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Longitude matters II: new evidence of the impact of time differences on international trade and communication

Edward Anderson

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Abstract

This paper looks at the impact of time differences on international trade using the gravity model framework. It builds on two previous studies of this issue (Stein and Daude 2007, Head et al 2009), by including a wider set of control variables, a longer time period, and by testing a series of additional related hypotheses. The main results indicate that time differences have a negative and statistically significant impact on overall trade. There is also evidence that the negative impact of time differences has fallen during recent decades, and is smaller where the rule of law in each trading partner is stronger, and where bilateral migrant populations are larger. There is also evidence that time differences reduce international communication, in the form of bilateral telephone traffic.

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1 Introduction

What impact do time differences have on international trade? It is well known that geographical distance reduces trade: this has been shown by the results of nearly 1,500 gravity models from over 100 research papers (Disdier and Head 2008).[1] But while time differences and geographical distances are clearly related, the correlation is by no means perfect. For example, the distance between London and Los Angeles (8,700km) is similar to that between London and Johannesburg (9,100km), but while the former involves a time difference of eight hours the latter involves a difference of just one hour (or two hours between October and March). There is therefore an interesting question as to whether time differences affect trade, holding geographical distance constant. Moreover, the few studies which have looked at the conditional impact of time differences on trade have so far yielded conflicting results. For instance, Stein and Daude (2007) find that time differences have a negative impact on overall trade, with each hour of difference reducing trade by between 7 and 11 per cent, ceteris paribus. By contrast, Head et al (2009) find that time differences have a positive impact on trade in goods, and no statistically significant impact on trade in financial, computing and communication services.

Why might time differences affect trade? On the one hand, time differences raise the non-pecuniary costs of travel and communication, by causing jet-lag among travellers and by reducing the amount of time in the normal working day in which simultaneous communication (e.g. telephone conversations, video-conferencing) can take place. If travel and simultaneous communication are important for trade – for example, by helping to establish and maintain trust, by spreading information about trading opportunities, or by facilitating the flow of complex, tacit know-how among vertically disintegrated production networks – greater time differences should lead

[1] "After using article search engines to construct a database of 1,467 estimates from 103 papers, we find that the mean effect [of distance on trade] is about 0.9, with 90% of estimates lying between 0.28 and 1.55. On average, then, a 10% increase in distance lowers bilateral trade by about 9%." (ibid.:37).

to less trade. On the other hand, time differences promote opportunities for trade in services (Marjit 2007, Gupta and Seshasai 2004). For example, by employing teams in different time zones, firms can work on product design and development around the clock, thereby reducing product turnaround times.

To determine whether time differences affect trade, this paper uses the well-known gravity model framework. Similar to Stein and Daude (2007) and Head et al (2009), the basic approach is to augment the standard set of explanatory variables (e.g. geographical distance, a common currency) to include the time difference between trading partners. The analysis differs however from these studies in certain important ways. First, the models estimated in this paper control for variables not always included by Stein and Daude (2007) and Head et al (2009), but which might nonetheless bias the estimated impact of time differences on trade. These include North-South distance and differences in latitude, as analysed by Melitz (2007), and a measure of the actual cargo distance as opposed to the great-circle distance between trading partners. Second, the datasets analysed in this paper cover a wider time-period – from 1950 to 2006 – than both Stein and Daude (2007), who use data for 1999 only, and Head et al (2009) who focus on the period 1992-2006.[2] This makes it possible to determine whether the impact of time differences has changed in recent decades. For example, one might expect the trade-enhancing effect of time differences to be apparent in more recent years only, on the grounds that the technology that allows large amounts of information to be transferred quickly between teams working in different zones has only recently become available (Marjit 2007).

Third, the paper tests a series of additional hypotheses. The first is that the negative effect of time differences on trade (via higher travel and communication costs) is greater where formal mechanisms of contract enforcement in each trading partner

[2] Stein and Daude (2007) consider a longer time-period when analysing how time differences affect foreign direct investment, which is the primary focus of their paper.

are weaker. The reasoning here is that face-to-face communication becomes more important in such cases as a means of establishing and maintaining trust. The second is that the negative effect of time differences on trade is smaller where co-ethnic networks among and between trading partners are more prevalent. The reasoning here is that such networks provide ways of acquiring information about foreign markets which avoid, or at least substantially reduce, the need for travel and communication across time zones. The paper also tests the hypothesis time differences reduce international communication, as measured by bilateral telephone traffic, as well as trade.

To give a flavour of the results, the paper finds that for a range of samples and estimation methods, time differences do have a negative and statistically significant impact on overall bilateral trade. For pooled samples across years, each hour of time difference is found to reduce trade by between 3 and 7 per cent, which is somewhat smaller than the range of 7 to 11 per cent reported by Stein and Daude (2007), but economically significant nonetheless. There is also evidence that the negative impact of time differences has fallen during recent decades, and is smaller where mechanisms of formal contract enforcement, as proxied by the Kaufman et al (2009) rule of law index, and co-ethnic networks, as proxied by the size of the bilateral migrant population, are more prevalent. Finally, the paper finds that time differences have a negative and statistically significant impact on international communication, with each hour of time difference reducing total bilateral telephone traffic by between 5 and 7 per cent.

The remainder of the paper proceeds as follows. Section 2 discusses the existing literature relating to this issue. Section 3 then outlines the econometric methods used and the sources of data, while Section 4 presents estimates of the impact of time differences on trade. Section 5 then presents estimates of the impact of time differences on international communication. Section 6 concludes and discusses possible areas for further research and potential implications for policy.

2 Relevant literature

The first paper to discuss the potential effects of time differences was Stein and Daude (2007). They argued that time differences raise the non-pecuniary costs of travel and communication, for two reasons.[3] First, air travel across time zones causes jet lag, which for many people is an unpleasant experience that diminishes well-being and productivity for significant periods of time. Second, simultaneous communication (e.g. telephone conversations, video-conferencing, instant messaging) becomes harder as time differences get larger, because there are fewer hours in a normal working day when such communication can take place. For example, a 6-hour time difference implies that two people working a 'normal' working day of eight hours can have a simultaneous conversation during only two of those hours. Although the main focus of Stein and Daude (2007) was on foreign direct investment, they argued that the higher travel and communication costs caused by time differences would tend to reduce trade as well as foreign direct investment (ibid: 107).[4]

There is a large literature on the health effects of jet lag. Key findings (e.g. Rajaratnam and Arendt 2001, Waterhouse et al. 2007) include: around two-thirds of travellers report getting jet lag; there are various adverse symptoms of jet lag, including tiredness, impaired alertness and performance, gastrointestinal problems

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[3] There are no obvious reasons for thinking that time differences will affect the pecuniary costs of travel and communication (e.g. the price of an international telephone call or a long-distance air ticket), at least when referring to the conditional effects of time differences, holding geographical distance constant. By contrast, geographical distance mainly affects the pecuniary cost of travel and communication (holding time differences constant), although long-distance travel can have some non-pecuniary costs independently of time differences, such as travel fatigue.

