Historical trade integration:
Globalization and the distance puzzle in the long 20^{th} century*

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Abstract

This paper studies the structure and the evolution of worldwide trade integration from 1880 up to 1995. Starting from historical trade and GDP data we use a state-space model to construct a bilateral historical trade index. This index is subsequently used to study globalization and the distance puzzle. The increased coverage of this index allows us to expand the period of analysis to include both the first and second globalization waves. We find that the first wave was marked by a strong diversification in the formation of trade links as well as a strong decrease in the effect of distance. The second globalization wave was marked by an initial strong decrease in the importance of distance which leveled out in the 1960s.

Key words: Trade integration, Globalization, Distance puzzle, State-space
JEL: F15, C4, F14

1 Introduction

Over the past century, globalization and the increase in international trade in goods and services has dramatically altered living conditions around the world for billions of people. Understanding the intricacies of the changes in the worldwide trade pattern is therefore of key importance. From as early as the 1980s, authors have visualized international trade using the instruments of network science. By representing countries as nodes and capturing their trade relations by drawing a link (or edge) between a pair of nodes, disaggregated trade data can be amalgamated into a complete overview of the worldwide trade network.

Initially, trade relations were modeled in a binary way (e.g. Serrano and Boguñá, 2003), but this was soon supplanted by a more realistic weighted and directed approach where the actual flows of import and/or exports were used as edge weights (e.g. Duernecker, Meyer, and Vega-Redondo, 2012). To grasp the fact that the importance of a trade flow for a country is proportional to its size, some authors have normalized the trade flows using the country's GDP

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(e.g. Fagiolo, Reyes, and Schiavo, 2008). The network approach has been used to express the openness of countries, to check whether there are clusters of closely integrated countries and to uncover the core-periphery structure proposed by world system analysis.

In spite of their success, the aforementioned methods have one major limitation: their high demands in terms of data availability. Constructing a proportionally weighted network requires data on imports and exports for each country-pair as well as the GDP of each country. This data is readily available from the 1950s onwards, which is why most studies are limited to this period. However, before the 1950s the high percentage of missing data restricts the use of these techniques. This means that the first globalization wave that took place at the end of the 19^{th} is left out entirely.

This paper proposes using a state-space model to combine several indicators of the level of trade integration into one overall index: the Historical Trade Index (*hti*). Because of the way it handles missing observations, the state-space model uses differences in availability in an offsetting rather than a reductive way. In other words, differences in availability can compensate for each other instead of reducing the dataset to instances when all data is available. Gaps in one measure can be imputed automatically using information in the others without imposing strict assumptions or ad hoc manipulations to the data. This allows us to double data availability in the period 1880-1914 and extend the analysis to the period 1880 to 1995, covering the first and second globalization waves.

The index of trade integration is subsequently used to take a look at relative globalization over this extended time period -as opposed to using trade flows to study absolute globalization. We first construct the trade integration network using the *hti* values as edge weights. An added advantage of the index is that we can use its distribution to statistically identify the edges, i.e. to separate country-couples that are integrated from those that are not. In this way, we avoid the problem of very small but positive trade flows between countries which would otherwise necessitate choosing an arbitrary cut-off value.

The historical trade network shows evidence of a strong diversification of international trade during the first globalization wave. When controlling for the increase in the number of countries, the network density increases sharply between 1880 and 1914. After restoring to its pre-World War One levels, the density increases slightly during the second globalization wave (which started after the Second World War).

Finally, we look at globalization within the concept of geographic neutrality which states that as trade becomes more globalized, distance becomes less important in determining trade patterns. Prevalent throughout this literature is the *distance puzzle*, the unexpected increase in the importance of distance from the 1960s onwards. Using the extended coverage of the *hti*, we can reframe this discussion in a broader historical perspective. While we still find an increase in the importance of distance from the 1960s onwards, we show that this is dwarfed by the sharp decrease during the first globalization wave. These results confirm the hypothesis of O'Rourke (2009), who stated that the first globalization wave was driven by an overall decrease in trade costs, while the second wave was induced by geopolitical factors centered on Western Europe and North America.

In the next section we introduce and validate the historical trade index and show how to construct the trade network. In the second part we see how our new technique can be used to study globalization, focussing on the network density and the distance puzzle. Section 4 concludes. The index is made available at `http://www.sherppa.ugent.be/hti/hti.html`.

2 Measuring historical trade integration

The definition of historical trade integration used in this paper is based on that of Actual Economic Integration by Mongelli, Dorrucci, and Agur (2005, p.6): *"the degree of interpenetration of economic activity among two or more countries [...] as measured at a given point in time."* The main difference is that because of data limitations, the historical trade index only focusses on traded goods.

Throughout this section, the new index will be compared with other measures used in the literature. In decreasing order of availability, these are exports over total exports, exports over GDP of the sender country (e.g. Fagiolo et al., 2008) and the sum of exports and imports over GDP of the sender country (e.g. Arribas, Pérez, and Tortosa-Ausina, 2011).

2.1 Sources

To measure the level of trade integration between countries we construct four measures that indicate the importance of the bilateral trade flows for the sender country. In order to correct for differences in scale the trade flows are normalized, since for example the importance of a million dollars worth of imports will be starkly different in the case of Latvia as opposed to the United States. Defining $X_{ij,t}$ as the total exports from the sender i to target country j in year t and $M_{ij,t}$ as the total imports from target j to sender i in year t, these measures are:

$$y_{ij,t} \equiv \{\frac{X_{ij,t}}{\sum_j X_{ij,t}}, \frac{M_{ij,t}}{\sum_j M_{ij,t}}, \frac{X_{ij,t}}{GDP_{i,t}}, \frac{M_{ij,t}}{GDP_{i,t}}\}.$$

Firstly, the level of trade integration is considered high when a significant fraction of total exports go to (or imports come from) a single partner country. This normalization has the advantage that it can be computed using only trade data, but has the weakness that it does not take the overall openness to trade into account. For this reason, the last two indicators normalize import and export flows using the GDP of the sender country. However, because of the additional need for GDP data, the availability of the latter indicators is significantly lower.

To the extent that all four indicators give a similar signal the resulting index will have small confidence intervals.[1] However, when these indicators start to diverge the standard deviation will enlarge, reflecting the underlying uncertainty of the indicators. For example, in the early sixties Russia imported between one and two million dollars from Pakistan, but exported nothing. Using only exports or imports would give a very skewed view of trade relations and using the sum of both misrepresents the ambiguity of the data. Instead, exports and imports are included separately and the uncertainty of the index is used in subsequent analyses.

