city distance travelled by card j is measured as:

$$t_j = \sum_{i=1}^{n_j} d(c_i, c_{i+1}), \tag{1}$$

where there are n_j point-of-sale transactions within the observation period on card j. This method of calculation is conservative, since cards can be used for example in different places within the 5-digit postal code, but should provide a reasonably fine approximate measure of inter-regional consumer movement.[8] Note that for this purpose we treat off-line (point-of-sale) purchases only: in online transactions, the distances between merchant locations in successive transactions do not have an interpretation as consumer movements, nor as movements of goods. Nonetheless, we are able to measure the numbers of cities or départements in which off-line transactions occur, and measure transactions external to the home département.

Figures 2a and 2b display different views of the distribution of this measure of the distances traveled by 20.3 million cards, within Metropolitan France in 2019.[9] Results on the 2018 data are very similar, and throughout this section we present only 2019 results for brevity. The horizontal axes indicate the interval of distances travelled, e.g. cards travelling between 90 and 100 km, while the vertical axis in each figure indicates the proportion of the cards in the given interval. In Figure 2a observations are aggregated into intervals of 10 km, although exact zeroes are shown separately; over 1 million cards show zero distance travelled. Total annual distances in the 10-30 km range are the most common, apart from zero. Figure 2b plots intervals of 1000 km, and we see a regular pattern of decay through the interval up to approximately 100,000 km travelled. Approximately 26% of

[6]Note that this method computes shortest distances between points on a sphere, as opposed to using road or rail network information.

[7]The data can be retrieved at the following address.

[8]Payment cards in the French CB system are unique to the individual; multiple cards with the same number (e.g. for parent and child) are not issued, although this may be possible in some other jurisdictions.

[9]We exclude overseas territories, and take a sample of valid cards over the period. In order to make cards comparable, we randomly select and focus on cards valid throughout the year 2019.

cards travelled less than one thousand kilometres, but over 19% traveled a distance greater than 10,000 km.[10] On average, a card travels about 6,000 kilometres per year across the country between off-line (point-of-sale) transactions; approximately 4.1 percent of cards are used (off-line) purely within a single postal code, and therefore show zero kilometres of distance travelled. Finally, a small number of cards cover extraordinary distances; over 5000 cards show measure distances exceeding 100,000 km (that is, beyond the range of Figure 2b), with the largest value in the sample exceeding 600,000 km.

(a) Intervals of 10km, up to 500km (b) Intervals of 1000km, up to 100,000km

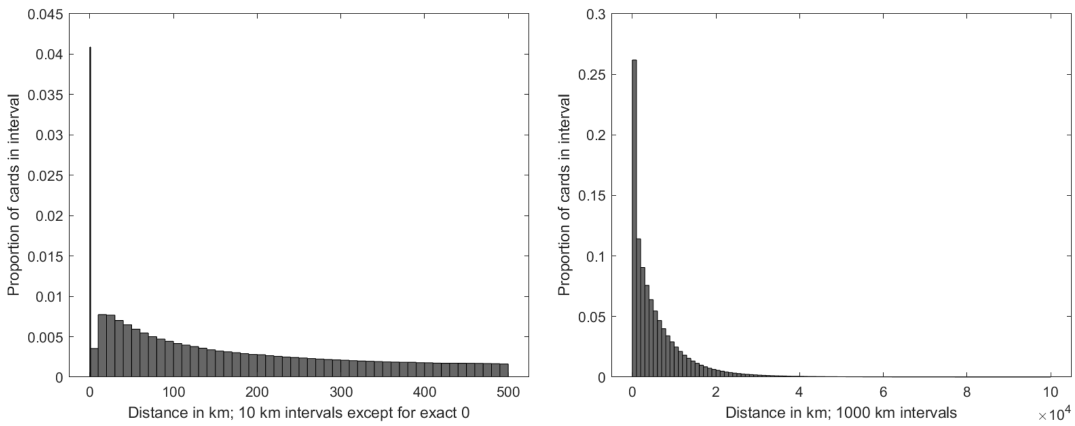

Figure 2: Distances travelled by cards between point-of-sale transactions, 2019

Figures 3a and 3b describe a different indicator of mobility, the number of cities and towns or départements in which each card is used. This measure can be computed for online transactions as well as off-line, and in both are recorded in this pair of figures, which plot the proportion of cards corresponding with each specific number of cities or départements 'visited' (i.e. locations at which a transaction is recorded), truncated at 100. Each of the proportionate values for 1 through 7 cities visited corresponds with over 1 million cards that were used in that number of cities, and there is a regular pattern of decay thereafter. Interestingly, in Figure 3b, we see that online shopping is more concentrated than off-line shopping: 18% of online payment cards visit a single city compared to 4% for off-line cards. The maxima are 321 cities visited for off-line transactions, and 343 for online transactions.

[10]Note again that this measure applies to cards, and not cardholders; we do not have information about consumers such as their postal addresses that would allow us to identify individuals. Since some individuals use more than one card, the measure is also conservative in that travel by an individual will in some cases be the sum of distances on two or more cards.

(a) Off-line (b) Online

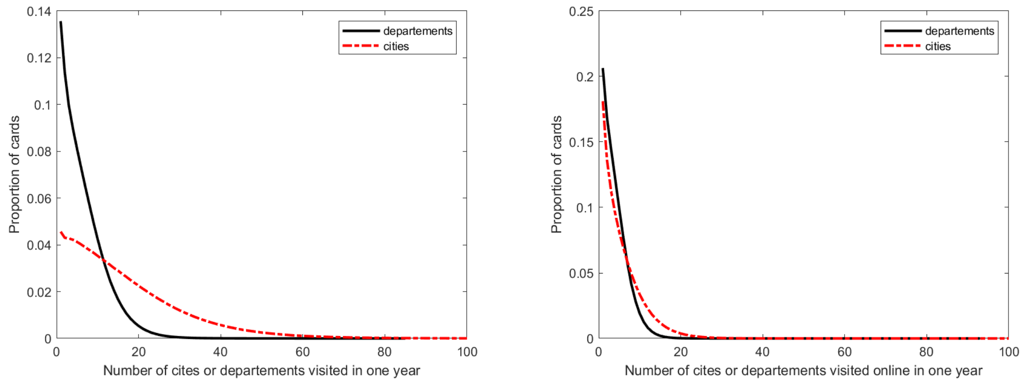

Figure 3: Card mobility by number of cities or départements in 2019, up to 100

Next, Figures 4a through 4d relate the volume and value of activity to the number of cities or départements visited by each card. Each line shows value or volume of transactions per card scaled by the average for the values corresponding with 1 to 10 cities visited. Overall, we find that mobility is associated with greater consumer spending. Regardless of whether we consider value or volume, city or department, we see clear differences between off-line and online cases: online transactions tend to be distributed among a smaller number of locations (concentrated toward smaller values on the lower axis) and show a particularly high degree of dispersion for the cards showing highest total transaction values (the vertical axes reach much higher values). We will see further evidence below of this tendency toward concentration in online purchases.

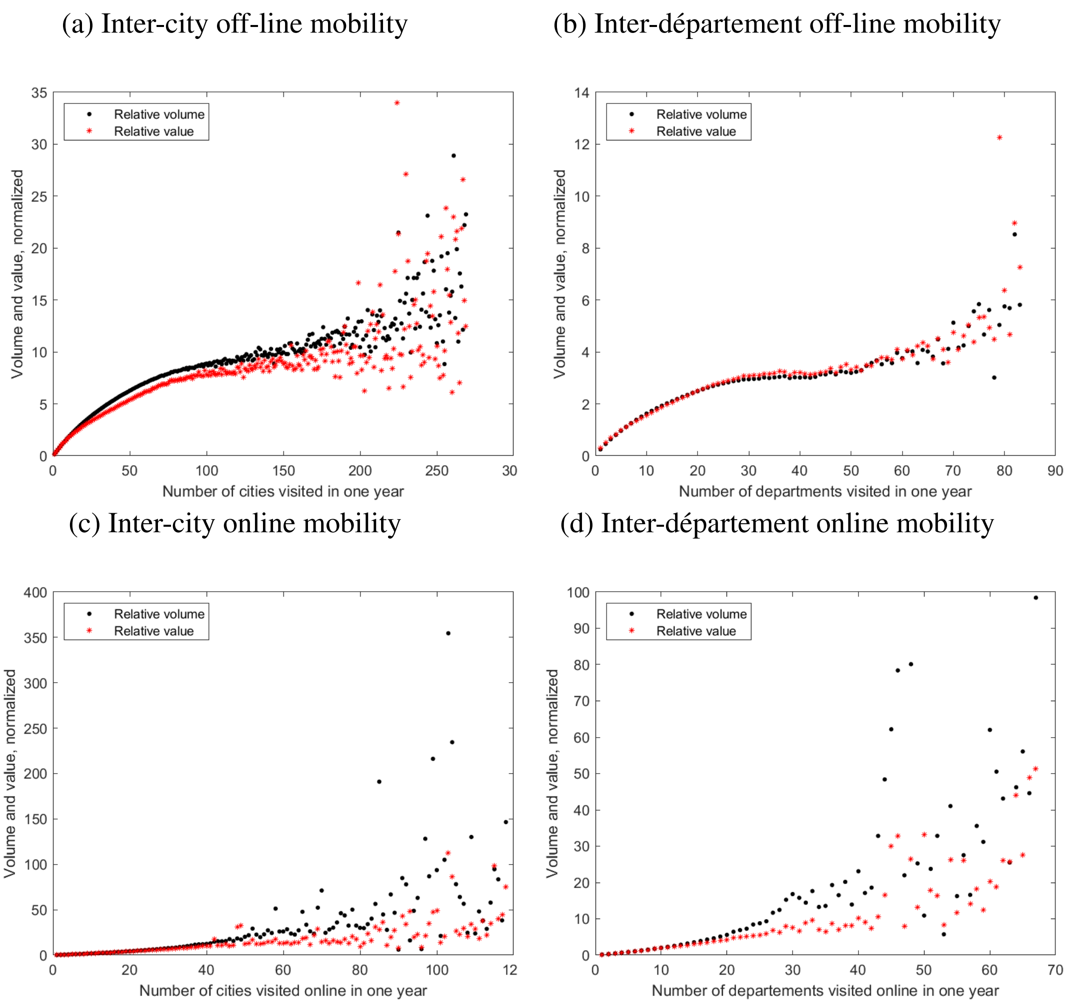

Figure 4: Transaction value and volume vs inter-city or inter-département mobility

3.2 'Home' and 'away' expenditures

In the previous subsection we looked at measures characterizing movements of cardholders throughout the country, without reference to a home base. In this subsection we consider expenditures in or outside the cardholder's home location, a feature which is readily interpretable for both off-line and online transactions.