[4] Stein and Daude (2007) did however expect the negative effect of time differences to be smaller in absolute terms on trade than FDI, on the grounds that "trade transactions are not as demanding in terms of real-time interaction between the parties as is generally the case for FDI" (ibid: 107). They go on to find that time differences reduce bilateral FDI by between 17 and 26 per cent, compared to between 7 and 11 per cent for trade.

and decreased short-term memory; jet lag is different to travel fatigue, which is determined by the length of journey rather than the time difference, and which normally disappears after a good night's sleep; jet lag can last for several days, with a rough guide being about two-thirds of the number of time zones that have been crossed (i.e. the time difference in hours); and jet lag generally occurs when at least three time zones are crossed rapidly. There is also evidence that working irregular hours has adverse consequences for health, similar to those caused by jet lag (Rajaratnam and Arendt 2001). Working irregular hours also reduces opportunities for social interaction (Hamermesh 1999) and can increase marital instability (Presser 2000).

There is also a large literature on the importance of travel and simultaneous communication for trade.[5] On the one hand, face-to-face communication can help buyers and sellers to establish and maintain trust (Leamer and Storper 2001; Storper and Venables 2004). This is partly due to the widespread use of sight to discern the personality, character and/or intentions of others; in addition, co-presence can be used as a signal of commitment, helping to creating a relationship bond. Travel can also be important in terms of obtaining information about trading opportunities in foreign markets.[6] There are of course ways of enforcing contracts (e.g. via the legal system) which avoid the need for face-to-face communication, and other ways of obtaining information about foreign markets which avoid or at least substantially reduce the need for long-distance travel, e.g. social, business or co-ethnic networks

[5] While time differences affect the cost of simultaneous communication they have no impact on the cost of non-simultaneous communication (e.g. written letters, faxes and telegraphs). The issue therefore is how important simultaneous communication is for trade, as opposed to communication per se.

[6] Moreover, travel need not be undertaken specifically for the purpose of obtaining market information for learning to take place. Kulendran and Wilson (2000) for example argue that people who are travelling for non-business reasons may happen to identify trading opportunities while they are away; thus greater ease of leisure travel can also lead to more trade.

(Rauch 1999a, 1999b, 2001; Rauch and Trindade 2002).[7] One would expect therefore that any negative effect of time differences on trade is greater where formal mechanisms of contract enforcement are weaker, or where social, business or co-ethnic networks are absent.[8]

There is also quite a lot of evidence that short-term movements of staff (e.g. training visits) play an important role in facilitating the transfer of technological and managerial knowledge transfer between firms engaged in different stages of vertically-disintegrated production networks or 'value chains' (Rauch 1999a, 2001; Anderson et al (2006); Anderson 2007; Andersen and Dalgaard 2009). Personal interaction is considered particularly important in this case, on the grounds that the know-how being transferred is generally tacit in nature, and transfer of tacit knowledge requires person-to-person demonstrations and instructions (Keller 2004; Storper and Venables 2004, Andersen and Dalgaard 2009).[9]

Time differences can also promote trade in services, as argued by Gupta and Seshasai (2004) and Marjit (2007) and also discussed by Head et al (2009). One example of the trade-creating potential of time differences is call centres, e.g. software support and help-desk operations (Gupta and Seshasai 2004). Customers who call a helpline out of normal office hours in their country of residence are automatically transferred to a

[7] In the words of Rauch (1999a: 175), "one way to avoid expensive and time-consuming factory visits and market research is to have contacts abroad who know your products and know the markets you want to penetrate".

[8] Equivalently, one would expect the negative impact of imperfect contract enforcement on trade to be greater where time differences are larger. For evidence that measures of imperfect contract enforcement are associated with significantly lower trade, see Anderson and Marcouiller (2002).

[9] According to Storper and Venables (2004: 354) for example, face-to-face communication permits "a depth and speed of feedback that is impossible in other forms of communication". In a similar vein, Leamer and Storper (2001) argue that the "successful transfer of complex uncodifiable messages [requires] a kind of closeness between the sender and receiver that the Internet does not allow"; in particular, it requires sight and touch. The idea that (physical) face-to-face interaction becomes more important as ideas become more complex is also well established in the urban literature; see for example Gaspar and Glaeser (1998).

centre in another time zone where the local time falls within normal office hours. Another example is product design and development (e.g. software).[10] The advantage for firms in organising production across time zones lies in the potential to reduce the length of time it takes to design and develop new products and services, even if the amount of labour input remains the same. Realising these gains requires a sufficiently large time difference to make a significant difference to turnaround times, and technology that allows large amounts of information to be transferred quickly between teams working in different zones (Marjit 2007).

In terms of the empirical evidence, Stein and Daude (2007) find that time differences have a negative and statistically significant impact on overall trade, with each hour of time difference reducing bilateral trade by between 7 and 11 per cent. By contrast, Head et al (2009) find that time differences have a positive and statistically significant impact on trade in goods, with each hour increasing trade by between 5 and 7 per cent. These studies are not directly comparable; aside from the different dependent variables analysed (overall trade vs. trade in goods), they use different samples, estimation methods, and controlling variables. For example, Stein and Daude (2007) use data for 1999 only, while Head et al (2009) focus on the period 1992-2006. The difference in results is still puzzling however, given the large proportion of goods trade in overall trade.[11] Head et al (2009) also find that time differences have no statistically significant impact on trade in financial, computing and communication

[10] In the words of Marjit (2007: 154): "[P]rogramming problems are e-mailed from the USA to India at the end of the day (in the USA). Indian software specialists start working on them in their regular office hours, while in the USA the office remains closed due to the time difference. By the time the offices reopen in the USA, the solutions have already arrived mainly as e-mail attachments. This essentially means that the business operations can continue almost for 24 h, with very little interruptions."

[11] Head et al (2009: 438) attempt to replicate the results of Stein and Daude (2007) using the same sample, estimation method and controlling variables, but again obtain a positive and statistically significant impact of time differences on trade.

services, which casts clear doubt on the hypothesis that time differences can promote trade.

There is also a large amount of empirical evidence that travel and communication promote trade. For example, Loungani et al (2002) and Portes and Rey (2005) estimate gravity models of trade which include telephone traffic between countries as an explanatory variable. Both report a positive and statistically significant coefficient for this variable which is quite large in size. Fink et al (2005) estimate a model including the price of a telephone call between trading partners, and show that this variable has a large and statistically significant negative impact on the amount of trade. Kulendran and Wilson (2000), using time-series analysis, find that business travel from the US to Australia Granger-causes higher total trade between the US and Australia, while business travel from the UK to Australia Granger-causes higher exports from the UK to Australia (ibid, Table 2).

However, while these studies indicate the importance of travel and communication for trade, and the adverse effects of pecuniary communication costs on trade, they give no indication of the effect of time differences on trade, which affect the non-pecuniary costs of travel and communication. Moreover, adding a measure of communication flows (e.g. telephone traffic) to the set of explanatory variables in a gravity model raises concerns about endogeneity. Fink et al (2005) advocate their use of a measure of communication costs (the price of a bilateral telephone call) on the grounds that it is more plausibly exogenous to trade flows than measures of communication flows. This argument applies even more strongly with regard to time differences, particularly when measured by ‘solar’ rather than ‘official’ time differences, which depend only on trading partners’ longitude, and can for this reason be considered completely exogenous to trade flows (see Section 3).