This data is collected for 196 countries from 1880 up to 1995, giving us a total of 944,930 observations. Because almost all trade data is missing during the World Wars, these periods were left out. It should be noted that because a lot of countries (politically speaking) did not exist at the beginning of the dataset, the total possible number of observations for this period is only 1,210,480. This is far less than the more than four million suggested by the total number of countries[2] and means that less than a quarter (in stead of four fifths) of the data is missing.

The historical import and export data comes from the Correlates of War database (Barbieri, Keshk, and Pollins, 2009; Barbieri and Keshk, 2012), and historical GDP data comes from the Maddison project (Bolt and van Zanden, 2013) supplemented by data from Barro and Ursua (2008) and the Penn World Tables version 8.0. The trade data is measured in current US

[1] Since we will estimate this model using Bayesian techniques it would be more correct to use the term *highest posterior density intervals*, but for readabilitys sake, we will use *confidence interval* throughout this paper.

[2] n^o of countries $\times$ (n^o of countries -1) $\times$ n^o of years $= 196 \times 195 \times 111 \approx 4,000,000$.

dollars, whereas the GDPs are in per capita international Geary Khamis dollars (or constant 1990 US dollars). To put them on equal footing, we used population data from Mitchell (2003) and computed the GDP deflator for the United States using the Historical Accounts Database of the Groningen Growth and Development Center (Smits, Woltjer, and Ma, 2009).

A few issues should be pointed out with respect to the data used. Firstly, to be consistent with the trade data, the GDPs were also converted to US Dollars using exchange rates. However, the Balassa-Samuelson effect tells us that means that the GDPs of developing countries will be consistently underestimated, implying that their trade index values will be skewed upwards. Nevertheless, alternative measures to control for the size of the sender country, like population, are likely to bias the measures in other and more significant ways. Lacking an alternative, GDPs converted using exchange rates are used, but the results should be interpreted with the necessary caution. Secondly, the trade data we use can only capture the official trade flows between countries. If all trade between two countries passes through a third country (e.g. re-exportation) or is smuggled, this will not be captured using this dataset.

2.2 The state-space model

Following the methodology outlined in (Rayp and Standaert, forthcoming), the four indicators were combined into the historical trade index (*hti*) using the following state-space model:

$$\begin{aligned} y_{ij,t} &= C + Z * hti_{ij,t} + \epsilon_{ij,t} && (1) \\ hti_{ij,t} &= T * hti_{ij,t-1} + \nu_{ij,t} && (2) \\ \epsilon_{ij,t} &\sim N(0, H) && (3) \\ \nu_{ij,t} &\sim N(0, Q) && (4) \end{aligned}$$

The measurement equation (1) states that the four indicators $y_{ij,t}$ try to measure the level of trade between sender i and target country j at time t. Unlike for example a simple average the scaling parameters Z and C, the slope and intercept, can vary for each indicator of trade integration. Similarly, the variance of the error term ϵ can differ over all indicators, in contrast to a principle component analysis where this is kept constant. On the other hand, cross-correlation between the error terms of different indicators is ruled out: $E[\epsilon^{(k)}, \epsilon^{(m)}] = 0, \forall\, k \neq m$.

The state equation (2) allows for the trade index to depend on its previous values in the manner of an AR(1) model. This level of dependence is assumed to be the same for all country-couples. Allowing it to be different for each country couple adds more than 30,000 parameters to the model and slows the regression algorithm down to an infeasible degree. In addition, initial tests found that the time-dependency is the same for the vast majority of country couples: 94.4% of the time T_{ij} is not significantly different at the 1% level from T_{kl} with $ij \neq jl$.

By defining the state equation as an AR(1) process, we implicitly restrict T to the [-1,1] interval, including the boundary values. In other words, both stationary and non-stationary values of *hti* are allowed but explosive series are not.

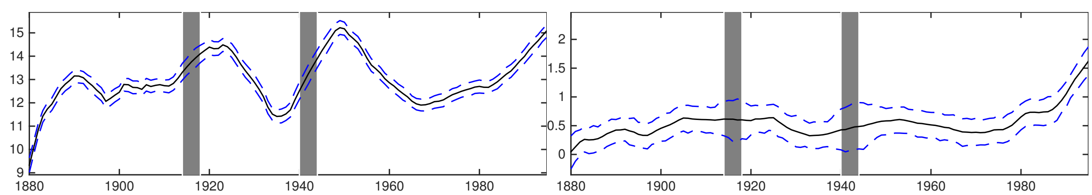
The issue of missing observations is solved by replacing them with information which is entirely uncertain and does not influence the resulting index: $y = 0$, $var(\epsilon) = \infty$. This allows the model to run uninterruptedly without fundamentally changing the nature of missing data. This, in combination with the time dependency, enables us to increase the number of countries and years for which the index can be calculated without having to impute or otherwise manipulate the data (Kim and Nelson, 1999; Durbin and Koopman, 2012).

This model is estimated using a Bayesian Gibbs sampler algorithm, mainly because of the convenience the Gibbs sampling algorithm provides. This algorithm allows us to split up the computation of a complex (posterior) probability into several much simpler conditional probabilities. For example, if the *hti* values were known, the state and measurement equations become very simple linear regressions models. A detailed description of the estimation procedure of this particular state-space model can be found in Kim and Nelson (1999, chapter 8).

The Gibbs sampler ran for 6000 iterations of which the first 4000 were discarded as burn-in.[3] The remaining were used to reconstruct the posterior distribution of the level of trade integration of each country-couple in each year. The resulting index is a continuous variable with values between -14 and 177. This level in itself has little meaning and can be rescaled as needed, but can be compared both over time and between different countries. A higher index value corresponds to a high level of trade.

2.3 The historical trade index

By way of illustration, figure 1 shows the standardized index values for USA-Mexican bilateral trade from the perspective Mexico (panel a) and the USA (panel b). It plots both the expected value of the index as well as its 95% confidence interval. It should be clear from this graph that the level of trade can differ significantly for each partner country. In addition, the increase in the width of the confidence interval in 1940-1950 shows the effect of a decrease in data availability on the index.



(a) Mexico-USA

(b) USA-Mexico

Figure 1: The normalized historical trade index.
The index was normalised such that the mean and standard deviation for all country-couples and years is respectively zero and one.

