The Global Network of Payment Flows*

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1 Introduction

Payments represent an integral part of the financial landscape. We can imagine a global payments universe consisting of all international and cross-border payments made during a fixed period of time; however, obtaining complete data from such a universe is not feasible. We can obtain data that represents a part of the global payments universe, and SWIFT message data in particular has been shown to be a useful proxy for economic activity (see, for example, Cook and Soramäki, 2015; Mesropyan 2015; and Collin, Soramäki, and Cook, 2016).

In 2014 the authors of this paper performed an analysis of the global payment networks formed by SWIFT MT 103 message counts aggregated monthly at the country level (Cook and Soramäki, 2014). MT 103 represents a single customer credit transfer and is the most commonly-sent SWIFT message type. Our previous paper showed that the payment networks follow an approximate core-periphery classification and have a stable community structure, with the United States as the most important country according to several measures. In the five years since that paper, the global financial and geopolitical landscape has changed in many important ways, including the continued emergence

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of China as a global power, growing instability and hyperinflation in Venezuela, and increasing regulatory pressure related to financial crime and the financing of terrorism. The updated SWIFT MT 103 data show that, although the number of direct relationships between countries continues to decrease over time, countries remain globally connected and the number of messages and the total value exchanged on SWIFT is increasing. This suggests that the structure of the payment networks has organically reorganised to cope with the disappearance of direct links between countries and to maintain all countries globally connected via other links that have gained importance. The analysis of the payment networks done in this paper will provide elements to support this idea.

Considering this context, this paper provides an update of our previous analysis with nearly five additional years of data, up to April 2018. As in our previous paper, we only consider inter-institutional traffic and we focus on traffic between countries, which corresponds to 62% of total message volume between January 2013 and April 2018. We also provide a brief analysis of within-country traffic.

2 Data Description

The MT 103 data analyzed here consist of monthly bilateral message counts aggregated at the country level between January 2003 and April 2018, and contain over 8 billion total messages exchanged among 231 countries in all 176 currencies in existence on SWIFT. Note that the concept of country here is not limited to independent, passport-granting states, but also includes territories (Guam, for example), dependencies (Guernsey and Jersey, for example) and autonomous constituent states (Greenland, for example).

The schematic in Table 1 shows the basic data format (with arbitrary volumes – i.e., number of messages sent – that do not correspond to the actual data).

Month	Country	Counterparty	Volume
200301	France	Belgium	1
200301	France	Germany	2
200301	Spain	Portugal	3

Table 1: Input data example

For each month between January 2003 and April 2018 we create a distinct network, whose nodes are countries and links represent the volume of messages sent from one country to another during that month. Throughout this paper, when we refer to a payment network (singular) we are referring to the single network created from SWIFT MT 103 volumes in a single month; when we refer to payment networks (plural) we are referring to the series of monthly networks from January 2003 to April 2018. As in our previous paper we analyze the volume, rather than value, of messages sent. Message volume has a longer time series available for analysis, and volumes are unaffected by inflation or exchange rates.

3 Basic Network Summaries

3.1 Countries and counterparty relationships

Figure 1 shows the complete time series of the number of countries (nodes) and links between them (counterparty relationships) in the payment networks.