3 Methods and data

To determine whether time differences affect trade, this paper uses the gravity model framework. As is well-known, this model explains exports from country *i* to country *j* by an equation of the form:

$$\ln x_{ij} = \ln A_i^X + \ln A_j^M - \theta \ln D_{ij} + \lambda L_{ij} + \varepsilon_{ij} \qquad (1)$$

where A_i^X and A_j^M are indices of the attributes of countries *i* and *j*, D_{ij} is the geographical distance between them, and L_{ij} is a vector of other linkage indicators, such as a common language, a common border, or a shared colonial history (Disdier and Head 2008: 39).[12] The basic approach in this paper is to augment the vector of linkage indicators to include the time difference between trading partners. In theory, the coefficient on this variable could be positive or negative, depending on which of the two possible effects of time differences on trade – the trade reducing effect, via travel and communication costs, and the trade-enhancing effect, via trade in services – prevails.

There are two possible measures of the time difference between countries. The first is the ‘official’ time difference, given by:

$$T_{ij} = abs(h_i - h_j) \text{ if } abs(h_i - h_j) \le 12 \qquad (2a)$$

$$T_{ij} = 24 - abs(h_i - h_j) \text{ if } abs(h_i - h_j) > 12 \qquad (2b)$$

where h_i and h_j are the official times in the principal cities of countries *i* and *j*, in hours and minutes before (-) or ahead (+) of Greenwich Mean Time (GMT), as determined by government decree. The other is the ‘solar’ time difference, which is given by replacing official times in the above formulae with the times of solar noon,

[12] Equation (1) can be extended to a time-series context by adding time subscripts and a common year-specific factor.

also in hours and minutes before (-) or ahead (+) of GMT.[13] The two measures are highly correlated, since governments typically set their official times with regard to the timing of solar noon in their principal city.[14] However, official time differences can be changed by government policy, and can therefore change over time. This raises the possibility that governments try to minimise official time differences with their larger trading partners, leading to reverse causation from trade to time differences. By contrast, solar time differences are fixed by geography: on average, it takes it takes the sun four minutes to transit one degree of longitude, so the solar time difference is essentially a function of the difference in longitude between two locations. This paper uses solar time differences, on the grounds that being fixed by geography they avoid endogeneity concerns.[15] But since the two measures are highly correlated, the results cannot be interpreted as indicating the conditional effect of solar time differences on trade, holding official time differences constant. The issue of whether official and solar time differences have different effects on trade is instead left for further research (see Section 6).

[13] Solar noon is the time at which the sun reaches its highest point in the sky, which occurs when the sun is directly south – in the northern hemisphere – or directly north – in the southern hemisphere – of a specified location. Note that both measures could be extended by considering the population-weighted average time difference between several large cities in each country, rather than considering the difference between principal cities only, but this is not attempted in this paper.

[14] Thus the correlation between the official time in each principal city of the world (in terms of hours and minutes ahead or behind GMT) and the time of solar noon in each city (also in terms of hours and minutes ahead of GMT) is close to unity. There are of course some discrepancies between official and solar time differences: for example, while the official time difference between London and Paris is one hour, the solar time difference is just 10 minutes. But on the whole significant discrepancies tend to arise within countries, particularly those which span large east-west distances but in which there are relatively few different official time zones. In China for example, there is just one official time zone, so the official time differences between any two locations in the country is zero, but differences in solar time can be quite large: for example, two hours between Beijing and Urumqi.

[15] Official time differences are also harder to collect, because official times change over time, if only by small amounts. In 2011 for example the UK government is considering moving the official time forward by one hour, which would reduce the official time difference with other European countries but increase it with the United States and Canada. Solar time differences will of course be unaffected by any such change.

Two further hypotheses discussed in Section 2 are also tested. The first is that time differences have a less negative impact on trade where formal mechanisms of contract enforcement in each country are stronger, while the second is that time differences have a less negative impact on trade, the greater are co-ethnic networks between each country. These hypotheses are tested by interacting time differences with measures of contract enforcement and co-ethnic networks – the former measured by the Kaufman et al (2009) rule of law index for each partner, the latter by the bilateral migrant population of trading partners, taken from Parsons et al (2007) – the expectation being that the coefficient on each interacted variable is positive. We also test for a possible non-linear relationship between time differences and trade. One possible reason for non-linearity is the evidence that jet lag only becomes significant for time differences exceeding three hours (see Section 3). Another is that for time differences exceeding around eight hours, the number of overlapping hours between two locations in a normal working day reaches zero, so that additional time differences beyond this level have no further adverse impact on the ease of (business) communication.

In terms of control variables, all regressions include separate fixed effects for each exporter and importer (for each year) in place of the attribute indices A_i^X and A_j^M. This version of the gravity model was proposed by Feenstra (2004) as a way of dealing with a serious drawback of the 'conventional' gravity model noted by Anderson and van Wincoop (2003). The conventional gravity model, by contrast, assumes that $A_i^X = Y_i^{a_1^X} y_i^{a_2^X}$ and $A_i^M = Y_i^{a_1^M} y_i^{a_2^M}$, where Y is GDP and y is GDP per capita (Disdier and Head 2008: 39). Thus the use of fixed effects in place of the attribute indices avoids the need to include GDP and GDP per capita as control variables in the gravity model, although the estimations are repeated with GDP and certain other variables (e.g. dummy variables for islands and landlocked countries) as additional explanatory variables, as a robustness test (see Section 4.4). Since separate fixed effects for each importer and exporter must be included for each year, the samples used for estimation are sometimes deliberately restricted in order to remain within computational limits.[16]

For the linkage indicators, seven indicators commonly used in gravity model estimations are included, namely: a shared border, a common language, membership of a common currency union, membership of a common preferential trade agreement, a common colonial history – both between a former colony and the mother country, and between two former colonies of the same mother country – and political union (e.g. an overseas dependency or territory and its controlling state). The regressions also control for three variables not typically included in gravity models but whose exclusion might nonetheless bias the estimated impact of time differences on trade. The first is the difference in latitude between trading partners, defined by

$$dlat_{ij} = abs\left[abs(lat_i) - abs(lat_j)\right] \tag{3}$$

where lat_i and lat_j stand for the respective latitudes of each trading partner, with Northern latitudes positive and Southern latitudes negative, while the second is the north-south (N-S) distance between trading partners, defined by

$$ns_{ij} = abs(lat_i - lat_j). \tag{4}$$

As argued by Melitz (2007), differences in latitude promote opportunities for trade, by causing differences in climate and other geographic conditions (e.g. soil type) which can form the basis for comparative advantage. Melitz also finds that N-S distance has a positive impact on trade, even when controlling for differences in latitude (ibid).[17] Since differences in latitude and N-S distance both reflect distance in

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[16] As noted by Head et al (2010), a panel dataset of 200 exporters and 200 importers over 50 years would require 20,000 dummy variables, which is beyond the capability of standard statistical software packages.

[17] A possible explanation for the positive effect of north-south distance on trade relates to the opposition of seasons (ibid: 979). For example, Spain may export fresh fruit to Argentina following

a N-S direction, they may be negatively correlated with time differences, which reflect distance in an east-west (E-W) direction. Thus failing to control for differences in latitude and N-S distance could bias the estimated effect of time differences on trade.