An important advantage of using the state-space model to compose the *hti* is its increased data availability. Overall coverage increases with 10% relative to exports over total exports and even with a third when compared to total trade flows over GDP. Moreover, the increase is highest when data availability is lowest. In the period before the first World War, the *hti* covers 31% of country couples, while the other indicators only cover between 14 and 21%. After 1950, these figures rise to 95% relative to 70% to 85%, respectively.

To ensure that the *hti* values conform to expectations, we regressed it on a number of economic and political variables that are expected to change the general level of trade (table 1). Following Head and Mayer (2013), sender-year and target-year fixed effects were included in columns 4 and 5 to counter the time-varying multilateral resistance terms in columns four and five. In order to estimate this many fixed effects, we used a strategy outlined in Guimarães and Portugal (2009) which was adapted to a Bayesian estimation framework (details in appendix). In addition, the standard errors reported also take into account the uncertainty of the *hti* (Standaert, 2014).

For completeness sake, columns one through three use different or no fixed effects. The last column uses the probability of their being a trade link (cf. infra) as a dependent variable in a

[3]The size of the dataset required the use of the resources of the Flemish Supercomputer Center, which was kindly provided by Ghent University, the Flemish Supercomputer Center (VSC), the Hercules Foundation and the Flemish Government − department EWI.

Table 1: Explaining historical trade integration

	(1) hti	(2) hti	(3) hti	(4) hti	(5) hti	(6) edge
log(Distance)	-0.028	-	-0.043	-0.044	-0.044	-0.635
	$(0.000)^a$		$(0.000)^a$	$(0.000)^a$	$(0.000)^a$	$(0.004)^a$
Contiguity	0.137	-	0.134	0.123	0.122	0.828
	$(0.002)^a$		$(0.001)^a$	$(0.002)^a$	$(0.002)^a$	$(0.015)^a$
log(GDP_i)	0.002	-0.002	-0.002	-	-	-0.0243
	$(0.000)^a$	$(0.001)^b$	$(0.001)^a$			$(0.002)^a$
log(GDP_j)	0.035	0.034	0.040	-	-	0.749
	$(0.000)^a$	$(0.001)^a$	$(0.000)^a$			$(0.003)^a$
Interbellum	-0.065	-0.020	-0.029	-	-	0.0229
	$(0.002)^a$	$(0.002)^a$	$(0.002)^a$			(0.0216)
EU	0.155	0.064	0.079	0.103	0.023	0.392
	$(0.003)^a$	$(0.002)^a$	$(0.003)^a$	$(0.003)^a$	$(0.008)^a$	$(0.0284)^a$
f_{10} EU	-	-	-	-	0.024	-
					$(0.005)^a$	
l_{10} EU	-	-	-	-	0.078	-
					$(0.006)^a$	
Cusfta/Nafta	0.668	0.113	0.536	0.578	0.056	0.622
	$(0.025)^a$	$(0.016)^a$	$(0.021)^a$	$(0.023)^a$	(0.035)	$(0.270)^b$
f_{10} Cusfta/Nafta	-	-	-	-	0.518	-
					$(0.028)^a$	
Availability	-0.249	-0.095	-0.124	-	-	-0.0659
	$(0.003)^a$	$(0.002)^a$	$(0.004)^a$			$(0.038)^c$
Year	-0.002	-0.001	-0.002	-	-	-0.0271
	$(0.000)^a$	$(0.000)^a$	$(0.000)^a$			$(0.0002)^a$
Constant	6.512	-	-	-	-	39.41
	$(0.034)^a$					$(0.381)^a$
Fixed Effects	none	sender-target	sender target	sender-year target-year	sender-year target-year	none
nObs	652912	652912	652912	944930	944930	652966

Linear (column 1) and fixed effects regression (columns 2-5) on the log of the historical trade index with standard errors (in parentheses) are corrected for the uncertainty of the hti. Column 6 shows the results of a probit regression on the edge variable. ^{a}, ^{b} and ^{c} indicate significance at the 1%, 5% and 10% level.

probit regression. However, the results are very similar over all different estimation procedures.

The coefficients on the traditional gravity parameters have the expected sign but are much smaller than when using trade flows. An increase in the distance of 1% lowers the level of trade with 0.04%, which is similar to the effect of the GDP of the target country. A rise in the GDP of the home country lowers trade integration, which could be because larger countries tend to be more focussed on their internal markets.[4] Neighboring your trading partner (*contiguity*) increases trade with $100 \times (e^{0.123} - 1)\% \approx 15\%$.

Interestingly, both the EU (11%) and Cusfta/Nafta[5] (78%) significantly raised the level of trade between their partner countries. In the case of the EU, the agreement was closed between countries that were already more likely to be integrated (2%), but the agreement also successfully raised the level of trade in the short (2%) and most importantly long term (8%).[6] Cusfta/Nafta on the other hand was closed between countries that were already highly integrated (67%), but it still succeeded in further raising the level of trade (6%) during the first ten years.

[4]Since the index is already normalized for the size of the sender country, the GDP of the sender country should actually be left out of the gravity model regressions. However, except for an even stronger negative effect of the Interbellum, its inclusion did not affect the results in a significant way.

[5]The European Union, the Canada-United States Free trade agreement (1978) and the North American Free Trade Agreement(1994)

[6]f_{10} EU and l_{10} EU are, respectively, the 10 year leading and lagged variable of the EU membership dummy.

During he Interbellum the average level of trade decreased by about 3%, but the number of links between countries increased significantly. This might be indicative of significant changes in trade relations between countries brought on by World War I, leading to many new links being formed. At the same time, this period was marked by a de-globalization wave which lowered the average strength of those links. The negative coefficient on time, while statistically significant, is too small to have any economic significance.

Finally, we find confirmation of selection bias issues in the earliest values of the *hti*. The initial values of the *hti* (before 1948) are marked by many missing observations, most likely between countries that do not or barely trade with each other. If left uncorrected, this makes the world seem more integrated in the earliest years of our dataset. We find that as the coverage of the index[7] increases, the average index levels decrease, fitting this selection bias theory. This issue will resurface in later analyses, necessitating circumspection when interpreting results.

2.4 The historical trade network

In order to combine the historical trade indices into a network, the index values corresponding to countries that are integrated need to be separated from those corresponding to countries that are not. A natural way of making this distinction is to contrast countries that trade with each other ($X_{ij,t} > 0$) to those that do not ($X_{ij,t} = 0$). The problem is that this approach is skewed by a large number of very small non-zero trade flows. For example, almost two thirds of (available) export flows are greater than zero, but less than half of which is higher than 100,000 USD (which corresponds to setting the cut-off for the total trade flows to GDP at 0.0005%).