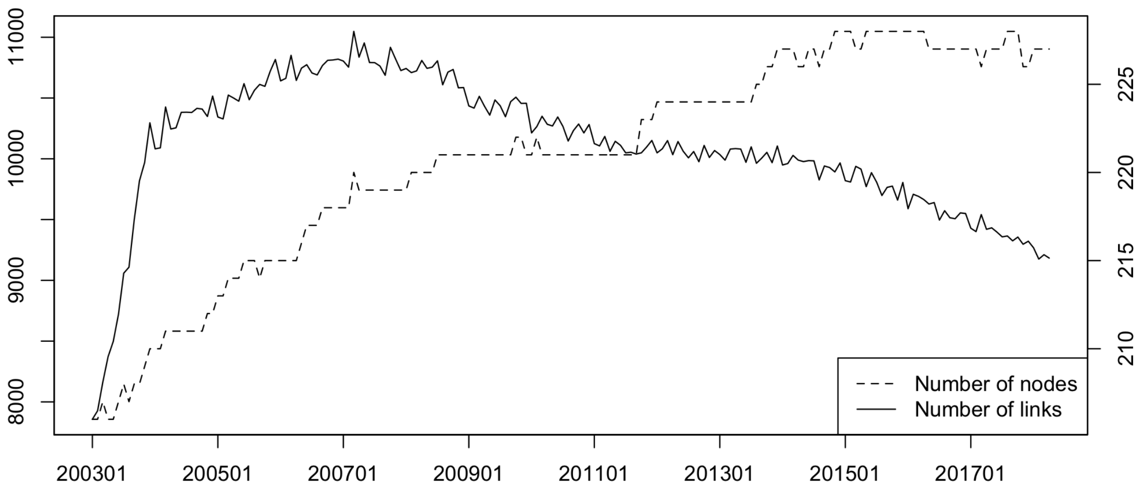


Figure 1: Time series of number of countries and links between them in the payment networks. Discerning readers may note that link counts in 2003 and 2004 are lower than those reported in our previous analysis of MT 103 traffic. The discrepancy is due to changes in data processing that only affected the first two years of the series. The overall trend of the time series and conclusions related to it are unaffected by these discrepancies early in the series. Data Source: SWIFT BI Watch.

As we found in our previous paper, the number of countries in the payment networks continues to increase over time. Of the 231 countries that appear at least once, 201 appear in all 184 months covered by the data. The countries that appear in at least one but not all 184 months consist mostly of new, developing, or at times politically unstable countries that entered the system at some point after January 2003 and were present in all or most of the networks after that (examples include South Sudan, Myanmar, and Iraq). There are two cases in the data of a country dividing into multiple countries. The Netherlands Antilles split into Bonaire, Saint Eustatius and Saba (one country); Curacao;

and Sint Maarten, while Serbia and Montenegro (one country) split into Montenegro and the Republic of Serbia.

In our previous paper, we found that the number of links in the payment networks steadily declined from a maximum in early 2007. Here we see that the reduction in the number of business relationships has continued during the five years since that paper was written. We investigate which countries lost the most links between the month with peak number of links (March 2007) and eleven years later (March 2018). Note that because of seasonal variation in volume, we only make direct comparisons between time periods that correspond to the same month[1].

The ten countries that lost the largest number of links between March 2007 and March 2018 are shown in Table 2 below. Seven of the ten countries are listed as offshore financial centers on at least one of the following three lists: FSF-IMF 2000, IMF 2007, or IMF 2018 (see IMF, 2000 and FSF, 2000; lists obtained from `https://en.wikipedia.org/wiki/Offshore_financial_centre#Lists`). Thus the more recent data continue to support the hypothesis proposed in our previous paper that link loss overall is largely due to link loss in countries that are offshore financial centers.

Country	Links lost (absolute)	Links lost (relative)	Offshore
Netherlands	85	24%	IMF 2007, IMF 2018
Monaco	74	55%	FSF-IMF2000
Denmark	70	24%	
Finland	68	28%	
Lebanon	68	41%	FSF-IMF2000
Switzerland	67	18%	FSF-IMF2000, IMF 2007
Luxembourg	64	27%	FSF-IMF2000, IMF 2007, IMF 2018
Israel	62	34%	
Isle of Man	61	40%	IMF 2007
Cyprus	59	34%	FSF-IMF2000, IMF 2007

Table 2: Countries that lost the largest number of links between March 2007 and March 2018. Data Sources: SWIFT BI Watch, FSF, IMF.

Table 3 shows the ten countries who lost the most links in relative terms. Here the top ten includes four countries designated as offshore centers, and three countries (Monaco, Lebanon, and Isle of Man) appear in both lists.

[1]We also note that Chinese New Year was at nearly the same time in these two years: 18 February in 2007 and 16 February in 2018.