Most gravity models measure distance by the great-circle distance, typically between the principal (i.e. most populous) cities of countries *i* and *j*.[18] This could also bias the estimated effect of time differences on trade. Consider Africa and America, two continents which are aligned in a predominantly N-S direction. Cargo shipments between countries in these continents aligned in a predominantly N-S direction (e.g. Argentina and Brazil, Kenya and Tanzania) can follow a fairly direct route by sea, but shipments between two countries aligned in a predominantly E-W direction (e.g. Argentina and Chile, Kenya and Nigeria) must follow a much more roundabout route – unless they travel by land, which is of course much more expensive. One might therefore expect to see more trade in these continents in a N-S direction than in an E-W direction, but for reasons unrelated to time differences.

To avoid this problem, the gravity models in this paper include two distance measures: the great-circle distance between the most populous cities of each country, denoted D_{ij}^{GC}, and a measure of the cargo distance between those cities, denoted D_{ij}^{AC}. The measure of cargo distance is given by:

$$D_{ij}^{AC} = D_{ij}^{S} + D_{i}^{L} + D_{j}^{L} \quad (5)$$

summer in the Northern hemisphere, and then Argentina may export fresh fruit to Spain following summer in the Southern hemisphere; in this way, consumers in each country can consume seasonal products more frequently throughout the year.

[18] Some more recent studies (e.g. Head et al 2010) measure distance by the population weighted average great circle distance between several large cities in countries *i* and *j*, rather than just the most populous city in each. A few studies have measured distance by actual distances travelled by road or sea, but this does appear to affect the estimated coefficient on distance (Disdier and Head 2008).

where D_{ij}^{S} is the sea distance between the main ports in countries *i* and *j*, and D_{i}^{L} and D_{j}^{L} are the great-circle distance between the main port and the most populous city of countries *i* and *j*. (For land-locked countries, the nearest major foreign port is used to calculate the sea distance.) One drawback with this measure is that the sum of D_{i}^{L} and D_{j}^{L} could exceed D_{ij}^{GC}, and in these cases it seems reasonable to assume that the great-circle route (by land) will be cheaper than the sea route. Thus if $D_{i}^{L} + D_{j}^{L} > D_{ij}^{GC}$ we set $D_{ij}^{AC} = D_{ij}^{GC}$.

Finally, both OLS and Tobit estimation methods are used. In the former case, observations with zero trade are omitted from the analysis; in the latter case, one is added to the value of the dependent variable prior to taking logs, so that the lower truncation point occurs at zero. All data sources are reported in the Appendix.

4 Main results: time differences and trade

4.1 Results, pooled by year

Table 1 shows the estimated impact of time differences on trade when pooling data across years. The results are shown for three different samples: 1950-95, 1970-2000 and 1975-2005, in each case with data at 15-year intervals, and the two different estimation methods: OLS and Tobit.[19] The coefficient for time differences is negative and statistically significant at the 0.1% level in all six cases. Depending on the sample and estimation method, each hour of time difference reduces trade by between 0.03 and 0.07 log points, or 3 and 7 per cent. The negative effect is slightly larger when using OLS rather than Tobit estimation and for samples including earlier years of data. The latter result suggests a possible time trend in the effect of time differences on trade, which is explored further in Section 4.2 below.

The remaining coefficients in Table 1 are on the whole signed according to expectation and similar in size to those obtained by previous studies. The distance measures are both negative and statistically significant at the 0.1% level, with the coefficient for great-circle distance being larger in absolute terms than that for cargo distance. The sum of the two coefficients ranges from -0.90 to -1.16, comfortably within the range of estimates for single distance measures reported by Disdier and Head (2008) in their meta-review.[20] The coefficient for N-S distance is positive and statistically significant; the size ranges between 0.05 and 0.08 log points, which is somewhat smaller than the range of 0.17 to 0.20 log points reported by Melitz (2007).

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[19] Ideally we would estimate the regressions for a single sample, e.g. 1950-2005 at 5-year intervals. This is not possible however for computational reasons (see Section 3). The three samples chosen are such that together they cover a range of years from the whole period of available data (as opposed to a particular sub-period), and have no overlap in terms of the precise years included.

[20] Disdier and Head (2008:40) find that the 5th percentile of estimates of the coefficient for distance is 0.28 (absolute value), while the 95th percentile is 1.55. Replicating the regressions in Table 1 with time differences excluded from the model yields coefficients for distance which are between 10% and 20% higher (in combined, absolute terms) than those shown in Table 1 (details available on request).

This suggests that at least part of the positive effect of N-S distance on trade reported by Melitz (2007) can be accounted for by the negative effect of time differences on trade, which reflect distance in an E-W direction.[21] The one result contrary to expectation is the negative and statistically significant impact of differences in latitude on trade, in columns 4 and 6.

The lower panel of Table 1 also shows the results when testing for a non-linear relationship between time differences and trade. In this case, only the coefficients for time difference and its square are reported; the other coefficients change relatively little in comparison with the values shown in the upper panel (details available on request). There is some evidence of non-linearity: for the first sample (columns 1 and 2), the coefficient for the squared time difference is positive and statistically significant at the 1% level, indicating that the negative impact of time differences on trade diminishes as time differences get larger.[22] This may be explained by the number of overlapping hours in a normal working day reaching a limit (at zero) as time differences get larger, as discussed in Section 3. For the other two samples however, the coefficient for the squared time difference is not statistically significant, and so the evidence of non-linearity does not appear that robust. Regressions were also estimated including a cubic as well as a quadratic term in the time difference, but the coefficient on this variable was not statistically significant in the majority of estimations (details available on request).

4.2 Results by year

Table 2 shows estimates of the effect of time differences on trade at five-year intervals, beginning in 1950 and ending in 2005. The same information is shown on

[21] Further confirmation is provided by replicating the regressions in Table 1 with time differences excluded from the model; in this case, the coefficient for N-S distance is 40%-80% larger than shown in Table 1 (details available on request).

[22] Note that in columns 1 and 2 the negative impact of time differences reaches a maximum at 17 and 20 hours respectively, which is beyond the maximum possible time difference of 12 hours.

an annual basis in Figure 1. These results indicate that the negative impact of time differences on trade has fallen substantially over the period. For the OLS estimates, the absolute size of the coefficient falls from 0.063 log points in 1950 to 0.021 log points in 2005; for the Tobit estimates, it falls from 0.071 log points in 1950 to 0.008 log points in 2005. (Note also that the coefficient for 2005 is not statistically significant for either the OLS or Tobit estimates.) There is also evidence that the impact of time differences fell by more in the first half of the period. For the OLS estimates, the coefficient on time differences in fact rises in absolute value during 1950-80, at an average rate of 0.008 log points per decade, before falling at a rate of 0.043 log points per decade during 1980-2005; for the Tobit estimates, the coefficient falls by 0.008 log points per decade during 1950-80 and 0.017 log points per decade during 1980-2005.[23]

There are two possible explanations for the apparent fall in the negative impact of time differences on trade. One is that new communication technologies have made communication across time zones easier. For example, it is possible that a lot of communication which used to occur via telephone or business travel now takes place by e-mail, and since communication by e-mail need not be simultaneous, it is less sensitive to time differences. However, this explanation conflicts with the argument that face-to-face communication remains particularly important for trade, and that new communication technologies cannot substitute for this form of communication (e.g. Leamer and Storper 2001; Storper and Venables, 2004).[24] The other possible explanation is that the negative impact of time differences, via travel and communication costs, has been increasingly offset by their positive impact, via opportunities for trade in services. As discussed by Marjit (2007), the trade-enhancing potential of time differences has only become possible in more recent

[23] These trends are derived from a linear regression of the absolute value of the slope coefficient for time differences on a time trend with a structural break at 1980. The difference in time trend before and after 1980 is statistically significant for both the OLS and Tobit estimates.