Rather than choosing an arbitrary cut-off value, the *hti* allows us to use significant differences to determine which countries are linked. To start, we identified a country-couple that did not, or barely trade with each other for as long as possible, with as few missing observations as possible. From 1880 to 1948, official imports and exports between Great Britain and Ecuador amounted to less than 0.2 percent of Great Britain's total flows; and from 1948 to 2000 there was no trade between Iraq and Honduras.[8] Labeling these observations as $hti_{0,t}$, define significant levels of trade in the following way: An edge exist from country i to country j if, and only if, its level of trade in year t is significantly higher than that of $hti_{0,t}$: $e_{ij,t} = 1 \iff hti_{0,t} < hti_{ij,t}$ in at least 99% of all iterations of the (converged) Gibbs sampler.

Table 2: Summary of the different edge definitions

	hti	X_{ij}	X_{ij}/X_i	$\frac{X_{ij}+M_{ij}}{GDP_i}$
Cut-off	$hti_{0,t}$	800,000	1.5%	0.004%
% edges	9.6	10.7	10.9	10.6
	Correlations			
X_{ij}	0.4030	1	-	-
X_{ij}/X_i	0.7341	0.4704	1	
$(X_{ij}+M_{ij})/GDP_i$	0.7352	0.4225	0.6821	1

Using the $hti_{0,t}$ definition, 92,612 edges were identified (9% of observations). The highest index value that was deemed insignificantly different from $hti_{0,t}$ was 29.17, while the lowest

[7] *availability* is the fraction of country couples in our dataset versus the total possible number in that year. The latter is computed using the number of countries in the world (n_t) from the Correlates of War database as: $n_t * (n_t - 1)$.

[8] For robustness sake, we also computed the edge using the index values of a fictional country couple that never traded with each other and the results were unchanged.

significant index value was 22.36. In contrast, if a simple cut-off was set halfway between these values (at 25.76), a third of the edges would no longer be identified. To get a similar fraction of edges the cut-off of total trade flows to GDP would have to be set at 0.04% and that of exports to total exports at 1.5%. As can be seen from the pairwise correlations in table 2, the edge identification using the *hti* lies somewhere in between those two: the correlation of *hti* with both indicators is around 0.73.

The *hti* and edge data were subsequently used to build the weighted, directed historical trade network in each year with the *hti* values serving as edge weights. Figure 2 shows the shape of this network over time. The higher the indegree (the sum of all incoming edges), the more central its position. The larger the pagerank (similar to the indegree, but it gives a higher weight to edges coming from countries that are themselves important), the bigger the size of the node. Finally, the higher the index value the darker the edge color.

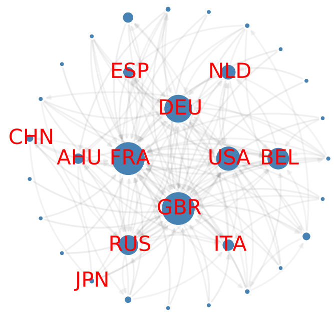
As figure 2 shows, the number of countries in the network increases notably over time. With a few exceptions, the indegree and pagerank come to a similar conclusion as to a country's importance in the network. Initially, France and Great Britain are the most central players, but over time the USA replaces them. After World War II, Germany starts to overtake both France and Great Britain rising to the second most central position. Also interesting is the slow rise of Japan throughout the late twentieth century. Other important countries according to their indegree and pagerank include Italy, the Netherlands and Belgium. The 1979 oil-crises also temporarily increases the position of Saudi Arabia to the top ten position. For more information, these and other yearly graphs are made available together with the indicator at `http://www.sherppa.ugent.be/hti/hti.html`.

3 Tracking globalization

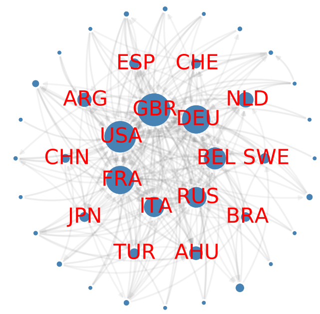
Since the 1980s, the term globalization has been used in several scientific disciplines, each using its own definition(s). In general, a common denominator to most definitions is the decreasing importance in economic transactions of the local market in favor of the global market. From this point of view three phases stand out in the period covered in our dataset: 1880-1914, 1918-1940 and 1945-1995.

As stated by O'Rourke (2009), the globalization phase preceding WWI was driven by decreasing trade costs brought on by political and technological improvements. With Great Britain in the lead, the mercantilist era was replaced by the idea of a more free trade regime. The European colonizers also imposed this new trading regime on their colonies and even forced independent countries to open up their trade. From a technological point of view, the use of steam engines and the installation of an extensive railway network lowered transaction costs, enabling a more internationally oriented trading pattern. At the same time, the gold standard offered a stable international trading climate (Crafts, 2004).

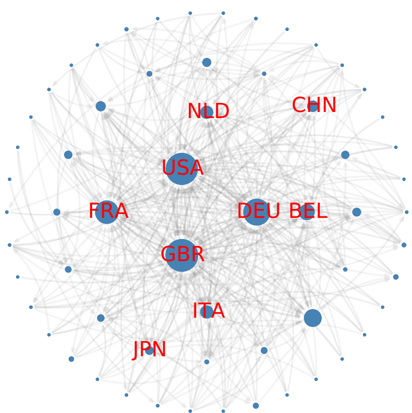
This liberalizing trend was undone by the first World War and the subsequent conference of Versailles which further sickened international relations. The situation was further exacerbated by the Great Depression and the protectionist policies it induced. At the time, the United States took over the leading role in the world economy but failed to further the free trade agenda and could not pull the world economy out of the recession. International relations were further deteriorated by the 1917 Russian revolution. World War II strengthened the anti-imperialist nationalist and communist states, the disintegrating effect of which lasting till the 1990s. As a result, the post-war efforts to improve international relations, with for example the GATTs and WTO, had a more regional character limited to Western Europe and North America. Intensification of trade relations took place in these regions, but did not extend to the rest of the world (O'Rourke, 2009; Irwin and O'Rourke, 2011).