Country	Links lost (absolute)	Links lost (relative)	Offshore
Monaco	74	55%	FSF-IMF 2000
Iceland	59	52%	
Andorra	48	51%	FSF-IMF 2000
Argentina	48	47%	
Trinidad and Tobago	39	44%	
Papua New Guinea	37	42%	
Ghana	37	41%	
Lebanon	68	41%	FSF-IMF 2000
Isle of Man	61	40%	IMF 2007
Moldova	23	35%	

Table 3: Countries that lost the largest percentage of links between March 2007 and March 2018. Data Sources: SWIFT BI Watch, FSF, IMF.

3.2 Message Volume

Figure 2 shows the full time series of message volume (i.e., total number of messages sent). We see that the trend is on average increasing, with notable seasonal variation.

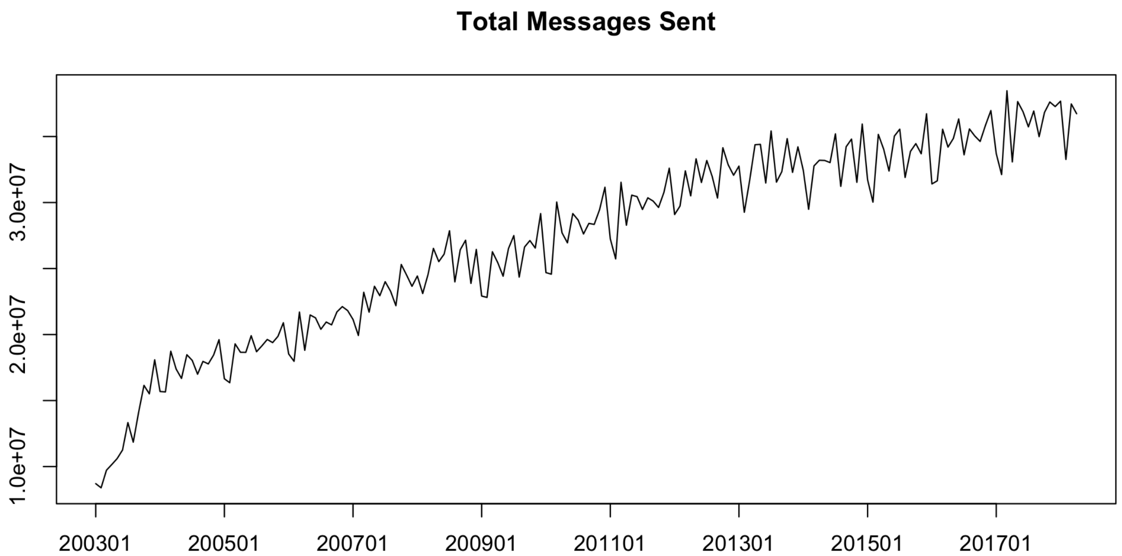


Figure 2: Time series of total message volume in payment networks. Data Source: SWIFT BI Watch.

Figure 3 shows the seasonal-trend decomposition (Cleveland, Cleveland, McRae, and Terpenning, 1990) of the time series of monthly message volume. The data show strong monthly variation, with volume being highest in December and March, and lowest in January and February. This analysis is consistent with the results from our previous paper: the overall trend of message volume is increasing with the exception of a dip around the time of the financial crisis of 2007-08. Using data up to July 2013, we previously found that message counts were 5.5% lower after the financial crisis than they would have been had the pre-crisis trend continued. The trend in message volume has been increasing since the financial crisis, although the rate of increase is lower towards the end of the series. In particular, if we compare four years following the financial crisis (July 2009 - July 2013) with the most recent four year period (April 2014 - April 2018), the average yearly growth in message volume has decreased from 5.4% to 3.1%.