We begin by defining a card's home city or département h, as the location in which the largest number of transactions takes place; we then compute the proportions of both transaction volume and value of expenditure taking place in the home location, and externally ('away'), for each card. Again, let i index transactions on card j, let k index the geographical unit, and let $v_{i,j}$ be the value of transaction i on card j, or the value 1 if we are counting number of transactions. We then compute the proportion of home transactions (value or volume) for card j, $q_{j,home} = \sum_{i:k=home} v_{i,j} / \sum_i v_{i,j}$, and the corresponding proportion of external transactions (value or volume) for card j, $q_{j,ext} = \sum_{i:k \neq home} v_{i,j} / \sum_i v_{i,j}$.

Figures 5a and 5b plot these proportions at intervals of 0.1 for off-line and online transaction values.[11] We observe that at the level of the département, the modal value is zero for the value of off-line transactions; that is, within this set of intervals, more cards are used exclusively within a département than in any interval. At the level of cities and towns, where of course the home unit is smaller and so would be expected to account for a smaller proportion of transactions, the most commonly occurring outcomes are in the range of 60-70% of transactions (and value) occurring outside the home city. Regarding online transactions, the patterns (similar at the levels of city or département) show a different picture: the proportions of transaction values outside the home city or département are significantly higher, and a significant proportion of cards (30%) carry out all transactions outside the home city or département.

(a) Off-line (b) Online

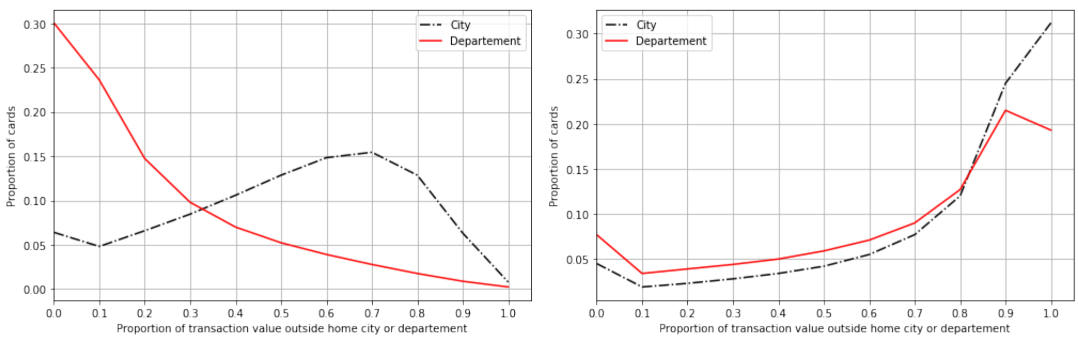

Figure 5: Value of off-line and online expenditures outside home region in 2019

The distinction between home and away expenditure patterns is also visible in the number of off-line and online retailers visited per card. Figures 6a and 6b present the cumulative distributions of the number of off-line and online retailers from which any purchases were made, truncated at 300. We observe that the number of online retailers patronized is substantially lower than for off-line retailers. Online transactions are on average more concentrated on a smaller number of merchants.

[11]The volume of expenditures outside the home region shows a very similar pattern to the value, and is therefore not recorded.

(a) Number of off-line retailers (b) Number of online retailers

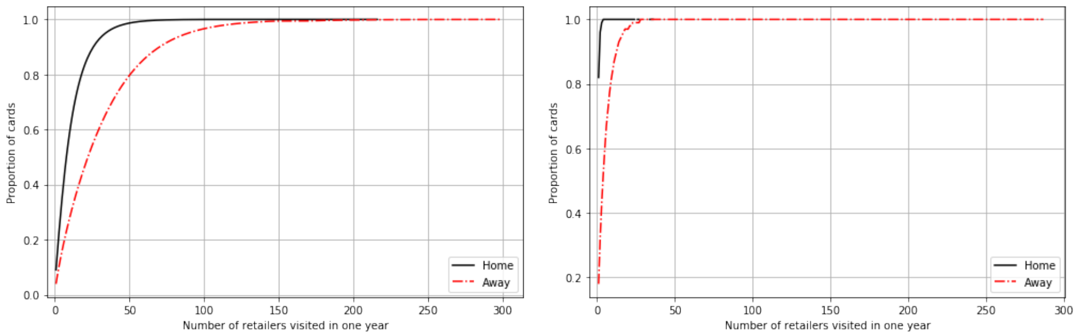

Figure 6: CDF of number of retailers from which purchases were made in 2019, up to 300

Finally, for each card we can compute the sum of the distances between retailer location and home location, across all purchases, either online or off-line.[12] Figure 7 plots the proportion of cards corresponding with each distance, for both online and off-line commerce, up to distances of 1000 km. A large proportion of cards show an exact zero distance, and these observations are excluded here in order to retain a scale which allows comparison of online and off-line patterns.[13] While total distances in off-line purchases show approximately monotonic decline from an early peak, online purchases show clear multimodality. A possible explanation for this lies in the concentration of online retail locations near Paris (and a few other large centres), such that the peaks represent population concentrations at particular distances from that city. This multimodality may therefore be suggestive of concentration of online purchases with retailers in particular locations, a phenomenon of which we will see further evidence in the next section. We also see that purchases from retailers farther from 'home' are relatively more important in online commerce.

[12]Again, an online or off-line merchant has an identification code linked to its geographical location. The merchant's location may simply correspond to the head office where the administrative activities of the company are hosted. However, the code can also be linked to the geographical location of the delivery warehouses of a company, for example, that delivers physical goods. In this case, the distance measures not the mobility of the consumer but the transport of goods.

[13]The proportions of cards that 'travel' 0 km are 4% and 18% for off-line and online, respectively. Overall, we find that a card 'travels' out of the home region on average less online than off-line.

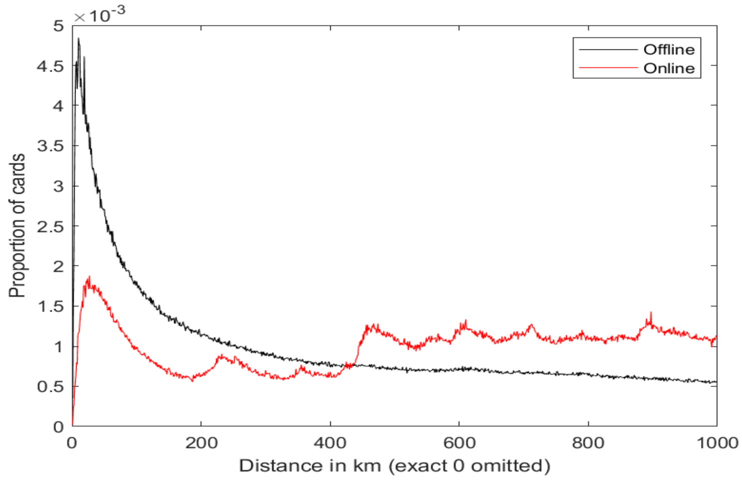

Figure 7: Proportion of cards showing a given cumulative distance between retailer location and home, off-line and online; exact 0 excluded.

4 Trade links between départements and gravity effects

In the previous sections we examined the behaviour of individual consumers, and defined home and away cardholders' expenditure. We now turn to the use of these measured characteristics of cardholder purchases to characterize linkages at the aggregate level, between départements, measured via both off-line and online purchases.

The standard model of inter-regional trade linkages is the gravity model, named by analogy to the physical phenomenon of gravitation, which is stronger for more massive bodies and weaker at greater distances. In the context of trade, the concept analogous to mass is a measure of the size of the national or regional economy, such as GDP. The gravity equation traditionally used to predict trade flows across countries has proven to be an exceptionally stable and robust empirical regularity. While the trend toward increasing global trade and technological progress have led to considerable reductions in transport costs and other trade barriers, the essential elements identified in gravity equations remain key predictors of the strength of trade linkages.

Here we apply models of this type to the study of inter-city and inter-département economic linkages, measured both by standard import-export trade flows, and also by a measure of common purchases by individual consumers. Although there have been studies of inter-regional trade using gravity models at a sub-national level, these studies have mainly focused on shipments at the level of establishments, and also suffered from the relatively poor quality of regional income estimates. The exceptionally rich and accurately measured data set used here obviates this concern.

A common practical problem in the estimation of trade models involving countries is that distance will typically be correlated with unmeasured differences of language, culture, legal structure and so on which may project onto the distance measure, thereby exaggerating its true effect. Here, of course, all units are parts of France. While there have been other studies of sub-national data which share this feature,[14] the present study has the advantage of the relatively large sample of regional units; from the set of 95 départements we have a sample of 8930 (95×94) pairings with which to estimate effects. Relatedly, because the data are at a sub-national level, only a subset of the units have a border with a foreign country. This allows us to estimate the effect of a border with another country on trade within the home country. Note that this contrasts with the type of border effect estimated in McCallum (1995), who used within-country and across-country state/province links to estimate the effect of the US-Canada border on regional trade.

Finally, and perhaps of particular importance, we are able to contrast the inter-regional economic links in online and point-of-sale purchases. While we find that the traditional gravity relationships are observable in online purchase data as well as for in-store purchases, there are important differences between online and point-of-sale trade.

4.1 Two measures of inter-département linkage

In order to estimate models of the strength of economic links between départements as a function of distance, size and other indicators, we define two measures of linkage between two départements.

The first is a traditional trade-related measure, in which we use the 'home' département defined in the previous section and obtain the expenditures (imports) made in each of the départements other than the home. Imports into the home département h from another département k are identical to the exports from k to h : there is no discrepancy such as is observed in international trade data. Formally, let $h = \{1,2,\dots 95\}$ index the home département, and let $k \neq h$ index the départements with which a given home département is linked. For each card ℓ with home département equal to h, let $V_{\ell,h,k}$ represent total pur-

[14] For example, the important study of McCallum (1995) uses data from Canadian provinces and U.S. states.

chases (value, volume) made in département k; then the import-based linkage measure is defined for each pair h, k as:

$$L_{I:h,k} = \sum_{\ell:home=h} V_{\ell,h,k}, \tag{2}$$

where ℓ indexes all cards: that is, the total of purchases in département k made on cards for which the home is h.

The second measure, which we call a 'commonality' linkage, is a symmetric measure which indicates the degree to which individual cards tend to show purchases in each of a pair of départements. For the commonality measure, we do not define a home département. Let $V_{\ell,r}$ represent total value or volume of purchases on card ℓ in département r. Then for any two départements r, s, the commonality measure is defined as:

$$L_{C:r,s} = \sum_{\ell} [V_{\ell,r} \cdot V_{\ell,s}]^{\frac{1}{2}}. \tag{3}$$

Note that, for a given value or volume of purchases dispersed across two départements, this measure will be greater as the expenditures are more evenly divided. If a card does not show positive expenditure in both départements, the value for that card is zero and there is no contribution to the commonality measure.