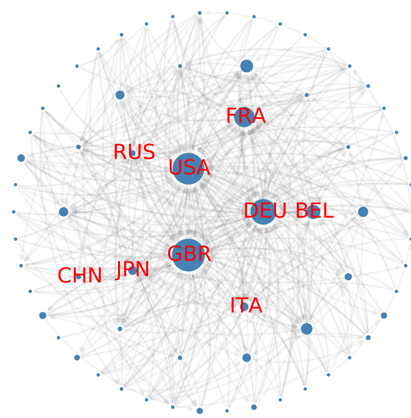
(a) 1880



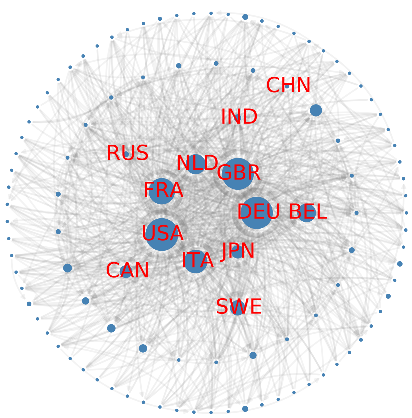
(b) 1900



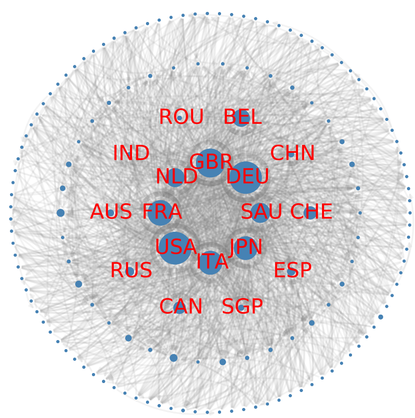
(c) 1920



(d) 1940



(e) 1960



(f) 1980

Figure 2: The historical trade network over time.
The higher the indegree of the node, the closer to the middle the node lies. The size of the nodes is determined by their pagerank. The higher the edgeweight is, the darker the edge.

The remainder of this paper tracks globalization through the trade network from 1880 to 1995. To do this, we narrow the focus down to two key elements that are often studied in the trade literature: diversification of trade links and geographic neutrality. The intensification of trade links is left out because the *hti* measures trade integration in a relative rather than absolute manner. As a result, a decease in the index value is not necessarily the result of a decrease in actual trade, but could also be caused by growing GDP or an increase in trade with a different trading partner.

3.1 The network density

To capture diversification of trade links we look at the density of the network: the number of existing links between countries divided by the total number of possible links. If globalization is accompanied with diversification, we expect the density to increase over time. Examples of studies that look at the network density are Kastelle, Steen, and Liesch (2006); De Benedictis and Tajoli (2011); Kali and Reyes (2007); Kim and Shin (2002) and Grinin, Ilyin, and Korotayev (2012).

Panel a of figure 3 shows the total network density gradually decreasing over time. Even though the number of edges keeps rising over time, it is completely offset by the increase in number of countries (panel b; based on the Correlates of War's state membership database). Especially in the 1960s it is clear the countries added are less well-connected than those already in the dataset: the number of nodes jumps while the number of edges remains unaffected, causing the density to drop sharply.

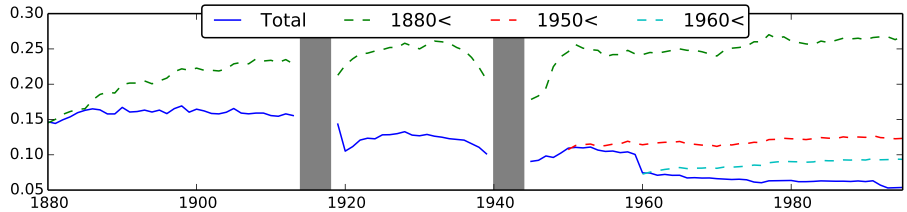
The decrease in density is unlikely to be driven by problems with data availability. Panel c shows that the availability is lowest before 1948 and rises almost continuously throughout the years. Conversely, if the drop in density had been caused by lack of available data, an increase in availability should have increased the density of the network. Instead, the change in network density seems to be driven by the addition of less well connected countries to the network.

The overall drop in density in combination with the negative coefficient on time in table 1 gives the impression that the HIN is becoming less connected over time, contrasting the literature on globalization. However, this decrease is entirely driven by the addition of new countries to the dataset. When we limit the dataset to countries that are continuously in the dataset since 1880, 1950 and 1960, the pattern changes drastically (panel a).[9] The biggest increase happens during the late 19^{th} century, which is temporarily undone during the Interbellum. After WWII the density keeps increasing steadily. In other words, once the density is corrected for the increasing number of countries, it conforms to the globalization pattern found in the literature.

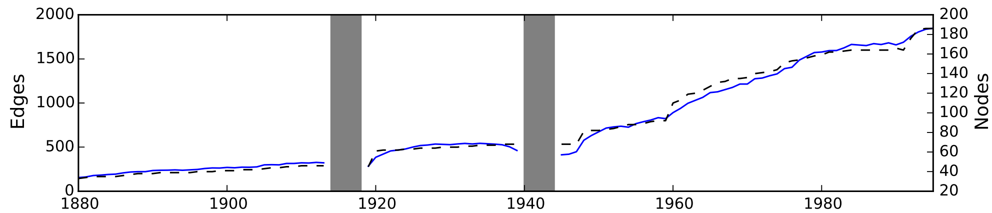
3.2 Geographic neutrality

Geographic neutrality states that the effect of distance on the trade patterns fades as the world becomes more globalized. The pinnacle of this process is the theoretical ideal of a geographically neutral trade pattern that is completely unaffected by distance. A striking observation in this literature is that distance seems to be getting more important in the second half of the 20^{th} century. The *distance puzzle* has been identified and discussed in a large number of articles, including Schiff and Carrere (2003); Brun, Carrère, Guillaumont, and De Melo (2005); Coe, Subramanian, and Tamirisa (2007); Disdier and Head (2008); Berthelon and Freund (2008); Jacks (2009); Siliverstovs and Schumacher (2009); Faqin (2009); Arribas et al. (2011); Boulhol and De Serres (2010); Lin and Sim (2012); Yotov (2012); Bosquet and Boulhol; Larch, Norbäck, Sirries, and Urban (2013); Yilmazkuday (2013) and Karpiarz, Fronczak, and Fronczak (2014).