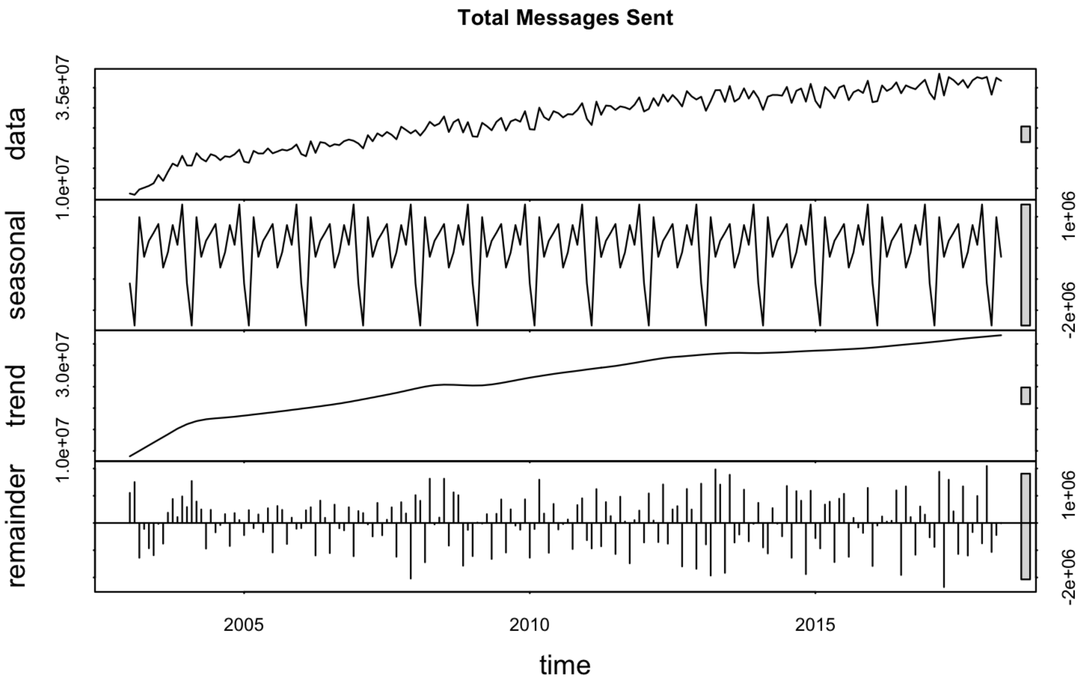


Figure 3: Seasonal-trend decomposition of message volume in payment networks. Data Source: SWIFT BI Watch.

3.3 Corridor Activity

Table 4 shows the top ten increases in terms of corridor activity, defined as the number of messages sent from one country to another, between March 2007 and March 2018. The data show that corridors involving the United States, the United Kingdom, China, Hong Kong, and Singapore – the five largest global financial centers according to the Global Financial Centres Index – have seen the largest increases in activity.

Top ten increasing activity corridors
United States-China
China-United States
United States-Hong Kong
United States-United Kingdom
United Kingdom-United States
United States-India
United Kingdom-Germany
Canada-United States
Singapore-United States
United States-Canada

Table 4: Countries pairs with largest increase of corridor activity. Data Source: SWIFT BI Watch.

4 Network Structure and Message Flows

In the remainder of this paper we limit our analysis to the payment networks that can be derived from the 201 countries that are present in all 184 months of available data. Limiting to the 201 countries that are present in all networks retains 95% of the links and 98% of the messages from the complete networks.

Figure 4 shows the maximum-spanning tree of the most recent payment network (April, 2018) based on message volume sent between countries. A network's maximum-spanning tree is the spanning tree (i.e., a subnetwork that contains all of the nodes present in the original network and is a tree) that has the maximum possible sum of link weights. Spanning trees allow us to filter down to the most important links in a network, and can be easily visualized for networks containing up to a few hundred nodes. The countries are colored by geographic region and node size scales with outgoing message volume.

Figure 4: Maximum spanning tree (based on message volume) of countries in April, 2018. Nodes are colored by geographic region (orange = North America; purple = South America; blue = Europe and the Middle East; red = Africa; green = Asia and Oceania) and sized by outgoing message volume. Data Source: SWIFT BI Watch.