[24] Note that the question of whether video-conferencing or telephone conversations can substitute for face-to-face communication is less of an issue, since these forms of communication are also simultaneous and therefore also sensitive to time differences.

years, with the increasing bandwidths associated with fibre-optic cabling that allow large amounts of information to be transferred quickly between teams working in different parts of world.[25] Since the focus of this paper is on overall trade, it is not possible to distinguish between these two different explanations for the fall in the negative impact of time differences on trade. Nevertheless, the fall does appear to be substantial, and in marked contrast to the persistent – perhaps even increasing – negative impact of distance on trade, as reported by Melitz (2007) and Disdier and Head (2008) amongst others.

4.3 Interaction effects: contract enforcement and co-ethnic networks

As discussed in Section 3, the negative impact of time differences on trade may be greater where formal mechanisms of contract enforcement via the legal system are weaker. This hypothesis is tested by including an interaction term between the time difference between trading partners and the combined value of the Kaufman et al (2009) rule of law index for each partner.[26] The sample in this case includes data for 1996-2004, at four year intervals. The negative impact of time differences may also be greater the less where co-ethnic networks between trading partners are less prevalent; we test this hypothesis by including an interaction term between time differences and the (log) bilateral migrant population of trading partners, taken from Parsons et al (2007).[27] In this case, the sample includes data for 2000 only.

The results are shown in Table 3. Once again, only the key coefficients of interest are reported; the remaining coefficients are on the whole signed according to expectation

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[25] This latter explanation does however conflict with the results of Head et al (2009), who find that time differences have no significant impact on trade in services.

[26] The combined index varies from 0.6 to 9.1, with percentiles at 3.3 (10^{th}), 5.1 (50^{th}) and 7.0 (90^{th}); recall that the original values of the index for each partner are re-scaled so that all values are positive (see Section 3). We also used another measure of institutional quality provided by Kaufmann et al (2009), the index of political stability, but this generated very similar results (details available on request).

[27] This variable varies from zero to 16.1 (the USA and Mexico), with percentiles at 1.4 (10^{th}), 4.9 (50^{th}) and 9.1 (90^{th}).

and statistically significant (details available on request). The interaction terms are all positive as expected, and statistically significant at the 1% level or below. The results in columns 1 and 2 indicate that while each hour of time difference reduces trade by 0.06 and 0.04 log points respectively at the median combined rule of law index, it does so by 0.13 and 0.08 log points at the 10th percentile.[28] Similarly, the results in columns 3 and 4 each hour of time difference reduces trade by 0.03 log points at the median bilateral migrant population, but by 0.06 and 0.05 log points respectively at the 10th percentile.

4.4 Additional results

Some additional results are shown in Table 4. First, the regressions in Panel A replaces the solar time difference measure used in Tables 1-3 with the official time difference, based on the prevailing official times (in hours before or ahead of GMT) in the principal cities of each trading partner. As can be seen, the results are very similar to those reported previously in Table 1: a consistently negative and statistically significant impact of time differences on trade, with coefficients between 0.04 and 0.07 log points. Second, the regressions in Panel B add a range of additional control variables for importer and exporting countries, namely population, GDP per capita, land area, and dummy variables for landlocked countries, island countries, and GATT membership. The estimated effect of time differences on trade is again very similar, at least when using OLS – the results for Tobit estimation are not reported in this case, since with the additional control variables included the Tobit models exceeded computational limits. Finally, the regressions in Panel C show the results of estimating 'conventional' gravity models, which include the hitherto mentioned control variables as well as those listed in Table 1, but do not include

[28] In columns 1 and 2, the effect of time differences becomes positive for partners with combined rule of law index of 6.7 and 6.8 respectively – slightly below the 90th percentile of the distribution. In columns 3 and 4, the effect becomes positive for bilateral migrant populations of 9 and 13 log points respectively; the former is just below the 90th percentile, while the latter exceeds the 99th percentile.

separate fixed effects (by year) for each importer and exporter. In this case the results are more different, with the effect of time differences being roughly half as large in columns 1-3 and no longer statistically significant in columns 4-6. This indicates the importance of controlling for exporter-importer fixed effects, and that simply augmenting ‘conventional’ gravity models to include the time difference between trading partners may lead to biased estimates.

5 Time differences and communication

The results in Section 4 show that time differences have had a negative and statistically significant impact on trade, at least until recently. This is consistent with the hypothesis that time differences raise the cost of travel and communication, which in turn leads to less trade. In this section we provide more direct evidence in support of this hypothesis, by looking at the relationship between time differences and telephone traffic. Telephone traffic has been used as a proxy for communication flows in previous work, e.g. Loungani et al (2002), Portes and Rey (2005) and Fink et al (2005). This section tests the hypothesis that time differences reduce telephone traffic, using the same gravity model framework set out in Section 3 – simply replacing the dependent variable with a measure of bilateral telephone traffic.[29]

Data on telephone traffic is taken from the 1999 Direction of Traffic (DoT) database (ITU 1999), which reports bilateral telephone flows for 149 countries between 1993 and 1997. For each country in the database, outgoing and incoming traffic (in minutes) is reported for the top 20 partner countries, ranked in terms of combined outgoing and incoming traffic in 1997.[30] The DoT database is used here to create two separate samples. In the first, the dependent variable is outgoing telephone traffic from reporting country i to partner country j in year t. The potential number of observations is 14,900 – 20 observations for each reporting country and year – although the actual sample is smaller, mainly due to missing data for one or more

[29] Note that time differences may reduce telephone traffic either by reducing the amount of time in the day in which telephone conversations can take place, or by making actual physical travel more difficult, which in turn reduces telephone traffic on the grounds that travel and communication are complements rather than substitutes. For evidence of such complementarity see Gaspar and Glaeser (1998); for evidence that time differences affect business travel, see Anderson (2007).

[30] The data include all traffic passing through international public switched telephone circuits (including that generated by mobile telephones, as well as fixed-line traffic), although in some (unspecified) cases only fixed-line telephone traffic (ibid: 183).

explanatory variables.[31] In the second sample, the dependent variable is bilateral telephone traffic (outgoing plus incoming) between reporting country *i* and partner country *j* in 1997. In this case, the potential number of non-censored observations is 2,980: 20 observations per reporting country. In addition, there are a further 203 censored observations for each reporting country, where the amount of bilateral traffic is known to be no greater than that with the partner country ranked in 20th place.[32] The total potential number of observations, including censored and non-censored observations, is therefore 22,201, although once again the actual sample is smaller due to missing data.[33]

For control variables, the same set of variables included in Tables 1-4 are used, with two additions. The first is the bilateral migrant population (see Section 3). Strictly speaking, this measure is not directly compatible with the DoT data, since it refers in

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[31] In addition, there are 558 cases where outgoing traffic is not reported for a particular year or destination; a further five observations are lost by reclassifying flows from the Philippines to Hawaii (reported separately by the DoT) among the figures for the United States. Allowing for these adjustments, there are 14,337 potential observations in the first sample.