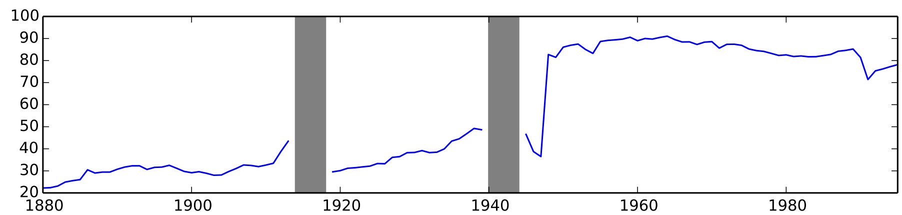
[9] The list of countries in each subset can be found in attachment B.



(a) Density



(b) Number of nodes and edges



(c) Availability (%)

Figure 3: Network density (panel a), number of nodes and edges (panel b) and the availability of the *hti* (panel c) over time.

In his study of the last quarter of the 19^{th} century, Flandreau (1995) found that declining transport costs had an important impact on the trade pattern. Moreover, based on estimations of transport costs, this decrease was much higher in the late 19^{th} than during the second globalization wave (Jacks, Meissner, and Novy, 2008, 2010, 2011). This suggests that when considered over a longer time period, the increasing importance of distance in the trade pattern should be limited to the second globalization wave.

To capture how the distance affects the level of trade we estimate a gravity equation with the distance variable split into 5 year blocks:

$$\log(hti_{ij,t}) = \sum_{\tau=0}^{n/5-1} \left[\alpha_\tau \log(\text{distance}_{ij}) \mathbb{1}_{\{5\tau<t\leq 5(\tau+1)\}}\right] + \beta X_{ij,t} + \mu_{i,t} + \mu_{j,t} + \epsilon_{ij,t} \qquad (5)$$

with $\mathbb{1}$ an indicator variable separating the (log of the) distance variable into five year blocks and α_τ the distance elasticity of the *hti* values. Similar to the regressions in columns four and five of table 1, the regression includes fixed effects to control for the time-varying multilateral resistance terms $\mu_{i,t}$ and $\mu_{j,t}$. Finally, $X_{ij,t}$ holds other control variables and $\epsilon_{ij,t}$ is a normally distributed error term. The estimations also take the uncertainty of the *hti* into account and are performed using the algorithm described in appendix.

Because of the inclusion of sender-year and target-year fixed effects, many of the control variables drop out of the model, most notably the GDP of sender and target. Whether or not the remaining control variables ($X_{ij,t}$) were included did not change the results. Estimating the distance effect in each year (as opposed to five-year blocks) increased the confidence intervals, but did not change the conclusion (available upon request).

Figure 4 plots the distance elasticity (α_τ) over time for different subsections of the data. At any time, an increase in the distance will lower the level of trade, explaining the negative coefficients. Overall, the effect of distance on the *hti* becomes smaller over time as the elasticity parameter moves closer to zero (panel a). There is a gradual decrease in the effect of distance during the first globalization wave. The decrease carries on through the interbellum, but gets reversed in the second half of the 1930s. The second wave starts with a sharp decrease immediately after World War II, which levels out in the 1960s.

Similar to the density computations, the regressions were repeated using only those countries that are continuously in the dataset since the 1880s, 1950s and 1960 (indicated with $<$). The biggest change of keeping the set of countries fixed is that this reveals the distance puzzle: in all three subset distance becomes more important from the 1960s onwards. However, the effect is small when compared to the drop in the distance elasticity before the Second World War.

These results indicate that the distance puzzle should be looked at from a broader historical point of view and fall in line with the mechanisms described in O'Rourke (2009) and Jacks et al. (2008, 2010, 2011). The increase in geographic neutrality during the first globalization wave can be explained by the political and technological developments significantly lowering trade costs. The second globalization wave on the other hand was less driven by changing trade costs, but instead by geopolitical determinants centered on Western Europe and North America. The limited effect on the rest of the world could explain why the decrease in the effect of distance tapers off after 1960.

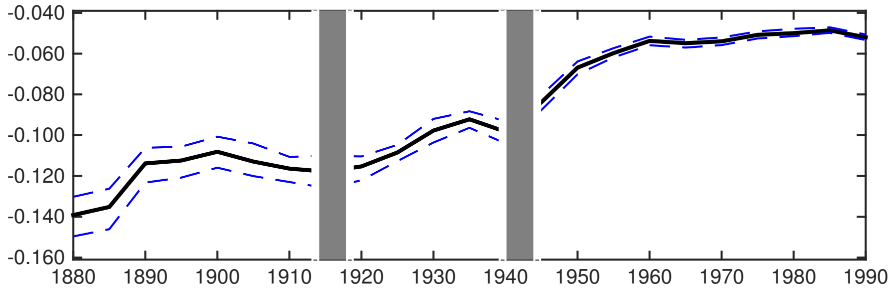
4 Conclusion

This paper uses historical trade and GDP data to construct a network tracking the level of trade integration from 1880-1995. We first summarize a number of indicators measuring the importance of bilateral trade into the historical trade index using a Bayesian state-space approach. This technique allows a more nuanced view of trade: taking into account both import and export flows and normalizing those using total flows as well as GDP. Using a state-space approach, as opposed to an average or a principle component analysis, we can more easily deal with missing information while making as few additional assumptions as possible.

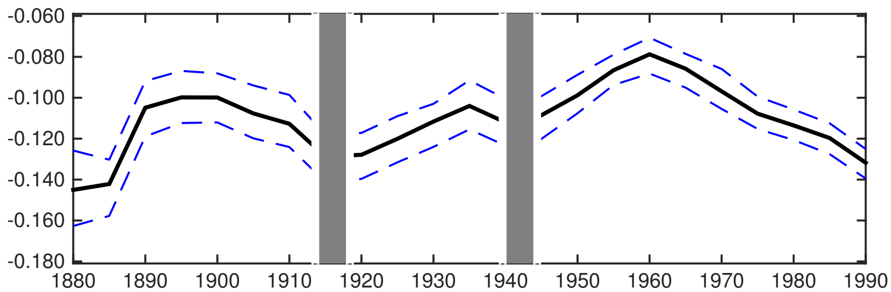
The *hti* behaves as expected when used as the dependent variable in a gravity model. Specifically, we find that the European Union and the North American Free Trade Agreement were both able to significantly increase the level of trade between their members. On average, EU members were already more likely to be integrated, but the agreement succeeded in raising the level of trade integration both in the short and most strongly in the long term. In the case of Nafta, there were strong self-selection effects indicating that the members were already trading intensively.

The index of the level of trade is subsequently used to construct the weighted, directed network. Instead of using an arbitrary cut-off value, the significance of differences between the index values is used to determine when two countries are integrated. This has the advantage over other indicators where the over abundance of very small non-zero trade flows makes it hard to unambiguously determine the edges.