The most notable feature of the spanning tree is the highly central position of the United States; in addition, the size of the United States node indicates that it is the country that sends the most messages. The United States has 122 links in the maximum spanning tree. (By this and other measures the United States is consistently, and by far, the most central country in the payment networks; see Section 5 for more on measuring countries' importance in the networks.) The United Kingdom, Germany, and France are the next most central countries in the payment network by this measure, with 19, 13, and 9 links, respectively. As in our previous paper, we define as a "hub" any country that has more than two links in the maximum spanning tree. The hub countries in the April 2018 payment network contain nearly all of the hub countries reported in our previous paper for the July 2013 payment network, as well as Austria, Cameroon, Czechia, Italy, South Korea, Mali, Portugal, Singapore, and Tunisia. The only countries that were classified as hubs in July 2013 but not in April 2018 are Canada and Norway.

4.1 Core-Periphery Structure

A core-periphery network, as defined by Craig and von Peter (2014), consists of core nodes and periphery nodes and has the following features.

- Core nodes are linked to all other core nodes.
- All core nodes are linked to at least one periphery node.
- Periphery nodes are not linked to any other periphery nodes.

Real-world networks rarely follow a core-periphery model exactly, but the classification of nodes as core and periphery can be helpful for understanding network structure. In our previous paper we found that the payment networks follow an approximate core-periphery structure, with the number of core countries slightly decreasing over time. The updated data align with our earlier findings: the core countries consist of the world's largest economies, including the United States and Canada, Australia and New Zealand, China, Russia, India, South Africa, most of Europe, and parts of the Middle East and southeast Asia. The number of countries classified as core peaked in 2008 at 31% and has been declining slightly ever since. In the most recent payment network, 53 countries (26%) were classified as core. Figure 5 shows a map of the April 2018 payment network with core countries colored blue and periphery countries green. Our previous paper showed a similar map from July 2013; the differences between that classification and the current one are that Estonia, Croatia, Ukraine, and Bulgaria were all classified as core in 2013 and are now classified as periphery.

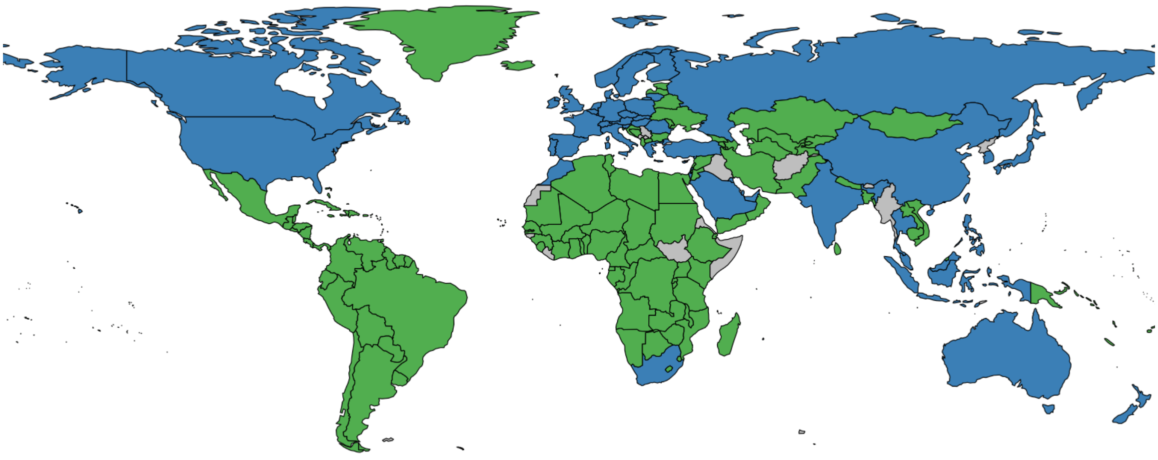


Figure 5: Core-periphery classification of countries in April, 2018. Core countries are colored blue; periphery countries are green; and countries that are not part of the network are colored grey. Data Source: SWIFT BI Watch.

4.2 Community Structure

Studying community structure within networks provides a deeper understanding of the relationships among participants in the network, as well as how those relationships change over time. Understanding the community structure in payment networks can highlight patterns in international flows that indicate changes in economic behaviors and may detect behavioral shifts that are indicative of macro economic and geopolitical factors.