[32] This assumes 223 possible partners for each source country, which is the number of countries (minus 1) in the Head et al (2010) dataset (all 149 reporting countries are among this set of countries). The underlying assumption is that data for all 203 partners outside the top 20 are collected by and available to the ITU, they are simply not reported. This may not always be the case. For instance, Cuba may not be listed among the top 20 partners of the US, not because telephone traffic with Cuba is known to be below 20th place, but simply because data are missing. In this case, the observation should be dropped rather than censored at the level of the country in 20th place. In attempt to avoid this problem, 40 reporting countries in the DoT database which do not report a full set of data (i.e., estimates of outgoing and incoming traffic for all top 20 partner countries) are excluded from the sample.

[33] The 149 reporting countries in the DoT database yield 11,026 potential observations of bilateral telephone ([149*148]/2). There are a further 11,175 potential observations (149*75) representing bilateral traffic between one of the 149 reporting countries and one of the 75 non-reporting countries. Note that sometimes there are two (non-censored) estimates of bilateral traffic: for example, if two reporting countries are among the top 20 partners of each other (e.g. the US and UK). In these cases, the average of the two figures is taken (usually they are very similar). If only one country is among the top 20 partners of each other (e.g. the US and Aruba), there is only one non-censored value, which is always used. If two reporting countries are not among the top 20 partners of each other (e.g. Aruba and Luxembourg), there are two censored values, the lower of which is used.

most cases to the year 2000. An argument for its inclusion can be made however, on the grounds that migrant stocks typically change only gradually over time. The second is the price of a bilateral phone-call measured in US dollars per minute (un-weighted average of peak and off-peak rates), at official/market exchange rates, taken from the DoT database. This is included when using the first sample, but not when using the second since the DoT provides price data for each country's top 20 partner countries only. In addition, the price data in the DOT database are not available for 1993 and 1994, so these years are omitted from the first sample.

The results are shown in Table 5. Column 1 shows the results for the first sample, when the estimation method is OLS (since there are no observations with zero traffic in this sample), while column 2 shows the results for the second sample, when estimation is by censored regression. The impact of time differences is negative and statistically significant at the 0.1% level in both cases, with each hour of time difference reducing telephone traffic by 0.05 and 0.08 log points respectively, or 5 and 7 per cent. The lower panel of Table 5 shows the results when adding a quadratic term in time differences. As for trade, there is some evidence of a non-linear relationship, with the positive and statistically significant coefficient for the squared time difference in column 1 indicating a diminishing negative impact of time differences on telephone traffic, which reaches its maximum at around 12 hours. However, this result is not robust, in that the coefficient on the squared time difference in column 2 is not statistically significant.

The remaining coefficients in Table 5 are on the whole signed according to expectation. The coefficient for the price of a phone-call (column 1) is negative as expected and statistically significant at the 0.1% level; the implied price elasticity is 0.57. The bilateral migrant population has a positive and statistically significant impact on traffic for both samples, also as expected, with elasticities of 0.27 and 0.41 respectively. The distance measures both have a negative impact on telephone traffic, but the effect of cargo distance is much smaller in absolute size than that of great-circle distance, and statistically insignificant in for the first sample (column 1). In addition, the coefficients for both distance measures are smaller for the first rather than second sample regressions. This is partly attributable to the fact that the former controls for the cost of a phone-call, which is positively correlated with both the great-circle and cargo distance measures (r=0.54 and 0.48 respectively).[34]

[34] This is confirmed by replicating the first sample regression with the price of a phone-call excluded from the model, which generates a coefficient for the great-circle distance measure which is closer to that shown in column 2, although still somewhat smaller in absolute terms (details available on request).

6 Conclusion

Recently, international economists have begun to investigate the possible impact of time differences on international trade, to complement the very large literature on the effects of geographical distance on trade. However, the two studies carried out to date have yielded conflicting results. On the one hand, Stein and Daude (2007) find that time differences have a negative and statistically significant impact on overall trade, with each hour of time difference reducing trade by between 7 and 11 per cent. On the other hand, Head et al (2009) find that time differences have a positive and statistically significant impact on trade in goods, and no significant impact on trade in financial, computing and communication services. Although not directly comparable, the two sets of results do not sit easily together, given the large share of goods trade in overall trade.

The aim of this paper is to shed further light on this issue. It uses the same gravity model framework used by Stein and Daude (2007) and Head et al (2009), but extends the analysis in three main ways. First, the models estimated control for variables not included by Stein and Daude (2007) and Head et al (2009) but which might nonetheless bias the estimated impact of time differences on trade. Second, the samples analysed cover a wider time-period, which makes it possible to determine whether the impact of time differences has changed in recent decades. Finally, the paper tests a series of additional hypotheses: that the negative effect of time differences on trade (via higher travel and communication costs) is smaller where formal mechanisms of contract enforcement in each trading partner are stronger, or where co-ethnic networks among and between trading partners are more prevalent; and that time differences reduce international communication as well as trade.

This paper finds that, for a range of samples and estimation methods, time differences do have a negative and statistically significant impact on overall bilateral trade, at least until recently. For pooled samples across years, each hour of time difference is found to reduce trade by between 3 and 7 per cent – somewhat smaller than the range of 7 to 11 per cent reported by Stein and Daude (2007), but economically significant nonetheless. There is also evidence that the negative impact of time differences is smaller where mechanisms of formal contract enforcement, as proxied by the Kaufman et al (2009) rule of law index, and co-ethnic networks, as proxied by the size of the bilateral migrant population, are more prevalent, and that time differences reduce international telephone traffic as well as trade. There is however evidence that the negative impact of time differences has fallen during recent decades, such that for the most recent years of data, the effect is no longer statistically significant for all estimation methods.

Like Stein and Daude (2007), the focus in this paper is overall trade. One obvious extension is therefore to consider the impact of time differences on trade in different types of goods, following Head et al (2009). Distinguishing different types of trade is of interest since the effects of time differences may vary. In particular, the trade-enhancing potential of time differences should apply only to trade in services, and so one might expect to find that time differences have a more negative impact on trade in goods than on overall trade. As already noted however, Head et al (2009) find that time differences have a positive impact on trade in goods, which is contrary to expectation and lacks an obvious explanation. Further research distinguishing between different types of trade may help to clarify this apparent puzzle.

Another issue for further research is whether official and solar time differences have different impacts on trade. No attempt is made in this paper to separate out the impacts of these two variables, since they are very highly correlated. One might expect official time differences to matter more, on the grounds that people organise their work-day to fit the official time in their location: for example, starting at 9am and ending at 5pm. However, if official times differ significantly from solar times, there is evidence that people tend to follow unofficial solar time instead, which suggests that solar time differences also matter.[35] This issue is not only of academic interest, it is also of relevance for policy. In Russia for example, plans were announced in 2009 to reduce the number of official time zones in the country from 11 to four, in the interests of economic efficiency (Cookson 2009).[36] This would reduce official time differences in the country, but will not affect solar time differences. Thus if it is the latter which primarily affect trade, the anticipated gains in economic efficiency may not be forthcoming. One way to investigate this issue further would be to look at communication and trade within countries that span large E-W distances, but in which governments remain averse to having multiple official time zones (e.g. China). There is therefore potential for further research on an issue which is not only of academic interest but also of relevance for policy.