4.2 Predictors of inter-département linkage

We now examine predictors of inter-département linkage using each of the two measures L_I and L_C, paying particular attention to the core gravity effects of distance and size, and to the comparison between online and point-of-sale purchases. Each of the measures can be computed either for the value or volume of total purchases; as well, we will examine various specifications of the gravity equation. In order to reduce the proliferation of tables we will focus on a single base-case specification of the model in the tables presented in the main text, and present tables of additional results in Appendix A.

The core regression specification takes as the dependent variable one of the measures of economic linkage – trade (imports) or commonality of purchases – together with a choice of value or volume of purchases. We will represent any of the four forms of this dependent variable generically as $L_{i,j}$ for the linkage between départements i and j. This quantity is modelled as a function of the distance $d_{i,j}$ between départements i and j, measures of the 'economic size' of each of the two départements, S_i, S_j, and a vector of other potential conditioning variables Z, many of which will be indicators.

We can therefore write the gravity model as:

$$\log(L_{i,j}) = \beta_0 + \beta_1 \cdot \log(d_{i,j}) + \beta_2 \cdot \log(S_i) + \beta_3 \cdot \log(S_j) + \delta Z_{i,j} + u_{i,j}. \quad (4)$$

Note that the conditioning variables Z may be specific to the pairing (i, j), such as an indicator that the two départements are neighbours or otherwise lie in the same region of the country, or may instead be specific to one of the two, such as an indicator that département i has a border with a foreign country, or borders the sea. Size of the economy of a département is measured using the total value (or volume) of card transactions. This may be viewed as a proxy for GDP, since GDP data are not available in France at the level of each département, but in any event our measures have the virtue of being based upon billions of observed card transactions, measured on a common basis throughout the country.

A theoretical basis for gravity equations is provided by Anderson and van Wincoop (2003); the additional price level terms obtained there do not apply in this case since all of our regional units (départements) are within a single country.

Our primary interest is in the parameters β pertaining to distance and economic size variables, and in contrasting their values between online and off-line cases. Nonetheless we will consider a variety of alternative specifications, both as robustness checks and because a number of the parameters δ will be of independent interest.

4.3 Main results: estimated gravity models

We will first present results of a base-case specification of the gravity models, along the $2 \times 2 \times 2$ dimensions described above: trade-based (import) and commonality measures of linkage; value and volume of purchases; off-line and online activity.[15] Tables 2 and 3 present the eight base-case regressions containing the results. A comparison of these two tables shows that the results are qualitatively the same whether we use a value or volume measure of transactions. In the discussion of this section we will therefore refer primarily to the value-based results of Table 2 which correspond most directly with the value of consumption which enters the national income identity as a component of GDP.

[15] The results presented in this section are based on 2019 data. Results on 2018 data are similar, and for brevity are generally omitted. However, the analogues of Tables 2 and 3 for 2018 data are presented in the Appendix.

Table 2: Base-case gravity models of L_I and L_C, off-line and online, measures based on transaction values

	Import-based		Commonality	
	Off-line	Online	Off-line	Online
	(1)	(2)	(3)	(4)
Log(Distance)	-0.85***	-0.39***	-0.72***	-0.27***
	(0.021)	(0.015)	(0.017)	(0.022)
Neighbors	1.43***	0.48***	0.8***	0.05
	(0.062)	(0.049)	(0.046)	(0.053)
SameRegion	0.52***	0.44***	0.37***	0.3***
	(0.056)	(0.037)	(0.043)	(0.051)
Log(GDP of Dep i)	1.04***	0.94***	0.92***	1.41***
	(0.01)	(0.009)	(0.007)	(0.01)
Log(GDP of Dep j)	1.03***	1.63***	0.92***	1.41***
	(0.009)	(0.011)	(0.007)	(0.01)
Constant	-26.2***	-40.54***	-19.13***	-45.25***
	(0.362)	(0.339)	(0.321)	(0.436)
Adj. R-squared	0.83	0.84	0.88	0.85
Observations	8930	8930	8930	8930

Notes: This table reports estimation results for the base-case gravity models. We regress the log trade links with the import-based (L_I, columns 1-2) and commonality (L_C, columns 3-4) measures using off-line and online transaction values on the log distance, neighbors dummy variable, same region dummy variable and log GDP of départements i and j. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 3: Base-case gravity models of L_I and L_C, off-line and online, measures based on transaction volumes

	Import-based		Commonality	
	Off-line	Online	Off-line	Online
	(1)	(2)	(3)	(4)
Log(Distance)	-0.9***	-0.33***	-0.75***	-0.23***
	(0.022)	(0.016)	(0.018)	(0.023)
Neighbors	1.34***	0.51***	0.73***	0.1*
	(0.062)	(0.05)	(0.045)	(0.055)
SameRegion	0.53***	0.42***	0.37***	0.32***
	(0.058)	(0.041)	(0.044)	(0.054)
Log(GDP of Dep i)	0.99***	0.87***	0.9***	1.37***
	(0.009)	(0.009)	(0.007)	(0.01)
Log(GDP of Dep j)	1.06***	1.62***	0.9***	1.37***
	(0.009)	(0.012)	(0.007)	(0.01)
Constant	-21.77***	-34.91***	-15.3***	-38.42***
	(0.295)	(0.301)	(0.268)	(0.377)
Adj. R-squared	0.83	0.83	0.88	0.85
Observations	8930	8930	8930	8930

Notes: This table reports estimation results for the base-case gravity models. We regress the log trade links with the import-based (L_I, columns 1-2) and commonality (L_C, columns 3-4) measures using off-line and online transaction volumes on the log distance, neighbors dummy variable, same region dummy variable and log GDP of départements i and j. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Column 1 of the tables provides the case that is comparable with the previous literature, that is of a trade-based measure for traditional point-of-sale purchases.[16] Distance between départements is a strongly negative predictor of the volume of trade, and even conditional on distance, being neighbours or from the same region has a substantial positive estimated effect. The coefficients on sizes of the regional economies are close to the theoretical values of unity in the model of Anderson and van Wincoop (2003), and indeed are closer to unity than in many existing empirical results, although nonetheless very precisely estimated and statistically significantly different from 1. Each of these results is consistent with findings in the previous literature.

Results based on the commonality measure, column 3, are qualitatively similar. Since the measure is identical for each member of a pair, the labels (i, j) are interchangeable and

[16] Again, our linkage measure uses imports; because the imports of i from j are identical to the exports of j to i, we can also interpret this as an export-based measure by reversing the labels on the size or GDP variable.

coefficients on the sizes of economies are identical as well.

The critical comparison for our present purposes is between columns 1 and 2, in which we are able to contrast online with off-line economic activity. We observe not surprisingly that distance (as well as being neighbours or from the same region) is a less strong predictor of trade; to the online purchaser, the region from which a purchase is made may be nearly irrelevant, or even entirely unknown. Nonetheless, the geographical proximity variables remain strongly significant and substantial predictors even of online economic linkages; the sole exception is the indicator that two départements are neighbours, which is not statistically different from zero for online purchases using the commonality measure.

The striking result however concerns the estimated parameter on the size of the economy from which the purchase is made, i.e. the exporting département: log(GDP of dep. j)). This value, the estimated regional income- or regional economic size- elasticity of exports, is approximately 60% larger for online than for off-line transactions (the coefficients are respectively 1.03 and 1.63 when we consider the import-based measure with transaction values). The value is approximately 50 standard errors from unity. Moreover, as we shall see in the next subsection, this result is very robust to numerous different specifications of the gravity model. We see a reflection of the same phenomenon in the commonality measures, where the importance of size of economy is again very much higher in online data (again, the symmetry of the commonality measure implies that the coefficients on size of the economy for each of the two départements must be the same, and we see the effect distributed across the two départements).

The result that the size of the 'exporting' département's economy has a much larger effect with online than with traditional in-store sales suggests that the increasing movement toward online purchasing may tend to increase the concentration of economic activity (that is, consumer expenditure moves further in the direction of the already-large regional economies as online sales come to represent a larger fraction of total expenditure).

In the next section we explore the robustness of this result to different specifications of the gravity equation, as well as examining the effects of additional indicator variables.

4.4 Sectoral disaggregation of gravity results

In the results above we noted that the coefficient on distance is reduced for online purchases, relative to off-line, but remains non-zero. In order to investigate this further, it is useful to distinguish purchases by type or sector. In particular we will consider the distinction between purchases which are made online for delivery to the consumer, and those which may be booked and paid for online (such as hotels) but which must be consumed in the same way regardless of whether the purchase is made online or on-site.

Tables 4 and 5 present such a disaggregation. The column headings correspond with classifications from the French *Nomenclature d'activités françaises*.[17] We note first of all that, in the off-line disaggregation, the coefficient on distance is similar in each case to the result in the aggregate: that is, negative and slightly less than one (with one exception) in absolute value.

To compare with the online results, first consider polar cases of purchases which we expect to be almost entirely, or conversely not at all, purchased online and delivered to the consumer. In the former case we expect distance to have little effect online; the consumer need not move. In the converse (purchase online, consumption on-site) case we expect distance to have similar effect online and off-line, as the consumer must move in either case. The case of appliances provides one polar example: we expect that almost all such purchases will be delivered to the consumer. Correspondingly, we see a large contrast in the off-line/online results; the distance coefficient for online purchases is close to zero. A contrasting polar case is that of transport: whether paid for on site or online, the consumer must undertake travel in the same way. We expect little difference in the coefficient on distance, and indeed we see little.[18]

Lodging also shows similar off-line and online distance coefficients; whether booked online or not, consumption must take place on site. Restaurant meals, as well, although they may be delivered to the consumer's home, tend to be constrained by the necessity of immediacy to a similar geographical range regardless of whether the consumer goes to the restaurant, or the restaurant comes to the consumer. The coefficients on distance are similar for off-line and online in each of these cases. A third example is leisure, which corresponds largely with cultural and sporting events. As with lodging, these can be booked and paid

[17] This classification of economic activities, maintained by INSEE, is analogous to the North American NAICS. The first two digits represent the division. The codes corresponding with the headings are: Appliances: 4754x; Food: 4721x, 4722x, 4723x, 4725x, 4729x; Clothing: 4771x, 4772x, 4782x; Health: 862xx, 4773x; Lodging: 551xx, 552xx; Leisure: 90xxx, 91xxx 93xxx; Personal care: 9602x, 9604x; Restaurants:561xx, 563xx; Supermarkets: 471xx; Transport: 49xxx, 51xxx; Automotive: 451xx, 453xx.

[18] A small difference may be attributable to selection of consumer type by payment method; for example older consumers may be less likely to book transportation online than to pay at the departure point.

for online, but are consumed on site; distance therefore continues to play a role in online purchases, and we see that the leisure and lodging categories behave similarly with respect to both their off-line and online coefficients.