Modularity-based community classification for networks attempts to find the grouping of nodes into communities such that the ratio of within-community links to between-community links is maximized. Performing community detection on the payment networks using the algorithm proposed by Clauset, Newman, and Moore (2004) gives results that are in line with those of our previous paper, but with some interesting differences in the more recent data. As in our previous paper, we found a fairly stable community structure over time, with the largest communities corresponding, roughly, to

1. the Americas, Australia and New Zealand, China, India, and parts of Africa and Asia (referred to below as US-led countries);
2. Europe, along with most of northern and southern Africa;
3. the former Soviet Union;
4. West Africa, with the exceptions of Nigeria and Ghana;
5. and Caribbean islands.

Figure 6 show the community classification in April, 2018, as well as the 2013 classification shown in our previous paper. The countries colored white (Aruba, Belize, Lesotho, Martinique, Malawi, Sierra Leone, Suriname, Syria, Tonga, and Western Samoa in the 2018 classification) were each classified as singleton communities (i.e., communities containing only one country). The emergence of the southeastern African community seen in the 2018 network is relatively recent. In 2013 those countries were classified either with the US-led countries, with West Africa, or as singletons, while in more recent months were often classified in the European community, and sometimes as singletons.

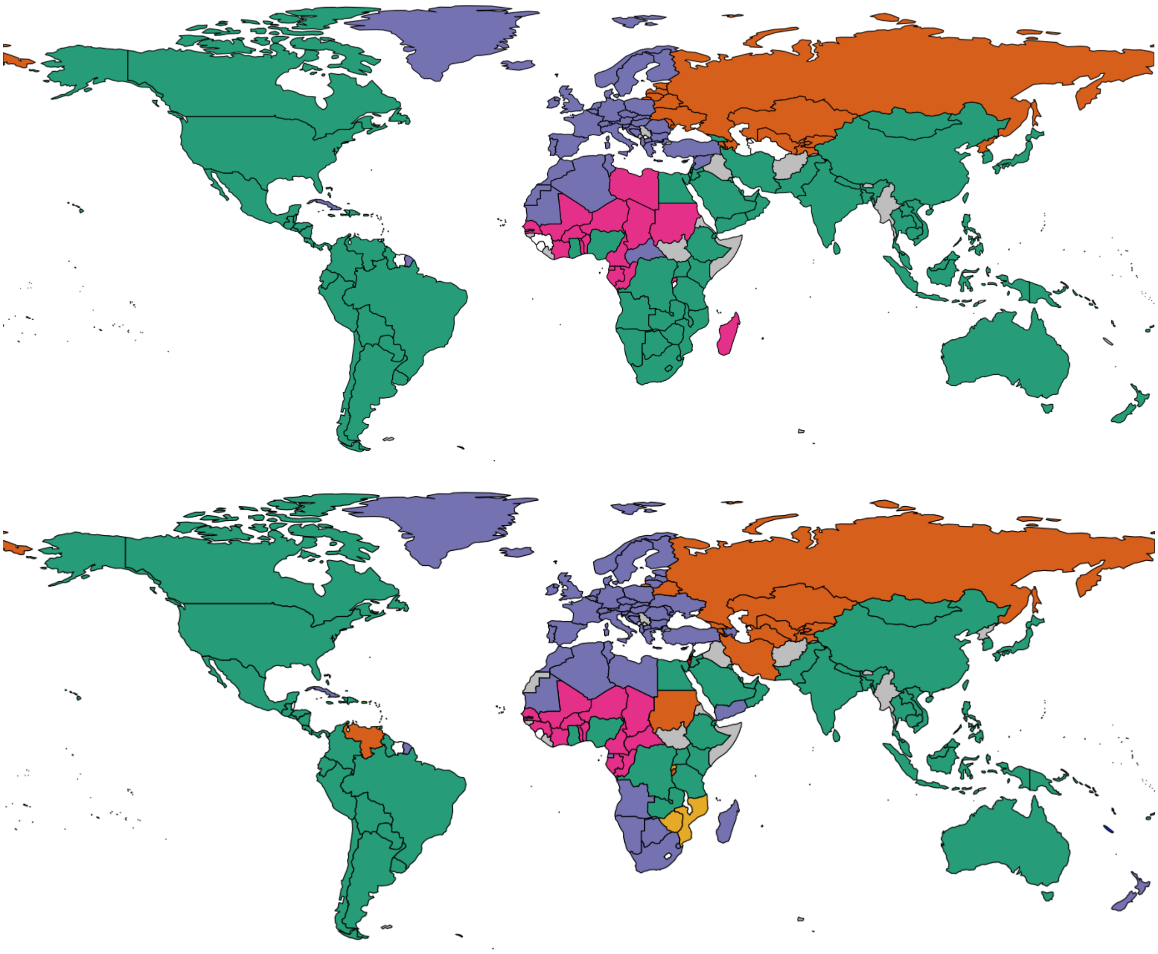


Figure 6: Upper map: Community classification in July, 2013. Lower map: Community classification in April, 2018. Data Source: SWIFT BI Watch.

5 Centrality

As in our previous paper, we measure the importance, or centrality, of countries in the payment networks using the volume of messages sent and received as well as by SinkRank (Soramäki and Cook, 2013), a centrality measure developed specifically for payment systems. SinkRank provides a measure of a country's importance in the payment network, characterized by how vulnerable the global system is to a disruption in that country's ability to send payments. By all three of these measures, the most central countries continue to be the United States, followed by Germany, the United Kingdom, France, China, and Hong Kong. Figure 7 shows the evolution of SinkRank values for the seven countries whose SinkRank is ever in the top five. In addition to the extreme importance of the United States, we see a slight decline in Germany's Sink Rank at the end of the series; increases in China's SinkRank at the beginning of the series, followed by a leveling off with notable seasonal variation; and slight decreases in SinkRank, especially at the beginning of the series, for France and Italy.

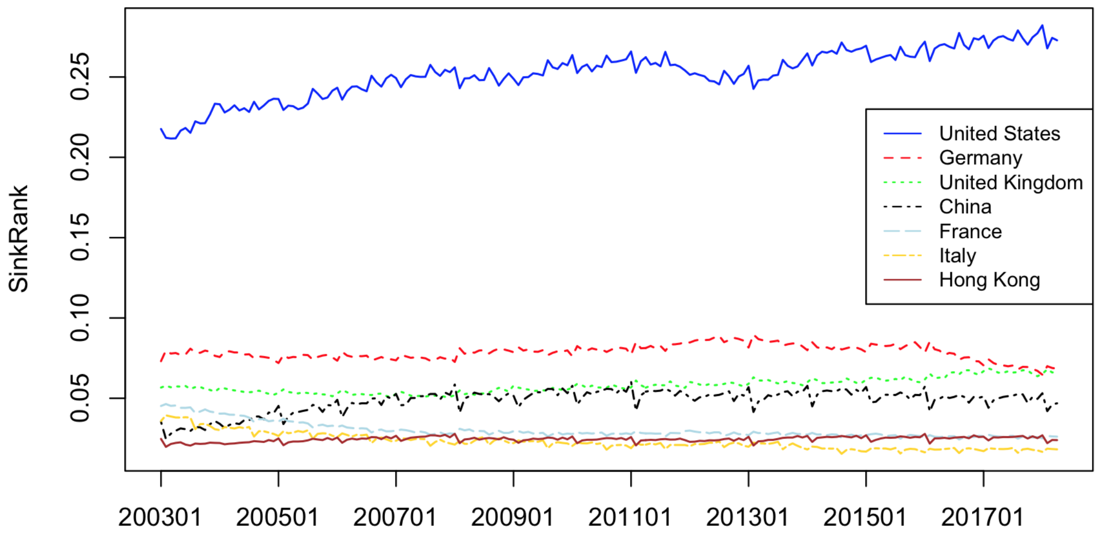


Figure 7: SinkRank for the seven countries whose SinkRank was ever in the top five. Data Source: SWIFT BI Watch.