[35] For example, in 1949 Mao Zedong replaced China's five time zones with one time zone, based on solar time in Beijing (Cookson 2009). Official time differences within the country were therefore eradicated. However, certain parts of the country – e.g. Xinjiang, roughly 2,000km east of Beijing – continue to remain on unofficial local time; at the region's airports, announcements are needed to remind travellers that scheduled times are official times, not local times (ibid).

[36] By 2011, the number of time zones in Russia had been reduced to nine.

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Table 1. Time differences and trade: pooled results across years

	1	**2**	**3**	**4**	**5**	**6**
Estimation method	OLS	Tobit	OLS	Tobit	OLS	Tobit
Sample	(1)	(1)	(2)	(2)	(3)	(3)
Time difference	-0.068	-0.053	-0.063	-0.043	-0.045	-0.030
	0.006	0.004	0.007	0.004	0.007	0.004
Distance (great- circle)	-0.535	-0.550	-0.703	-0.667	-0.900	-0.779
	0.040	0.025	0.043	0.026	0.042	0.027
Distance (cargo)	-0.430	-0.255	-0.334	-0.164	-0.251	-0.157
	0.031	0.020	0.034	0.021	0.034	0.021
N-S distance	0.084	0.075	0.077	0.050	0.097	0.048
	0.019	0.011	0.020	0.011	0.019	0.011
Difference in latitude	(0.008)	(-0.017)	(-0.023)	-0.040	(-0.027)	-0.038
	0.016	0.009	0.017	0.009	0.017	0.009
Common language	0.717	0.561	0.798	0.547	0.839	0.654
	0.054	0.033	0.055	0.034	0.055	0.034
Common border	0.359	0.338	0.401	0.301	0.460	0.367
	0.065	0.040	0.070	0.042	0.073	0.044
Common currency	0.688	0.509	0.755	0.593	0.714	0.532
	0.071	0.044	0.085	0.051	0.090	0.054
Common legal origin	0.140	0.113	0.169	0.114	0.130	0.099
	0.024	0.015	0.025	0.015	0.024	0.015
Common coloniser	0.633	0.592	0.490	0.515	0.573	0.524
	0.048	0.026	0.047	0.025	0.046	0.026
Political union	0.959	0.724	1.034	0.663	0.965	0.740
	0.132	0.103	0.214	0.136	0.239	0.152
Colonial history	1.020	0.897	1.085	0.901	1.058	0.863
	0.053	0.044	0.057	0.047	0.054	0.049
Common trade	0.505	0.453	0.525	0.490	0.394	0.370
agreement	0.054	0.036	0.050	0.034	0.047	0.032
N	31,733	55,916	31,286	49,276	34,065	50,784
R^2	0.75	0.44	0.75	0.42	0.75	0.40
Time difference	-0.101	-0.080	-0.070	-0.052	*-0.047*	-0.031
	0.014	0.009	0.015	0.009	0.014	0.009
Time difference	*0.003*	0.002	(0.001)	(0.001)	(0.0002)	(0.0001)
squared	0.001	0.001	0.001	0.001	0.001	0.001

Notes: The samples used for analysis are 1950-1995 (1), 1970-2000 (2) and 1975-2005 (3), in each case with data at 15-year intervals. The dependent variable in each case is the natural logarithm of exports from country *i* to country *j*; for Tobit estimation, one is added to observations of zero trade to avoid taking logarithms of zero; for OLS estimation, observations of zero trade are excluded from the sample. All regressions include separate fixed effects for each exporter and importer for each year. All coefficients are significant at the 0.1% level except where otherwise indicated, either by italics (significant at the 1% level) or in parentheses (not significant at the 1% level).

Table 2. Time differences and trade: results by year

Estimation method	OLS			Tobit		
Year	N	b	s.e.	N	b	s.e.
1950	3,111	-0.063	0.017	9,314	-0.071	0.009
1955	3,864	-0.067	0.015	10,179	-0.063	.
1960	4,921	-0.059	0.013	11,649	-0.053	.
1965	6,177	-0.073	0.011	13,353	-0.058	0.007
1970	8,017	-0.082	0.012	14,723	-0.05	0.006
1975	9,181	-0.072	0.012	14,940	-0.051	0.007
1980	9,831	-0.093	0.012	14,780	-0.063	0.008
1985	10,039	-0.078	0.012	16,158	-0.05	0.007
1990	11,448	*-0.033*	0.011	17,443	-0.026	0.007
1995	12,614	*-0.028*	0.010	18,469	-0.021	0.006
2000	13,230	(-0.021)	0.010	18,395	-0.021	0.007
2005	13,436	(-0.021)	0.011	18,401	(-0.008)	0.007

Notes: All regressions include separate fixed effects for each exporter and importer, and the same set of control variables shown in Table 1. All coefficients are significant at the 0.1% level except where otherwise indicated, either by italics (significant at the 1% level) or in parentheses (not significant at the 1% level). The standard errors for the Tobit estimates in 1955 and 1960 are not reported by STATA.

Table 3. Time differences and trade: interaction effects

Estimation method	**1** OLS	**2** Tobit	**3** OLS	**4** Tobit
Time difference	-0.253	-0.167	-0.073	-0.052
	0.015	0.009	0.015	0.009
Time difference * rule of law index	0.037	0.025	-	-
	0.002	0.001		
Time difference* bilateral migrant population	-	-	0.008	0.004
			0.002	0.001
N	37,551	51,156	13,022	17,766
R^2	0.78	0.41	0.78	0.42

Notes: As Table 1. The regressions also include the rule of law index for each trading partner (columns 1 and 2) and the bilateral migrant population (columns 3 and 4) as separate explanatory variables. The 1996-2004 sample includes data at 4-year intervals only. All coefficients are significant at the 0.1% level.

Table 4. Time differences and trade: additional results

	1	2	3	4	5	6
Estimation method	OLS	Tobit	OLS	Tobit	OLS	Tobit
Sample	(1)	(1)	(2)	(2)	(3)	(3)
Panel A: official time differences						
Time difference	-0.071	-0.060	-0.066	-0.053	-0.050	-0.040
	0.006	0.004	0.006	0.004	0.006	0.004
R^2	0.75	0.44	0.75	0.42	0.75	0.40
N	31,733	55,916	31,286	49,276	34,065	50,784
Panel B: additional control variables (including fixed effects)						
Time difference	-0.072	.	-0.065	.	-0.047	.
	0.007	.	0.007	.	0.007	.
R^2	0.75	.	0.76	.	0.76	.
N	28,834	.	30,131	.	32,291	.
Panel C: conventional gravity model (no fixed effects)						
Time difference	-0.038	-0.021	-0.026	(-0.008)	(-0.001)	(0.009)
	0.007	0.004	0.007	0.004	0.007	0.005
R^2	0.66	0.33	0.67	0.32	0.67	0.32
N	28,834	45,119	30,131	45,876	32,291	46,707