Other cases tend to embody a mix of products which may be delivered and others which must be consumed on site. The health category comprises visits to professionals such as dentists and physiotherapists, but also products which may be purchased online and delivered, so that the category is a blend of products for which distance is important and others for which delivery makes distance relatively unimportant. Correspondingly, again, we see that the online coefficient lies between zero and the off-line coefficient. The automotive category blends vehicle purchases, where distance presumably remains a factor, and automotive equipment and parts, which will often be delivered to the consumer or repair facility.

Table 4: Sectoral disaggregation of gravity models with import-based measure L_I: measures based on off-line transaction values

	Appliances	Food	Clothing	Health	Lodging	Leisure	Personal Care	Restaurant	Supermarket	Transport	Automotive
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Log(Distance)	-0.99***	-0.7***	-0.89***	-0.81***	-0.8***	-0.77***	-0.74***	-0.91***	-0.7***	-0.59***	-1.05***
	(0.023)	(0.021)	(0.017)	(0.018)	(0.015)	(0.019)	(0.021)	(0.015)	(0.015)	(0.029)	(0.019)
Neighbors	1.87***	1.61***	1.76***	2.23***	0.44***	1.63***	1.9***	1.21***	1.79***	1.25***	1.82***
	(0.062)	(0.057)	(0.046)	(0.049)	(0.042)	(0.052)	(0.058)	(0.04)	(0.041)	(0.077)	(0.05)
SameRegion	0.7***	0.69***	0.57***	0.81***	0.17***	0.66***	0.78***	0.53***	0.56***	1.05***	0.58***
	(0.065)	(0.059)	(0.048)	(0.052)	(0.044)	(0.055)	(0.061)	(0.042)	(0.043)	(0.081)	(0.053)
Log(GDP of Dep i)	1.09***	1.13***	1.02***	1.09***	1.06***	1.04***	1.17***	1.05***	1.02***	1.26***	1.1***
	(0.013)	(0.012)	(0.009)	(0.01)	(0.009)	(0.011)	(0.012)	(0.008)	(0.008)	(0.016)	(0.01)
Log(GDP of Dep j)	1.42***	0.95***	1.39***	1.17***	0.86***	1.06***	0.93***	1.05***	0.73***	1.53***	0.92***
	(0.014)	(0.012)	(0.009)	(0.01)	(0.009)	(0.011)	(0.012)	(0.008)	(0.008)	(0.016)	(0.01)
Constant	-40.51***	-31.4***	-36.53***	-34.95***	-25.77***	-30.64***	-32.51***	-28.37***	-21.94***	-48.34***	-28.42***
	(0.439)	(0.372)	(0.301)	(0.323)	(0.274)	(0.343)	(0.385)	(0.264)	(0.266)	(0.521)	(0.333)
Adj. R-squared	0.73	0.7	0.83	0.8	0.77	0.74	0.71	0.83	0.79	0.65	0.77
Observations	8426	8918	8929	8929	8930	8929	8887	8930	8930	8802	8891

Notes: This table reports the estimation results for the sectoral disaggregation of the gravity model. For each sector (columns 1-11), we regress the logarithm of the import-based trade link measure (L_I), using off-line transaction values, on the variables used in Table 2. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 5: Sectoral disaggregation of gravity models with import-based measure L_I: measures based on online transaction values

	Appliances	Food	Clothing	Health	Lodging	Leisure	Personal Care	Restaurant	Supermarket	Transport	Automotive
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Log(Distance)	0.04	-0.05	-0.38***	-0.25***	-0.62***	-0.7***	-0.26***	-0.71***	-0.53***	-0.52***	-0.46***
	(0.066)	(0.038)	(0.038)	(0.049)	(0.023)	(0.029)	(0.038)	(0.032)	(0.031)	(0.07)	(0.031)
Neighbors	0.32*	0.16	0.12	0.55***	0.26***	0.79***	0.74***	1.25***	1.98***	0.04	0.3***
	(0.177)	(0.101)	(0.101)	(0.125)	(0.062)	(0.079)	(0.094)	(0.081)	(0.082)	(0.174)	(0.081)
SameRegion	0.33*	0.57***	0.1	0.55***	0.35***	0.45***	0.68***	0.58***	0.69***	1.01***	0.22***
	(0.188)	(0.106)	(0.106)	(0.131)	(0.065)	(0.083)	(0.097)	(0.084)	(0.086)	(0.182)	(0.085)
Log(GDP of Dep i)	0.6***	0.76***	0.79***	0.52***	1.14***	0.94***	0.64***	1.02***	0.94***	0.75***	0.7***
	(0.041)	(0.023)	(0.022)	(0.029)	(0.013)	(0.017)	(0.023)	(0.019)	(0.019)	(0.042)	(0.017)
Log(GDP of Dep j)	0.93***	0.87***	2.02***	0.85***	1.38***	1.52***	0.57***	1.11***	1.11***	1.68***	1.48***
	(0.044)	(0.024)	(0.023)	(0.033)	(0.013)	(0.017)	(0.023)	(0.019)	(0.019)	(0.045)	(0.018)
Constant	-27.17***	-28.55***	-50.91***	-21.96***	-41.48***	-40.38***	-18.63***	-35.58***	-34.27***	-41.95***	-35.67***
	(1.406)	(0.772)	(0.746)	(1.017)	(0.414)	(0.536)	(0.767)	(0.629)	(0.609)	(1.452)	(0.576)
Adj. R-squared	0.19	0.28	0.54	0.19	0.69	0.59	0.24	0.5	0.51	0.23	0.5
Observations	2719	6042	7110	4767	8838	8644	5334	7104	7636	5658	8083

Notes: This table reports the estimation results for the sectoral disaggregation of the gravity model. For each sector (columns 1-11), we regress the logarithm of the import-based trade link measure (L_I), using online transaction values, on the variables used in Table 2. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Globally these results reinforce those noted earlier: online purchase and delivery of goods shows much less distance sensitivity, and so may facilitate concentration of economic activity. Online booking of services to be consumed on site does not show an effect of similar magnitude. In product categories which blend these two types of activity, the distance coefficient tends to be reduced in magnitude for online cases, but is not driven near zero.

4.5 Gravity models at city level

In previous sections we analyzed inter-département trade relations. In this section we extend the baseline analyses to study inter-city trade relations. Tables 6 and 7 report the estimation results and can be compared with Tables 2 and 3. We note however that the 'Neighbors' variable is not directly comparable; in the case of cities, we use this variable to indicate that the cities are located in départements which are neighbours, i.e. share a border.[19]

Three main conclusions can be drawn from the estimation results. First, distance between cities is still a negative predictor of off-line trade. However, the strength of the

[19]While there are some cases of cities which literally border each other, in most cases there is no contiguity with the boundaries of another city.

effect is less than that observed at the level of the département (the coefficients are approximately 0.6 and 0.9 respectively). This observation also holds for online trade relations. Secondly, being neighbours or from the same département or region has still a substantial positive estimated effect on off-line trade relations, although the effect of proximity between cities is also less. Interestingly, this result no longer holds when considering online trading relations: for cities, being neighbours has a negative impact on economic linkages. The département and the region, which constitute larger areas of activity, continue to be important in explaining commercial relations.

Table 6: Base-case gravity models at city level of L_I and L_C, off-line and online, measures based on transaction values and GDP as economic size

	Import-based		Commonality	
	Off-line	Online	Off-line	Online
	(1)	(2)	(3)	(4)
Log(Distance)	-0.58***	-0.25***	-0.66***	-0.19***
	(0.017)	(0.013)	(0.007)	(0.011)
Neighbors	0.41***	-0.11***	0.65***	-0.24***
	(0.02)	(0.011)	(0.018)	(0.013)
SameDep	1.66***	0.48***	1.45***	0.06*
	(0.049)	(0.027)	(0.045)	(0.033)
SameRegion	0.4***	0.23***	0.65***	0.31***
	(0.02)	(0.011)	(0.019)	(0.015)
Log(GDP of City i)	0.67***	0.42***	0.8***	0.51***
	(0.003)	(0.003)	(0.0)	(0.002)
Log(GDP of City j)	0.56***	0.5***	0.8***	0.51***
	(0.003)	(0.003)	(0.0)	(0.002)
Constant	-12.96***	-9.27***	-15.2***	-10.6***
	(0.098)	(0.06)	(0.045)	(0.053)
Adj. R-squared	0.43	0.22	0.73	0.28
Observations	11,102,900	4,636,310	31,631,600	8,743,210

Notes: This table reports estimation results for the base-case gravity models at city level. We regress the log trade links with the import-based (L_I, columns 1-2) and commonality (L_C, columns 3-4) measures using off-line and online transaction values on the log distance, neighbours dummy variable, same département dummy variable, same region dummy variable and log GDP of city i and j. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 7: Base-case gravity models at city level of L_I and L_C, off-line and online, measures based on transaction volumes and GDP as economic size

	Import-based		Commonality	
	Off-line	Online	Off-line	Online
	(1)	(2)	(3)	(4)
Log(Distance)	-0.58***	-0.25***	-0.67***	-0.21***
	(0.016)	(0.013)	(0.007)	(0.011)
Neighbors	0.41***	-0.11***	0.65***	-0.23***
	(0.018)	(0.011)	(0.017)	(0.012)
SameDep	1.55***	0.43***	1.42***	0.1*
	(0.045)	(0.03)	(0.043)	(0.033)
SameRegion	0.39***	0.15***	0.67***	0.26***
	(0.018)	(0.01)	(0.018)	(0.014)
Log(GDP of City i)	0.63***	0.47***	0.78***	0.5***
	(0.003)	(0.003)	(0.001)	(0.002)
Log(GDP of City j)	0.54***	0.47***	0.78***	0.5***
	(0.003)	(0.003)	(0.001)	(0.002)
Constant	-11.15***	-8.83***	-12.55***	-10.93***
	(0.081)	(0.06)	(0.043)	(0.048)
Adj. R-squared	0,51	0.28	0.74	0.32
Observations	11,102,900	4,636,310	31,631,600	8,743,210

Notes: This table reports estimation results for the base-case gravity models at city level. We regress the log trade links with the import-based (L_I, columns 1-2) and commonality (L_C, columns 3-4) measures using off-line and online transaction volumes on the log distance, neighbors dummy variable, same département dummy variable, same region dummy variable and log GDP of city i and j. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

A final and related point concerns the estimated parameter on the size of the economy from which the purchase is made, i.e. the exporting city (log(GDP of city j)). This coefficient remains positive at city level, but is only a third the size of the effect observed in the analysis of départements. This result again emphasizes the fact that the geography of online business relationships is markedly different from those off-line; while proximity between cities is crucial in off-line commerce, it is a much smaller factor in online commerce.

4.6 Robustness checks

In this section, we provide a number of robustness tests, in the form of alternative model specifications, to check the stability of the results. These results pertain to the département-level estimates, which are our primary representation of inter-regional linkage. Tables 16 through 23 in Appendix A provide estimation results for these alternative specifications.