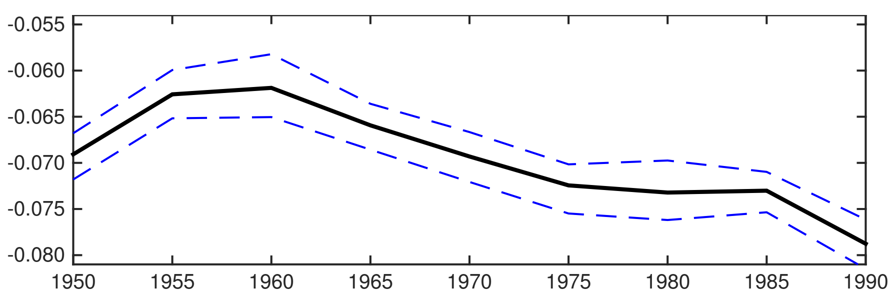
The increased coverage of the index allows us to shed light on globalization since the 1880s, including both globalization waves in our analysis. When the increase in the number of countries



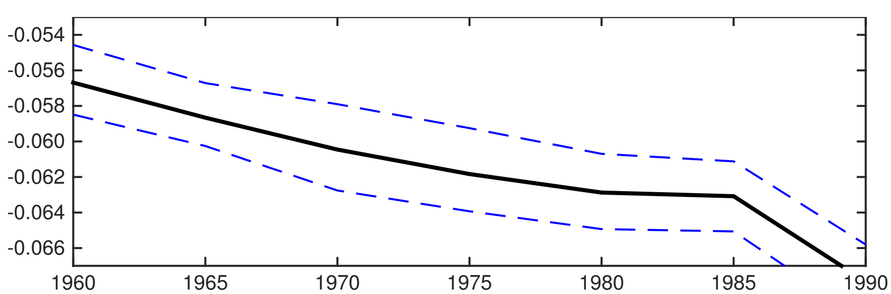
(a) Total



(b) 1880< subset



(c) 1950< subset



(d) 1960< subset

Figure 4: The distance elasticity of the historical trade index (α_τ) over time

is taken into account, the network displays a strong diversification (measured as an increase in density) of trade linkages. This increase is strongest during the first globalization period. After the Second World War the density quickly restores to its pre-World War One levels after which it keeps growing but only very slowly.

Finally, we used the index to take a renewed look at the distance puzzle. While we do find that from the sixties onwards the effect of distance on trade tends to increase, this is overshadowed by the strong decrease that precedes it during the first globalization wave. Similar to the density, the importance of distance decreases strongly after the Second World War whereafter it stabilizes or even increases slightly.

The index of historical trade integration, the edge variable and plots of the network over time are available for download at `http://www.sherppa.ugent.be/hti/hti.html`.

References

I. Arribas, F. Pérez, and E. Tortosa-Ausina. A new interpretation of the distance puzzle based on geographic neutrality. *Economic Geography*, 87(3):335–362, 2011.

K. Barbieri and O. Keshk. Correlates of war project trade data set codebook, verion 3.0, 2012. URL `http://correlatesofwar.org`.

K. Barbieri, O. Keshk, and B. Pollins. Trading data: Evaluating our assumptions and coding rules. *Conflict Management and Peace Science*, 26(4):471–491, 2009.

R. J. Barro and J. F. Ursua. Macroeconomic crises since 1870. *Brookings Papers on Economic Activity, Economic Studies Program, The Brookings Institution*, 39(1):225–350, 2008.

M. Berthelon and C. Freund. On the conservation of distance in international trade. *Journal of International Economics*, 75(2):310–320, 2008.

J. Bolt and J. van Zanden. The first update of the maddison project; re-estimating growth before 1820. *Maddison Project Working Paper 4*, 2013. URL `http://www.ggdc.net/maddison/maddison-project/data.htm`.

C. Bosquet and j. p. y. p. Boulhol, Hervé. What is really puzzling about the "distance puzzle".

H. Boulhol and A. De Serres. Have developed countries escaped the curse of distance? *Journal of Economic Geography*, 10(1):113–139, 2010.

J.-F. Brun, C. Carrère, P. Guillaumont, and J. De Melo. Has distance died? evidence from a panel gravity model. *The World Bank Economic Review*, 19(1):99–120, 2005.

D. T. Coe, A. Subramanian, and N. T. Tamirisa. The missing globalization puzzle: Evidence of the declining importance of distance. *IMF Staff Papers*, pages 34–58, 2007.

N. Crafts. Globalisation and economic growth: a historical perspective. *The World Economy*, 27(1):45–58, 2004.

L. De Benedictis and L. Tajoli. The world trade network. *The World Economy*, 34(8):1417–1454, 2011.

A.-C. Disdier and K. Head. The puzzling persistence of the distance effect on bilateral trade. *The Review of Economics and statistics*, 90(1):37–48, 2008.

G. Duernecker, M. Meyer, and F. Vega-Redondo. Being close to grow faster: A network-based empirical analysis of economic globalization. 2012.

J. Durbin and S. Koopman. *Time Series Analysis by State Space Methods.* Oxford University Press, 2 edition, 2012.

G. Fagiolo, J. Reyes, and S. Schiavo. On the topological properties of the world trade web: A weighted network analysis. *Physica A: Statistical Mechanics and its Applications*, 387(15): 3868–3873, 2008.

L. Faqin. Are distance effects really a puzzle. *Available at SSRN 1520864*, 2009.

M. Flandreau. Trade, finance, and currency blocs in nineteenth century europe: Was the latin monetary union a franc-zone? 1860-1880. *Historical Perspective on International Monetary Arrangements. New York: Macmillan*, 1995.

L. E. Grinin, I. V. Ilyin, and A. V. Korotayev. *Globalistics and Globalization Studies.* Uchitel Publishing House, 2012.

P. Guimarães and P. Portugal. A simple feasable alternative procedure to estimate models with high-dimensional fixed effects. *IZA Discussion paper*, 3935, 2009.

K. Head and T. Mayer. Gravity equations: Workhorse, toolkit, and cookbook. *Centre for Economic Policy Research*, 9322, 2013.

D. A. Irwin and K. H. O'Rourke. Coping with shocks and shifts: The multilateral trading system in historical perspective. Technical report, National Bureau of Economic Research, 2011.

D. S. Jacks. On the death of distance and borders: Evidence from the nineteenth century. *Economics Letters*, 105(3):230–233, 2009.