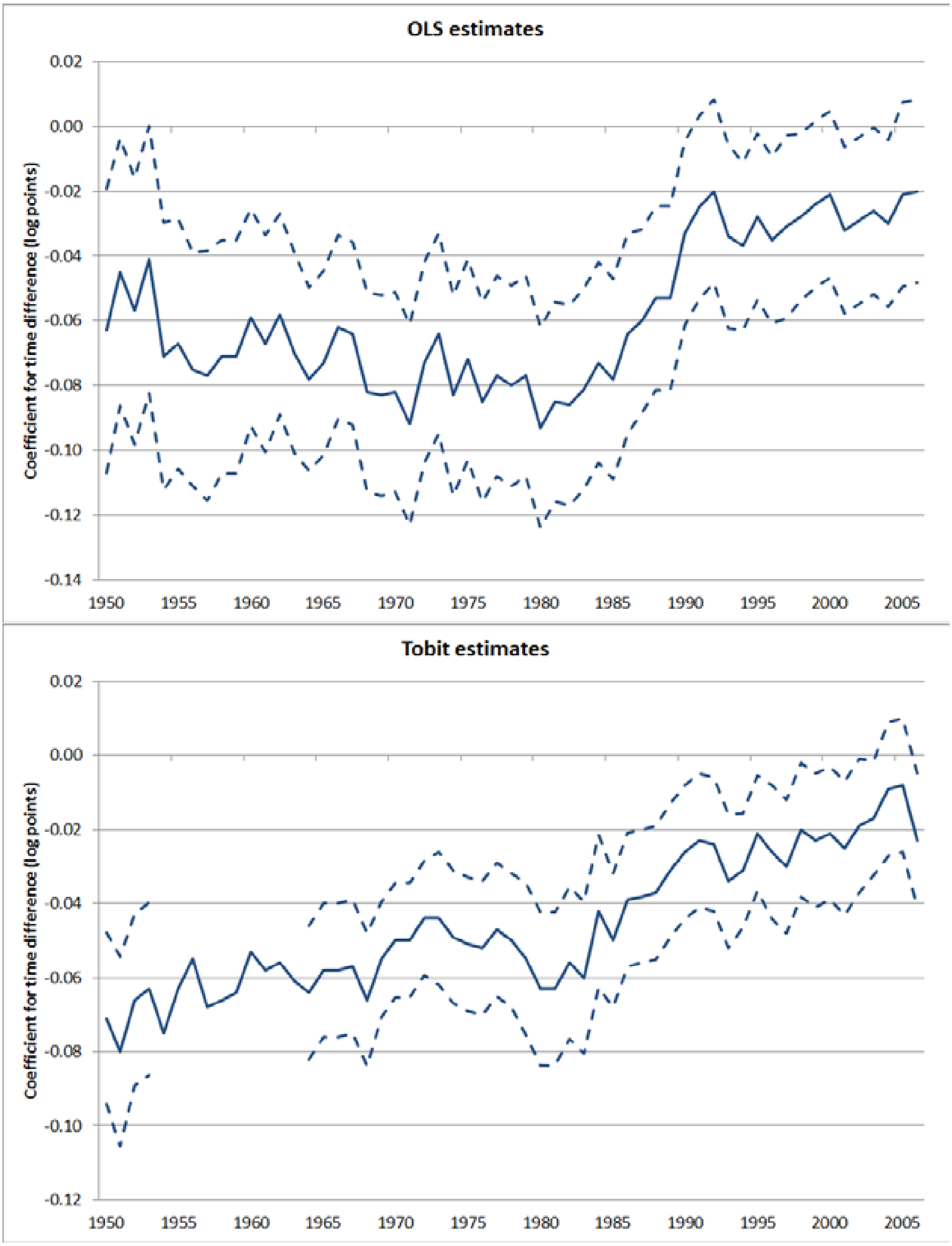
Notes: As Table 1. All regressions include separate fixed effects for each exporter and importer for each year, except in the regressions in Panel C which include year dummies only. The additional control variables included in the Panel B regressions are population, GDP per capita, land area, and dummy variables for landlocked countries, island countries, and members of GATT (in each case for both importer and exporter countries); these variables are also included in the Panel C regressions. STATA is unable to estimate the Tobit version of the fixed effects gravity model with additional control variables.

Table 5. Time differences and international telephone traffic

Method	1 OLS	2 Censored regression
Time difference	-0.053	-0.075
	0.007	0.013
Distance (great-circle)	-0.407	-0.731
	0.041	0.076
Distance (cargo)	(-0.010)	*-0.137*
	0.024	0.051
N-S distance	(-0.028)	(-0.034)
	0.020	0.040
Difference in latitude	0.069	(0.093)
	0.019	0.037
Phone tariff	-0.565	.
	0.046	
Bilateral migrant population	0.274	0.409
	0.009	0.013
Common border	(0.049)	(-0.231)
	0.040	0.091
Common language	0.424	1.000
	0.058	0.098
Common currency	0.553	1.064
	0.127	0.195
Common legal origin	0.190	0.157
	0.024	0.045
Common coloniser	*0.146*	0.375
	0.055	0.086
Political union	(0.714)	(-0.458)
	0.363	0.446
Colonial history	0.629	0.407
	0.053	0.010
Common trade agreement	0.143	0.324
	0.038	0.074
N	5,275	8,214
R^2	0.95	0.69
Time difference	-0.101	-0.137
	0.018	0.031
Time difference squared	*0.004*	(0.005)
	0.001	0.002

Notes: Each regression includes separate fixed effects for each exporter and importer (and for each year in column 1). All coefficients are significant at the 0.1% level except where otherwise indicated, either by italics (significant at the 1% level) or in parentheses (not significant at the 1% level).

Figure 1. Time differences and trade: results by year



Notes: All regressions include separate fixed effects for each exporter and importer, and the same set of control variables shown in Table 1. The solid line shows the point estimate; the dashed lines show the upper and lower limits of the 99% confidence interval. The standard errors for the Tobit estimates between 1954 and 1963 are not reported by STATA.

Data Appendix

For data on bilateral trade, this paper uses the publicly available dataset assembled by Head et al (2010), which reports bilateral trade (exports and imports reported separately) between 208 countries over the period 1948-2006. This dataset is available at http://www.cepii.fr/anglaisgraph/bdd/gravity.htm. Data for all other explanatory variables are taken from the Head et al (2010) dataset, except the following.

The data on latitude and longitude of the most populous city in each country, used to calculate differences in latitude, N-S distances, great-circle and cargo distances, are from www.travelmath.com. The times of solar noon in each principal city are taken from http://www.timeanddate.com. The most populous cities in each country are from the CIA World Factbook; the nearest major port to the most populous city is calculated using data and satellite imagery available at www.worldportsource.com. Data on sea distances between major ports were kindly provided by John Howe at AtoBviaC Plc (www.a2bviaconline.com).

Institutional quality is measured by the rule of law index calculated by Kaufmann et al (2009), which is available for the period 1996-2008. To facilitate interpretation of results we rescale the index (by adding 2.6 to each value) so that all values are positive.

Co-ethnic networks are measured by the bilateral migrant population of each country pair: i.e., the sum of persons from country i living in country j and persons from country j living in country i. This is taken from Parsons et al (2007) and refers to the year 2000 (or closest available estimate).

For common language, the 'direct communication' measure provided by Melitz (2008) is used, given by:

$$M_{ij} = \sum_k p_{ik} p_{jk}$$

where p_{ik} and p_{jk} are the shares of population in countries *i* and *j* speaking language *k*, with 29 major world languages being included in the calculation. This language measure is designed to capture the ability for two people based in two different countries to communicate directly with one another, in the same language. Melitz (2008) shows that it has a much larger positive impact on trade than previous language measures used in the literature, such as that used by Frankel and Rose (2002).