Tables 16 through 19 treat alternative measures of the size of a regional economy, including population, number of cards, number of retailers, and département fixed effects. Each column provides an alternative specification of one of the columns in Table 2 (left-hand columns) or 3 (right-hand columns). Our primary interest is in the robustness of results, particularly with respect to the online/off-line contrast, to these alternative specifications.

Comparing Tables 16 and 18, we see again that distance continues to play a significant role in online purchases, but that the effect is greatly reduced relative to traditional off-line purchases. Coefficients on the economy size measures remain in the neighbourhood of 1 for off-line purchases and for the importing département with online purchases (although all such coefficients are statistically significantly different from 1 as well as from 0), but again the effect of size of the exporting economy is greatly elevated for online purchases; when considering online transaction values for instance, coefficients on the exporting département measure of economy size are estimated as 1.82 (population), 1.63 (number of cards) and 1.9 (number of retailers). The commonality linkage measure again shows the same contrasts as earlier (Tables 17 and 19), again with the effect of online sales distributed across the two départements, because of the symmetry of the commonality measure.

Tables 20 through 23 add additional indicator variables to the base specification, particularly for Paris as a special case and for the presence of a foreign border, a sea border, or both. Comparing Table 20 with Table 22 and Table 21 with Table 23, particularly with respect to the effects of distance and size of the economy of the exporting département j, we again see that the online/off-line contrasts just described are robust to these changes in specification.

The effects of additional indicator variables (Z in the notation of equation 4) are of independent interest. In the trade-based results (Tables 20 and 22), the indicators tend to play a bigger role for the exporting department j and a smaller, or insignificant, role for the importing department i. (Again, for results based on commonality, coefficients for the two départements are necessarily identical.) Paris is particularly likely to be a source of exports to the regions (i.e. an indicator for Paris is strongly significant as exporting department j); as importers, however, Parisians do not differ much, if at all, from residents of the rest of the country. Possessing a foreign border or a seacoast is a strong predictor of 'in-store' exports to other regions (i.e the indicators for department j are strongly significant for off-line sales; Table 20), presumably because such areas attract a disproportionate amount of tourism. Less evidently, these same effects are strongly negative as predictors of online exports (Table 22). This may be the result of inland locations of corporate headquarters or distribution centres for major online sellers.

Globally, the main result is both clear and robust: traditional gravity relationships are changed by online purchases, which are much more heavily directed toward regions which are already economically 'large' than are traditional point-of-sale purchases. We have been able to quantify the extent of this effect using aggregated consumption data which are measured with very high accuracy, and which measure online and point-of-sale purchases by the same mechanism for full comparability.

5 Conclusion and research directions

Little is known about geographical movements of consumers, their purchases outside their home areas, and the associated effects on economic activity throughout the country, nor do economists fully understand the impacts that the increasing importance of online consumption may have on traditional patterns.

This study provides evidence on these questions. Using a data set of exceptional size, coverage and detail concerning the purchases of individual cardholders, and an attribution of a home region using information on the individual's purchasing patterns, we are able to track mobility patterns throughout France for approximately 70 million cardholders. The volume and value of point-of-sale expenditures outside the home region indicate that these external expenditures form an important part of overall consumption, and will have substantial impact.

We next turn to the question of how online consumption patterns differ. To do so we separate online and off-line transactions and estimate separate gravity based models of inter-regional retail trade based on aggregates of the individual expenditures. We find that the patterns in online expenditure differs substantially, with much diminished effects of distance (a finding noted previously by Hortaçsu et al. (2009) and Lendle et al. (2016) in the context of purchases made via eBay, and by Gomez-Herrera et al. (2014) and Francois (2016) in the context of cross-border e-commerce in the EU). This diminished distance effect, compatible with the fact that mobility of the individual is no longer necessary when making purchases online from a distant region, may have important implications for the growth or health of retail industries outside major hubs.

Online purchasing is tending to change the standard gravity relationships, which have previously been very stable; the trend toward online purchases may be concentrating retail activity in regions which are already economically strong.

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A Appendix: Supplementary Tables

[Intended for online posting only]

In this appendix, we provide supplementary tables on a variety of alternative specifications to test the robustness of the results obtained in the baseline regressions. Tables 8 and 9 present regressions similar to the four base-case regressions displayed in Tables 2 and 3, but for the year 2018. Tables 10 through 15 present gravity models for sectoral disaggregations based on alternative measures. Tables 16, 17, 18 and 19 presents alternative gravity models with import-based and commonality measures. Finally, Tables 20, 21, 22, and 23 present expanded gravity models by adding additional indicator variables to the base specification, particularly for Paris as a special case and for the presence of a foreign border, a sea border, or both.

Table 8: 2018 Trade links with the traditional trade-related measure: value

	Import-based		Commonality	
	Off-line	Online	Off-line	Online
	(1)	(2)	(3)	(4)
Log(Distance)	-0.82***	-0.4***	-0.7***	-0.29***
	(0.02)	(0.015)	(0.017)	(0.023)
Neighbors	1.46***	0.45***	0.79***	0.02
	(0.062)	(0.05)	(0.045)	(0.052)
SameRegion	0.54***	0.41***	0.38***	0.26***
	(0.055)	(0.038)	(0.043)	(0.051)
Log(GDP of Dep i)	1.06***	0.97***	0.9***	1.4***
	(0.01)	(0.009)	(0.007)	(0.01)
Log(GDP of Dep j)	0.98***	1.59***	0.91***	1.4***
	(0.009)	(0.011)	(0.007)	(0.01)
Constant	-25.57***	-40.24***	-18.4***	-44.52***
	(0.357)	(0.34)	(0.32)	(0.44)
Adj. R-squared	0.83	0.84	0.88	0.85
Observations	8930	8930	8930	8930

Notes: This table reports estimation results for gravity models using 2018 trade links with the import-based (L_I, columns 1-2) and commonality (L_C, columns 3-4) measures using off-line and online transaction values. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 9: 2018 Trade links with the traditional trade-related measure: volume

	Import-based		Commonality	
	Off-line	Online	Off-line	Online
	(1)	(2)	(3)	(4)
Log(Distance)	-0.85***	-0.37***	-0.73***	-0.26***
	(0.02)	(0.016)	(0.018)	(0.023)
Neighbors	1.39***	0.44***	0.72***	0.05
	(0.061)	(0.048)	(0.044)	(0.053)
SameRegion	0.58***	0.36***	0.4***	0.27***
	(0.057)	(0.041)	(0.043)	(0.055)
Log(GDP of Dep i)	1.02***	0.9***	0.89***	1.35***
	(0.009)	(0.009)	(0.007)	(0.01)
Log(GDP of Dep j)	0.97***	1.58***	0.89***	1.35***
	(0.009)	(0.012)	(0.007)	(0.01)
Constant	-20.79***	-34.17***	-14.59***	-37.37***
	(0.297)	(0.296)	(0.268)	(0.381)
Adj. R-squared	0.84	0.83	0.87	0.84
Observations	8930	8930	8930	8930

Notes: This table reports estimation results for gravity models using 2018 trade links with the import-based (L_I, columns 1-2) and commonality (L_C, columns 3-4) measures using off-line and online transaction volumes. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 10: Sectoral disaggregation of gravity models with import-based measure L_I: measures based on off-line transaction volumes

	Apparel	Food	Clothing	Health	Hosting	Leisure	Personal Care	Restaurant	Hyper/Supermarket	Transport	Auto Sales/Parts
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Log(Distance)	-0.9***	-0.68***	-0.86***	-0.69***	-0.92***	-0.78***	-0.75***	-1.02***	-0.74***	-0.69***	-0.89***
	(0.018)	(0.021)	(0.017)	(0.016)	(0.015)	(0.019)	(0.018)	(0.014)	(0.015)	(0.025)	(0.017)
Neighbors	1.69***	1.62***	1.8***	2.01***	0.56***	1.51***	1.9***	1.2***	1.68***	1.22***	1.84***
	(0.048)	(0.056)	(0.045)	(0.044)	(0.04)	(0.05)	(0.048)	(0.039)	(0.04)	(0.068)	(0.045)
SameRegion	0.73***	0.75***	0.61***	0.8***	0.21***	0.66***	0.78***	0.54***	0.63***	1.05***	0.62***
	(0.051)	(0.058)	(0.048)	(0.046)	(0.042)	(0.053)	(0.05)	(0.04)	(0.042)	(0.072)	(0.048)
Log(GDP of Dep i)	0.93***	1.06***	0.95***	1.04***	0.97***	1.01***	1.07***	1.0***	0.98***	1.17***	0.95***
	(0.01)	(0.011)	(0.009)	(0.009)	(0.008)	(0.01)	(0.009)	(0.008)	(0.008)	(0.014)	(0.009)
Log(GDP of Dep j)	1.22***	0.91***	1.27***	0.96***	0.77***	1.0***	0.88***	1.01***	0.72***	1.64***	0.66***
	(0.01)	(0.011)	(0.009)	(0.009)	(0.008)	(0.01)	(0.009)	(0.008)	(0.008)	(0.014)	(0.009)
Constant	-29.99***	-25.61***	-28.63***	-26.1***	-19.44***	-24.82***	-26.15***	-22.13***	-18.32***	-41.32***	-19.58***
	(0.276)	(0.299)	(0.243)	(0.237)	(0.216)	(0.269)	(0.258)	(0.207)	(0.215)	(0.375)	(0.244)
Adj. R-squared	0.79	0.71	0.83	0.81	0.78	0.76	0.78	0.85	0.8	0.74	0.76
Observations	8426	8918	8929	8929	8930	8929	8887	8930	8930	8802	8891

Notes: This table reports the estimation results for the sectoral disaggregation of the gravity model. For each sector (columns 1-11), we regress the logarithm of the import-based trade link measure (L_I), using off-line transaction volumes, on the variables used in Table 2. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 11: Sectoral disaggregation of gravity models with import-based measure L_I: measures based on online transaction volumes