D. S. Jacks, C. M. Meissner, and D. Novy. Trade costs, 1870-2000. *The American Economic Review*, pages 529–534, 2008.

D. S. Jacks, C. M. Meissner, and D. Novy. Trade costs in the first wave of globalization. *Explorations in Economic History*, 47(2):127–141, 2010.

D. S. Jacks, C. M. Meissner, and D. Novy. Trade booms, trade busts, and trade costs. *Journal of International Economics*, 83(2):185–201, 2011.

R. Kali and J. Reyes. The architecture of globalization: a network approach to international economic integration. *Journal of International Business Studies*, 38(4):595–620, 2007.

M. Karpiarz, P. Fronczak, and A. Fronczak. International trade network: fractal properties and globalization puzzle. *arXiv preprint arXiv:1409.5963*, 2014.

T. Kastelle, J. Steen, and P. Liesch. Measurig globalisation: an evolutionary economic approach to tracking the evolution of international trade. In *DRUID Summer Conference on Knowledge, Innovation and Competitiveness: Dynamycs of Firms, Networks, Regions and Institutions-Copenhagen, Denemark, June*, pages 18–20, 2006.

C.-J. Kim and C. R. Nelson. *State-Space Models with Regime Switching: Classical and Gibbs-Sampling Approaches with Applications.* MIT Press, 1999.

S. Kim and E.-H. Shin. A longitudinal analysis of globalization and regionalization in international trade: A social network approach. *Social Forces*, 81(2):445–468, 2002.

M. Larch, P.-J. Norbäck, S. Sirries, and D. Urban. Heterogeneous firms, globalization and the distance puzzle. Technical report, IFN Working Paper, 2013.

F. Lin and N. Sim. Death of distance and the distance puzzle. *Economics Letters*, 116(2): 225–228, 2012.

B. Mitchell. *International Historical Statistics: Europe 1750-2000*. Palgrave Macmillan, 2003.

F. P. Mongelli, E. Dorrucci, and I. Agur. What does european institutional integration tell us about trade integration. *European Central Bank Occasional Paper Series*, (40), December 2005.

K. O'Rourke. Politics and trade: lessons from past globalisations. Technical report, Bruegel, 2009.

G. Rayp and S. Standaert. Measuring actual integration. In G. Genna and P. D. Lombaerde, editors, *The Measurement and Assessment of Regional Integration*. Springer UNU series, forthcoming.

M. Schiff and C. Carrere. On the geography of trade: Distance is alive and well. *Available at SSRN 441467*, 2003.

M. A. Serrano and M. Boguñá. Topology of the world trade web. *Physical Review E*, 68(1): 015101, 2003.

B. Siliverstovs and D. Schumacher. Disaggregated trade flows and the missing "globalization puzzle". *Economie internationale*, (3):141–164, 2009.

J. Smits, P. Woltjer, and D. Ma. *A Dataset on Comparative Historical National Accounts, ca. 1870-1950: A Time-Series Perspective*. Groningen Growth and Development Research Memorandum GD-107, Groningen: University of Groningen, 2009.

S. Standaert. Divining the level of corruption: a bayesian state-space approach. *Journal of Comparative Economics*, 2014.

H. Yilmazkuday. A solution to the missing globalization puzzle by non-ces preferences. *Available at SSRN 2258804*, 2013.

Y. V. Yotov. A simple solution to the distance puzzle in international trade. *Economics Letters*, 117(3):794–798, 2012.

A Estimating models with high-dimensional fixed effects

Following Guimarães and Portugal (2009), the number of fixed effects can be reduced by half by first demeaning both dependent and explanatory in the sender-year dimension, leaving only the sender-target dummies. Using conditional probabilities, the fixed effects (c_i) can be separated from the explanatory variables ($X_{i,t}$), which significantly reduces the size of the matrix that needs to be inverted.

$$y_{i,t} = c_i + X_{i,t}\beta + \epsilon_{i,t} \quad \text{with } \epsilon_{i,t} \sim N(0, \sigma^2) \tag{6}$$

Equation 6 can be estimated using a three-step Gibbs sampling procedure. For example, when using flat (uninformative) priors, the conditional probabilities are:

1. $\beta | c_i, \sigma^2 \sim N(e_\beta, v_\beta)$
   $e_\beta = (X'X)^{-1}(X'(y-c))$ with $\{X\}_{i,t} = X_{i,t}$ and $\{y-c\}_{i,t} = y_{i,t} - c_i$
   $v_\beta = \sigma^2(X'X)^{-1}$
2. $c_i | beta, \sigma^2 \sim N(\bar{c_i}, \sigma^2/n)$
   $\bar{c_i} = \sum_t^n (y_{i,t} - X_{i,t}\beta)/n$ with n the number of observations of country i
3. $\sigma^2 | beta, c_i \sim$ inverse Wishart$(e'e, N)$
   $e = y_{i,t} - c_i - X_{i,t}\beta$

B Country subsets

Group 1: included in 1880<, 1950< and 1960<			
Argentina	Ecuador	Japan	Spain
Belgium	France	Mexico	Sweden
Bolivia	(West) Germany	Morocco	Switzerland
Brazil	Greece	Netherlands	Tunisia
Chile	Guatemala	Peru	Turkey
China	Haiti	Portugal	United Kingdom
Colombia	Iran	Romania	United States
Denmark	Italy	Russia	Venezuela
Group 2: included in 1950< and 1960<			
Afghanistan	Ethiopia	Latvia	Panama
Albania	Finland	Lebanon	Paraguay
Australia	Honduras	Liberia	Philippines
Austria	Hungary	Lithuania	Poland
Bulgaria	Iceland	Luxembourg	Saudi Arabia
Canada	India	Mongolia	South Africa
Costa Rica	Indonesia	Myanmar	Sri Lanka
Cuba	Iraq	New Zealand	Syria
Dominican Rep.	Ireland	Nicaragua	Thailand
Egypt	Israel	Norway	Uruguay
El Salvador	Jordan	Pakistan	Yugoslavia
Estonia	Korea		
Group 3: included in 1960<			
Benin	Congo, Dem. Rep.	Mali	Rep. of Vietnam
Burkina Faso	Gabon	Mauritania	Senegal
Cameroon	Ghana	Nepal	Somalia
Central African Rep.	Guinea	Niger	Sudan
Chad	Ivory Coast	Nigeria	Taiwan
Congo	Malaysia	North Korea	Togo