	Apparel	Food	Clothing	Health	Hosting	Leisure	Personal Care	Restaurant	Hyper/Supermarket	Transport	Auto Sales/Parts
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Log(Distance)	-0.01	-0.02	-0.34***	-0.17***	-0.77***	-0.65***	-0.27***	-0.8***	-0.5***	-0.59***	-0.37***
	(0.052)	(0.034)	(0.037)	(0.045)	(0.018)	(0.026)	(0.032)	(0.021)	(0.029)	(0.057)	(0.029)
Neighbors	0.16	0.27***	0.06	0.61***	0.2***	0.9***	0.7***	1.31***	1.91***	0.08	0.35***
	(0.138)	(0.091)	(0.098)	(0.114)	(0.048)	(0.071)	(0.079)	(0.055)	(0.075)	(0.142)	(0.078)
SameRegion	-0.04	0.64***	0.12	0.52***	0.25***	0.53***	0.66***	0.62***	0.73***	0.85***	0.09
	(0.147)	(0.095)	(0.104)	(0.119)	(0.05)	(0.075)	(0.082)	(0.058)	(0.079)	(0.148)	(0.082)
Log(GDP of Dep i)	0.46***	0.61***	0.7***	0.43***	1.0***	0.84***	0.56***	0.86***	0.81***	0.69***	0.58***
	(0.031)	(0.019)	(0.02)	(0.025)	(0.009)	(0.014)	(0.019)	(0.012)	(0.016)	(0.032)	(0.016)
Log(GDP of Dep j)	0.57***	0.88***	1.9***	0.77***	1.14***	1.42***	0.52***	0.99***	1.1***	1.73***	1.38***
	(0.032)	(0.02)	(0.021)	(0.028)	(0.009)	(0.014)	(0.018)	(0.012)	(0.016)	(0.034)	(0.017)
Constant	-16.73***	-24.86***	-41.47***	-18.53***	-29.47***	-32.6***	-16.31***	-26.66***	-28.67***	-37.01***	-29.55***
	(0.891)	(0.56)	(0.589)	(0.75)	(0.259)	(0.394)	(0.523)	(0.346)	(0.454)	(0.953)	(0.451)
Adj. R-squared	0.16	0.32	0.55	0.2	0.76	0.63	0.28	0.67	0.54	0.35	0.5
Observations	2719	6042	7110	4767	8838	8644	5334	7104	7636	5658	8083

Notes: This table reports the estimation results for the sectoral disaggregation of the gravity model. For each sector (columns 1-11), we regress the logarithm of the import-based trade link measure (L_I), using online transaction volumes, on the variables used in Table 2. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 12: Sectoral disaggregation of gravity models with commonality measure L_C: measures based on off-line transaction values

	Apparel (1)	Food (2)	Clothing (3)	Health (4)	Hosting (5)	Leisure (6)	Personal Care (7)	Restaurant (8)	Hyper/Supermarket (9)	Transport (10)	Auto Sales/Parts (11)
Log(Distance)	-0.99***	-0.51***	-0.8***	-0.65***	-0.61***	-0.65***	-0.56***	-0.82***	-0.58***	-0.71***	-0.97***
	(0.023)	(0.018)	(0.015)	(0.015)	(0.011)	(0.016)	(0.017)	(0.011)	(0.012)	(0.02)	(0.016)
Neighbors	1.39***	1.2***	1.44***	1.84***	0.3***	1.22***	1.47***	0.67***	1.34***	0.62***	1.56***
	(0.059)	(0.049)	(0.041)	(0.042)	(0.03)	(0.044)	(0.047)	(0.03)	(0.033)	(0.055)	(0.042)
SameRegion	0.66***	0.69***	0.47***	0.8***	0.14***	0.58***	0.74***	0.38***	0.5***	0.9***	0.56***
	(0.062)	(0.051)	(0.043)	(0.044)	(0.031)	(0.046)	(0.05)	(0.031)	(0.035)	(0.058)	(0.044)
Log(GDP of Dep i)	1.26***	0.99***	1.26***	1.05***	0.72***	1.04***	1.04***	0.97***	0.74***	1.42***	0.85***
	(0.013)	(0.01)	(0.008)	(0.009)	(0.006)	(0.009)	(0.01)	(0.006)	(0.007)	(0.011)	(0.009)
Log(GDP of Dep j)	1.26***	0.99***	1.26***	1.05***	0.72***	1.04***	1.04***	0.97***	0.74***	1.42***	0.85***
	(0.013)	(0.01)	(0.008)	(0.009)	(0.006)	(0.009)	(0.01)	(0.006)	(0.007)	(0.011)	(0.009)
Constant	-41.06***	-28.78***	-37.8***	-31.25***	-15.33***	-29.3***	-32.37***	-22.95***	-14.81***	-47.36***	-22.05***
	(0.439)	(0.321)	(0.269)	(0.274)	(0.195)	(0.29)	(0.313)	(0.196)	(0.216)	(0.365)	(0.278)
Adj. R-squared	0.73	0.72	0.86	0.82	0.79	0.78	0.76	0.87	0.79	0.79	0.78
Observations	7950	8930	8930	8930	8930	8930	8910	8930	8930	8910	8906

Notes: This table reports the estimation results for the sectoral disaggregation of the gravity model. For each sector (columns 1-11), we regress the logarithm of the commonality trade link measure (L_c), using off-line transaction values, on the variables used in Table 2. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 13: Sectoral disaggregation of gravity models with commonality measure L_C: measures based on online transaction values

	Apparel (1)	Food (2)	Clothing (3)	Health (4)	Hosting (5)	Leisure (6)	Personal Care (7)	Restaurant (8)	Hyper/Supermarket (9)	Transport (10)	Auto Sales/Parts (11)
Log(Distance)	0.42***	-0.19***	-0.27***	0.07	-0.27***	-0.57***	-0.14***	-0.48***	-0.34***	-0.49***	-0.26***
	(0.143)	(0.056)	(0.05)	(0.067)	(0.011)	(0.03)	(0.051)	(0.031)	(0.028)	(0.084)	(0.035)
Neighbors	1.45**	-0.09	0.25*	0.35*	0.21***	0.29***	0.01	0.98***	1.8***	-0.99***	-0.17*
	(0.599)	(0.166)	(0.146)	(0.179)	(0.029)	(0.079)	(0.121)	(0.075)	(0.071)	(0.219)	(0.094)
SameRegion	-0.25	0.03	-0.14	0.4**	0.27***	0.36***	0.34***	0.63***	0.59***	0.87***	0.15
	(0.508)	(0.164)	(0.153)	(0.186)	(0.03)	(0.083)	(0.119)	(0.079)	(0.074)	(0.225)	(0.101)
Log(GDP of Dep i)	0.46***	0.48***	1.45***	0.51***	0.92***	1.33***	0.37***	0.79***	0.87***	1.32***	1.1***
	(0.086)	(0.034)	(0.033)	(0.046)	(0.006)	(0.017)	(0.033)	(0.019)	(0.017)	(0.057)	(0.021)
Log(GDP of Dep j)	0.46***	0.48***	1.45***	0.51***	0.92***	1.33***	0.37***	0.79***	0.87***	1.32***	1.1***
	(0.086)	(0.034)	(0.033)	(0.046)	(0.006)	(0.017)	(0.033)	(0.019)	(0.017)	(0.057)	(0.021)
Constant	-17.64***	-14.32***	-54.98***	-17.27***	-27.71***	-46.31***	-10.04***	-26.12***	-28.84***	-47.69***	-37.74***
	(2.821)	(1.174)	(1.191)	(1.542)	(0.19)	(0.561)	(1.106)	(0.627)	(0.568)	(2.007)	(0.7)
Adj. R-squared	0.18	0.15	0.42	0.1	0.84	0.59	0.16	0.41	0.48	0.22	0.41
Observations	306	2114	4262	2196	8930	8170	1410	5924	6974	3658	7144

Notes: This table reports the estimation results for the sectoral disaggregation of the gravity model. For each sector (columns 1-11), we regress the logarithm of the commonality trade link measure (L_c), using online transaction values, on the variables used in Table 2. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 14: Sectoral disaggregation of gravity models with commonality measure L_C: measures based on off-line transaction volumes

	Apparel (1)	Food (2)	Clothing (3)	Health (4)	Hosting (5)	Leisure (6)	Personal Care (7)	Restaurant (8)	Hyper/Supermarket (9)	Transport (10)	Auto Sales/Parts (11)
Log(Distance)	-0.93***	-0.5***	-0.8***	-0.58***	-0.69***	-0.66***	-0.55***	-0.92***	-0.62***	-0.79***	-0.86***
	(0.019)	(0.018)	(0.015)	(0.015)	(0.011)	(0.016)	(0.016)	(0.011)	(0.012)	(0.019)	(0.016)
Neighbors	1.28***	1.23***	1.46***	1.68***	0.31***	1.16***	1.48***	0.62***	1.25***	0.69***	1.62***
	(0.049)	(0.049)	(0.042)	(0.04)	(0.03)	(0.043)	(0.044)	(0.03)	(0.033)	(0.053)	(0.042)
SameRegion	0.68***	0.74***	0.49***	0.79***	0.14***	0.57***	0.76***	0.36***	0.55***	0.96***	0.58***
	(0.052)	(0.052)	(0.044)	(0.042)	(0.031)	(0.045)	(0.046)	(0.031)	(0.035)	(0.055)	(0.045)
Log(GDP of Dep i)	1.11***	0.94***	1.18***	0.95***	0.66***	1.01***	0.96***	0.92***	0.74***	1.43***	0.71***
	(0.011)	(0.01)	(0.008)	(0.008)	(0.006)	(0.008)	(0.009)	(0.006)	(0.007)	(0.01)	(0.008)
Log(GDP of Dep j)	1.11***	0.94***	1.18***	0.95***	0.66***	1.01***	0.96***	0.92***	0.74***	1.43***	0.71***
	(0.011)	(0.01)	(0.008)	(0.008)	(0.006)	(0.008)	(0.009)	(0.006)	(0.007)	(0.01)	(0.008)
Constant	-31.6***	-23.5***	-29.75***	-23.63***	-11.84***	-23.81***	-25.9***	-16.99***	-12.56***	-40.29***	-15.96***
	(0.294)	(0.265)	(0.223)	(0.213)	(0.16)	(0.231)	(0.235)	(0.159)	(0.179)	(0.284)	(0.228)
Adj. R-squared	0.78	0.72	0.85	0.82	0.78	0.79	0.78	0.88	0.8	0.83	0.75
Observations	7950	8930	8930	8930	8930	8930	8910	8930	8930	8910	8906

Notes: This table reports the estimation results for the sectoral disaggregation of the gravity model. For each sector (columns 1-11), we regress the logarithm of the commonality trade link measure (L_c), using off-line transaction volumes, on the variables used in Table 2. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 15: Sectoral disaggregation of gravity models with commonality measure L_C: measures based on online transaction volumes

	Apparel (1)	Food (2)	Clothing (3)	Health (4)	Hosting (5)	Leisure (6)	Personal Care (7)	Restaurant (8)	Hyper/Supermarket (9)	Transport (10)	Auto Sales/Parts (11)
Log(Distance)	0.21**	-0.11**	-0.27***	0.12**	-0.3***	-0.52***	-0.06	-0.79***	-0.35***	-0.58***	-0.2***
	(0.107)	(0.046)	(0.049)	(0.06)	(0.009)	(0.028)	(0.041)	(0.022)	(0.025)	(0.072)	(0.034)
Neighbors	0.39	-0.12	0.22	0.4**	0.23***	0.42***	0.11	0.9***	1.69***	-0.77***	-0.1
	(0.449)	(0.137)	(0.143)	(0.163)	(0.026)	(0.074)	(0.097)	(0.055)	(0.064)	(0.189)	(0.09)
SameRegion	-0.32	0.31**	-0.16	0.29*	0.24***	0.47***	0.44***	0.52***	0.56***	0.61***	0.17*
	(0.38)	(0.135)	(0.15)	(0.169)	(0.027)	(0.078)	(0.096)	(0.057)	(0.067)	(0.194)	(0.097)
Log(GDP of Dep i)	0.16***	0.51***	1.34***	0.46***	0.77***	1.24***	0.31***	0.76***	0.8***	1.33***	1.01***
	(0.061)	(0.026)	(0.031)	(0.039)	(0.005)	(0.015)	(0.025)	(0.013)	(0.015)	(0.046)	(0.019)
Log(GDP of Dep j)	0.16***	0.51***	1.34***	0.46***	0.77***	1.24***	0.31***	0.76***	0.8***	1.33***	1.01***
	(0.061)	(0.026)	(0.031)	(0.039)	(0.005)	(0.015)	(0.025)	(0.013)	(0.015)	(0.046)	(0.019)
Constant	-6.24***	-16.75***	-44.96***	-15.9***	-20.41***	-37.81***	-10.21***	-21.0***	-24.24***	-42.01***	-32.18***
	(1.713)	(0.777)	(0.938)	(1.124)	(0.137)	(0.425)	(0.714)	(0.369)	(0.414)	(1.388)	(0.544)
Adj. R-squared	0.05	0.24	0.42	0.11	0.84	0.61	0.19	0.61	0.52	0.3	0.42
Observations	306	2114	4262	2196	8930	8170	1410	5924	6974	3658	7144

Notes: This table reports the estimation results for the sectoral disaggregation of the gravity model. For each sector commonality trade link measure (L_c), using online transaction volumes, on the variables used in Table 2. Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 16: Alternative gravity models with import-based measure L_I : off-line

	Value				Volume			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(Distance)	-0.77***	-0.79***	-0.91***	-1.04***	-0.85***	-0.85***	-0.99***	-1.09***
	(0.024)	(0.021)	(0.02)	(0.021)	(0.025)	(0.021)	(0.021)	(0.022)
Neighbors	1.47***	1.48***	1.4***	1.3***	1.35***	1.39***	1.28***	1.18***
	(0.065)	(0.062)	(0.061)	(0.066)	(0.065)	(0.062)	(0.062)	(0.066)
SameRegion	0.64***	0.58***	0.43***	0.34***	0.62***	0.59***	0.41***	0.35***
	(0.062)	(0.057)	(0.055)	(0.059)	(0.065)	(0.059)	(0.057)	(0.061)
Log(Population of Dep i)	1.16***				1.18***			
	(0.012)				(0.013)			
Log(Population of Dep j)	1.07***				1.16***			
	(0.011)				(0.012)			
Log(NumberCards Dep i)		1.09***				1.1***		
		(0.01)				(0.01)		
Log(NumberCards Dep j)		0.97***				1.02***		
		(0.009)				(0.01)		
Log(NumberRetailers Dep i)			1.18***				1.18***	
			(0.011)				(0.011)	
Log(NumberRetailers Dep j)			1.22***				1.31***	
			(0.01)				(0.011)	
Constant	-11.63***	-6.9***	-3.0***	19.06***	-16.19***	-10.99***	-7.01***	15.68***
	(0.308)	(0.233)	(0.195)	(0.133)	(0.313)	(0.236)	(0.2)	(0.141)
Dep i and Dep j fixed effects	No	No	No	Yes	No	No	No	Yes
Adj. R-squared	0.77	0.8	0.84	0.92	0.77	0.82	0.83	0.92
Observations	8930	8930	8930	8930	8930	8930	8930	8930

Notes: This table reports estimation results for alternative gravity models. We use alternative measures of the size of a regional economy, including population, number of cards, number of retailers, and département fixed effects. The dependent variable is the log trade links with the import-based measure (L_I) using off-line transaction values (columns 1-4) and volumes (columns 5-8). Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 17: Alternative gravity models with commonality measure L_C : off-line

	Value				Volume			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(Distance)	-0.64***	-0.67***	-0.77***	-0.85***	-0.7***	-0.73***	-0.83***	-0.88***
	(0.021)	(0.018)	(0.017)	(0.017)	(0.02)	(0.018)	(0.017)	(0.018)
Neighbors	0.83***	0.81***	0.77***	0.71***	0.73***	0.72***	0.67***	0.64***
	(0.049)	(0.045)	(0.044)	(0.047)	(0.049)	(0.045)	(0.044)	(0.048)
SameRegion	0.48***	0.42***	0.29***	0.23***	0.46***	0.4***	0.27***	0.22***
	(0.05)	(0.045)	(0.043)	(0.045)	(0.05)	(0.046)	(0.044)	(0.048)
Log(Population of Dep i)	0.99***				1.03***			
	(0.009)				(0.01)			
Log(Population of Dep j)	0.99***				1.03***			
	(0.009)				(0.01)			
Log(NumberCards Dep i)		0.91***				0.94***		
		(0.008)				(0.008)		
Log(NumberCards Dep j)		0.91***				0.94***		
		(0.008)				(0.008)		
Log(NumberRetailers Dep i)			1.07***				1.11***	
			(0.008)				(0.009)	
Log(NumberRetailers Dep j)			1.07***				1.11***	
			(0.008)				(0.009)	
Constant	-6.13***	-1.71***	1.41***	20.88***	-10.54***	-5.78***	-2.47***	17.46***
	(0.271)	(0.207)	(0.165)	(0.105)	(0.279)	(0.213)	(0.174)	(0.112)
Dep i and Dep j fixed effects	No	No	No	Yes	No	No	No	Yes
Adj. R-squared	0.8	0.85	0.89	0.95	0.81	0.87	0.89	0.95
Observations	8930	8930	8930	8930	8930	8930	8930	8930

Notes: This table reports estimation results for alternative gravity models. We use alternative measures of the size of a regional economy, including population, number of cards, number of retailers, and département fixed effects. The dependent variable is the log trade links with the import-based measure (L_C) using off-line transaction values (columns 1-4) and volumes (columns 5-8). Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 18: Alternative gravity models with import-based measure L_I : online

	Value				Volume			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(Distance)	-0.29***	-0.36***	-0.45***	-0.36***	-0.28***	-0.37***	-0.45***	-0.34***
	(0.019)	(0.016)	(0.014)	(0.012)	(0.02)	(0.017)	(0.016)	(0.011)
Neighbors	0.53***	0.48***	0.44***	0.58***	0.52***	0.44***	0.43***	0.59***
	(0.057)	(0.051)	(0.045)	(0.044)	(0.056)	(0.048)	(0.046)	(0.044)
SameRegion	0.58***	0.45***	0.33***	0.31***	0.53***	0.37***	0.28***	0.29***
	(0.048)	(0.039)	(0.038)	(0.035)	(0.05)	(0.039)	(0.043)	(0.035)
Log(Population of Dep i)	1.06***				1.04***			
	(0.011)				(0.013)			
Log(Population of Dep j)	1.82***				1.9***			
	(0.014)				(0.016)			
Log(NumberCards Dep i)		1.0***				0.97***		
		(0.009)				(0.01)		
Log(NumberCards Dep j)		1.63***				1.69***		
		(0.011)				(0.013)		
Log(NumberRetailers Dep i)			1.08***				1.05***	
			(0.01)				(0.011)	
Log(NumberRetailers Dep j)			1.9***				1.98***	
			(0.012)				(0.014)	
Constant	-23.81***	-17.09***	-11.76***	15.14***	-29.38***	-22.17***	-17.01***	9.8***
	(0.285)	(0.222)	(0.173)	(0.079)	(0.309)	(0.235)	(0.192)	(0.071)
Dep i and Dep j fixed effects	No	No	No	Yes	No	No	No	Yes
Adj. R-squared	0.81	0.8	0.85	0.97	0.79	0.79	0.83	0.98
Observations	8930	8930	8930	8930	8930	8930	8930	8930

Notes: This table reports estimation results for alternative gravity models. We use alternative measures of the size of a regional economy, including population, number of cards, number of retailers, and département fixed effects. The dependent variable is the log trade links with the import-based measure (L_I) using online transaction values (columns 1-4) and volumes (columns 5-8). Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 19: Alternative gravity models with commonality measure L_C : online

	Value				Volume			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Log(Distance)	-0.16***	-0.25***	-0.35***	-0.19***	-0.17***	-0.26***	-0.36***	-0.18***
	(0.026)	(0.024)	(0.021)	(0.008)	(0.027)	(0.024)	(0.023)	(0.008)
Neighbors	0.1	0.05	0.01	0.24***	0.12*	0.04	0.02	0.27***
	(0.062)	(0.055)	(0.048)	(0.029)	(0.063)	(0.054)	(0.051)	(0.03)
SameRegion	0.45***	0.32***	0.19***	0.14***	0.44***	0.27***	0.16***	0.15***
	(0.062)	(0.052)	(0.047)	(0.026)	(0.065)	(0.053)	(0.053)	(0.027)
Log(Population of Dep i)	1.57***				1.61***			
	(0.013)				(0.014)			
Log(Population of Dep j)	1.57***				1.61***			
	(0.013)				(0.014)			
Log(NumberCards Dep i)		1.43***				1.45***		
		(0.011)				(0.012)		
Log(NumberCards Dep j)		1.43***				1.45***		
		(0.011)				(0.012)		
Log(NumberRetailers Dep i)			1.64***				1.67***	
			(0.011)				(0.012)	
Log(NumberRetailers Dep j)			1.64***				1.67***	
			(0.011)				(0.012)	
Constant	-26.79***	-19.28***	-13.76***	15.21***	-32.16***	-24.22***	-18.77***	10.29***
	(0.364)	(0.291)	(0.221)	(0.056)	(0.387)	(0.307)	(0.241)	(0.056)
Dep i and Dep j fixed effects	No	No	No	Yes	No	No	No	Yes
Adj. R-squared	0.82	0.84	0.87	0.99	0.81	0.84	0.85	0.99
Observations	8930	8930	8930	8930	8930	8930	8930	8930

Notes: This table reports estimation results for alternative gravity models. We use alternative measures of the size of a regional economy, including population, number of cards, number of retailers, and département fixed effects. The dependent variable is the log trade links with the import-based measure (L_C) using online transaction values (columns 1-4) and volumes (columns 5-8). Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 20: Expanded gravity models with import-based measure L_I : off-line

	Value			Volume		
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Distance)	-0.85***	-0.93***	-0.94***	-0.89***	-0.99***	-0.99***
	(0.021)	(0.022)	(0.021)	(0.022)	(0.023)	(0.022)
Neighbors	1.45***	1.37***	1.35***	1.35***	1.26***	1.25***
	(0.063)	(0.062)	(0.062)	(0.062)	(0.061)	(0.061)
SameRegion	0.52***	0.47***	0.48***	0.53***	0.48***	0.48***
	(0.056)	(0.055)	(0.054)	(0.058)	(0.057)	(0.056)
Log(GDP of Dep i)	1.03***	1.03***	1.03***	0.99***	0.98***	0.98***
	(0.01)	(0.011)	(0.01)	(0.01)	(0.01)	(0.01)
Log(GDP of Dep j)	1.02***	0.94***	0.97***	1.05***	0.98***	1.0***
	(0.009)	(0.01)	(0.01)	(0.009)	(0.01)	(0.01)
Paris Dep i	0.16*	0.17*		0.0	0.04	
	(0.089)	(0.089)		(0.087)	(0.088)	
Paris Dep j	0.41***	0.69***		0.29***	0.55***	
	(0.062)	(0.068)		(0.067)	(0.073)	
SeaBorder Dep i		0.08***	0.07***		0.12***	0.12***
		(0.019)	(0.018)		(0.019)	(0.019)
ForeignBorder Dep i		0.04**	0.04*		0.08***	0.08***
		(0.018)	(0.019)		(0.02)	(0.02)
SeaBorder Dep j		0.36***	0.32***		0.33***	0.31***
		(0.02)	(0.019)		(0.021)	(0.02)
ForeignBorder Dep j		0.11***	0.1***		0.08***	0.07***
		(0.021)	(0.021)		(0.021)	(0.021)
SeaForeignBorder Dep i		-0.18***	-0.18***		-0.26***	-0.26***
		(0.038)	(0.038)		(0.042)	(0.042)
SeaForeignBorder Dep j		0.07**	0.08**		0.06	0.06
		(0.036)	(0.037)		(0.036)	(0.037)
Constant	-25.86***	-23.65***	-24.35***	-21.64***	-19.84***	-20.22***
	(0.358)	(0.4)	(0.401)	(0.296)	(0.332)	(0.327)
Adj. R-squared	0.83	0.85	0.84	0.84	0.85	0.85
Observations	8930	8930	8930	8930	8930	8930

Notes: This table reports estimation results for expanded gravity models. We include in the traditional gravity model Paris, sea border, foreign border and sea and foreign borders dummy variables. The dependent variable is the log trade links with the import-based measure (L_I) using off-line transaction values (columns 1-3) and volumes (columns 4-6). Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 21: Expanded gravity models with commonality measure L_C : off-line

	Value			Volume		
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Distance)	-0.71***	-0.78***	-0.78***	-0.74***	-0.81***	-0.81***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)	(0.019)
Neighbors	0.81***	0.74***	0.73***	0.74***	0.66***	0.65***
	(0.046)	(0.045)	(0.045)	(0.045)	(0.045)	(0.044)
SameRegion	0.37***	0.34***	0.35***	0.37***	0.35***	0.35***
	(0.044)	(0.043)	(0.042)	(0.045)	(0.044)	(0.043)
Log(GDP of Dep i)	0.91***	0.87***	0.89***	0.9***	0.86***	0.87***
	(0.007)	(0.008)	(0.008)	(0.007)	(0.008)	(0.008)
Log(GDP of Dep j)	0.91***	0.87***	0.89***	0.9***	0.86***	0.87***
	(0.007)	(0.008)	(0.008)	(0.007)	(0.008)	(0.008)
Paris Dep i	0.25***	0.38***		0.24***	0.37***	
	(0.067)	(0.07)		(0.067)	(0.071)	
Paris Dep j	0.26***	0.39***		0.25***	0.38***	
	(0.063)	(0.066)		(0.063)	(0.067)	
SeaBorder Dep i		0.2***	0.19***		0.21***	0.19***
		(0.014)	(0.013)		(0.014)	(0.014)
ForeignBorder Dep i		0.02	0.01		0.03*	0.02
		(0.014)	(0.014)		(0.014)	(0.014)
SeaBorder Dep j		0.2***	0.19***		0.21***	0.19***
		(0.014)	(0.013)		(0.014)	(0.014)
ForeignBorder Dep j		0.02	0.01		0.03*	0.02*
		(0.014)	(0.014)		(0.014)	(0.014)
SeaForeignBorder Dep i		-0.06**	-0.06**		-0.1***	-0.1***
		(0.026)	(0.026)		(0.028)	(0.028)
SeaForeignBorder Dep j		-0.06**	-0.06**		-0.1***	-0.1***
		(0.026)	(0.026)		(0.028)	(0.028)
Constant	-18.83***	-16.75***	-17.37***	-15.08***	-13.44***	-13.92***
	(0.317)	(0.359)	(0.361)	(0.267)	(0.306)	(0.303)
Adj. R-squared	0.88	0.88	0.88	0.87	0.88	0.88
Observations	8930	8930	8930	8930	8930	8930

Notes: This table reports estimation results for expanded gravity models. We include in the traditional gravity model Paris, sea border, foreign border and sea and foreign borders dummy variables. The dependent variable is the log trade links with the import-based measure (L_C) using off-line transaction values (columns 1-3) and volumes (columns 4-6). Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 22: Expanded gravity models with import-based measure L_I : online

	Value			Volume		
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Distance)	-0.37***	-0.33***	-0.34***	-0.31***	-0.3***	-0.31***
	(0.015)	(0.016)	(0.016)	(0.016)	(0.017)	(0.017)
Neighbors	0.51***	0.56***	0.54***	0.55***	0.58***	0.55***
	(0.049)	(0.049)	(0.05)	(0.05)	(0.049)	(0.05)
SameRegion	0.44***	0.44***	0.44***	0.42***	0.41***	0.41***
	(0.037)	(0.038)	(0.038)	(0.041)	(0.041)	(0.042)
Log(GDP of Dep i)	0.94***	0.95***	0.95***	0.88***	0.88***	0.88***
	(0.009)	(0.01)	(0.01)	(0.009)	(0.011)	(0.01)
Log(GDP of Dep j)	1.59***	1.63***	1.67***	1.57***	1.61***	1.67***
	(0.011)	(0.012)	(0.011)	(0.012)	(0.012)	(0.012)
Paris Dep i	-0.07	-0.06		-0.16*	-0.14*	
	(0.074)	(0.074)		(0.08)	(0.08)	
Paris Dep j	1.28***	1.12***		1.6***	1.48***	
	(0.05)	(0.05)		(0.051)	(0.052)	
SeaBorder Dep i		-0.01	-0.01		0.01	0.02
		(0.02)	(0.02)		(0.022)	(0.022)
ForeignBorder Dep i		0.11***	0.11***		0.12***	0.12***
		(0.02)	(0.02)		(0.022)	(0.022)
SeaBorder Dep j		-0.3***	-0.36***		-0.24***	-0.31***
		(0.021)	(0.021)		(0.024)	(0.024)
ForeignBorder Dep j		-0.06***	-0.07***		0.06***	0.04**
		(0.019)	(0.019)		(0.019)	(0.02)
SeaForeignBorder Dep i		-0.08*	-0.08*		-0.08	-0.08
		(0.044)	(0.044)		(0.048)	(0.049)
SeaForeignBorder Dep j		0.53***	0.53***		0.35***	0.35***
		(0.04)	(0.039)		(0.049)	(0.048)
Constant	-39.82***	-41.04***	-41.91***	-34.24***	-35.06***	-35.92***
	(0.34)	(0.381)	(0.372)	(0.296)	(0.327)	(0.326)
Adj. R-squared	0.85	0.85	0.85	0.83	0.84	0.83
Observations	8930	8930	8930	8930	8930	8930

Notes: This table reports estimation results for expanded gravity models. We include in the traditional gravity model Paris, sea border, foreign border and sea and foreign borders dummy variables. The dependent variable is the log trade links with the import-based measure (L_I) using online transaction values (columns 1-3) and volumes (columns 4-6). Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.

Table 23: Expanded gravity models with commonality measure L_C : online

	Value			Volume		
	(1)	(2)	(3)	(4)	(5)	(6)
Log(Distance)	-0.25***	-0.16***	-0.17***	-0.21***	-0.15***	-0.16***
	(0.022)	(0.023)	(0.023)	(0.023)	(0.024)	(0.024)
Neighbors	0.09*	0.18***	0.16***	0.15***	0.22***	0.2***
	(0.052)	(0.053)	(0.053)	(0.054)	(0.054)	(0.055)
SameRegion	0.31***	0.33***	0.33***	0.33***	0.33***	0.33***
	(0.05)	(0.05)	(0.051)	(0.053)	(0.053)	(0.054)
Log(GDP of Dep i)	1.38***	1.43***	1.46***	1.34***	1.38***	1.41***
	(0.01)	(0.011)	(0.011)	(0.01)	(0.011)	(0.011)
Log(GDP of Dep j)	1.38***	1.43***	1.46***	1.34***	1.38***	1.41***
	(0.01)	(0.011)	(0.011)	(0.01)	(0.011)	(0.011)
Paris Dep i	0.83***	0.68***		0.84***	0.72***	
	(0.061)	(0.06)		(0.061)	(0.061)	
Paris Dep j	0.83***	0.68***		0.85***	0.73***	
	(0.061)	(0.06)		(0.061)	(0.061)	
SeaBorder Dep i		-0.3***	-0.33***		-0.25***	-0.28***
		(0.021)	(0.021)		(0.023)	(0.022)
ForeignBorder Dep i		-0.03*	-0.04**		0.05**	0.04**
		(0.018)	(0.018)		(0.019)	(0.019)
SeaBorder Dep j		-0.3***	-0.33***		-0.25***	-0.28***
		(0.021)	(0.021)		(0.023)	(0.022)
ForeignBorder Dep j		-0.03*	-0.04**		0.05**	0.04**
		(0.018)	(0.018)		(0.019)	(0.019)
SeaForeignBorder Dep i		0.39***	0.39***		0.31***	0.31***
		(0.041)	(0.041)		(0.045)	(0.045)
SeaForeignBorder Dep j		0.39***	0.39***		0.31***	0.31***
		(0.041)	(0.041)		(0.045)	(0.045)
Constant	-44.27***	-46.6***	-47.71***	-37.63***	-39.26***	-40.19***
	(0.44)	(0.492)	(0.474)	(0.38)	(0.419)	(0.406)
Adj. R-squared	0.86	0.86	0.86	0.85	0.86	0.86
Observations	8930	8930	8930	8930	8930	8930

Notes: This table reports estimation results for expanded gravity models. We include in the traditional gravity model Paris, sea border, foreign border and sea and foreign borders dummy variables. The dependent variable is the log trade links with the import-based measure (L_C) using online transaction values (columns 1-3) and volumes (columns 4-6). Robust standard errors clustered at the distance level are reported in parentheses. ***, **, * indicate significance at the 1%, 5% and 10% levels, respectively.