The SinkRank values show an interesting contrast to the maximum spanning tree shown in Figure 4: Although Germany's SinkRank is slightly higher than that of the United Kingdom in the most recent network (at the far right of Figure 7), the United Kingdom has more links (19 vs. 13) in the maximum spanning tree of the most recent network (Figure 4). The maximum spanning tree highlights the strongest links in a network, and for many countries their strongest link is to the United Kingdom, hence the more central location of the UK in the maximum spanning tree. SinkRank, on the other hand takes, into account the entire structure of the network: not only the countries that a country is directly linked to, but the countries its neighbors are linked to, and links between its neighbors, and so on, and by that measure Germany is more central.

In addition to the most central countries, we are also interested in the countries whose centrality has changed the most in the five year period since our previous paper. The five countries whose relative importance, measured by SinkRank, was most variable were Angola, El Salvador, Central African Republic, Yemen, and Guernsey. Their ranking over the past five years is shown in Figure 8. Countries are ranked in decreasing order, so that countries with higher ranks are more central.

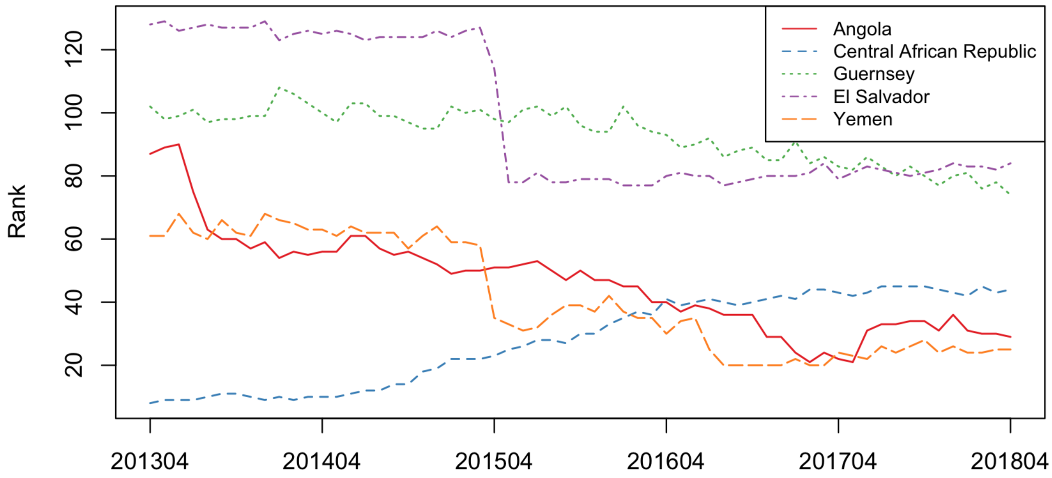
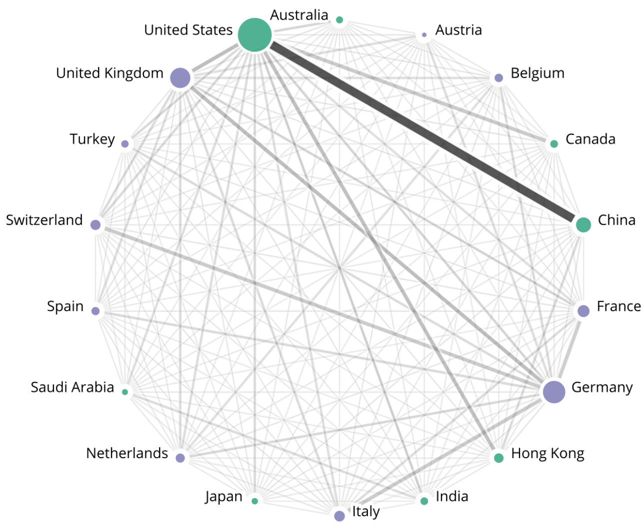


Figure 8: SinkRank-based rankings for the five countries whose importance changed the most in the past five years. Data Source: SWIFT BI Watch.

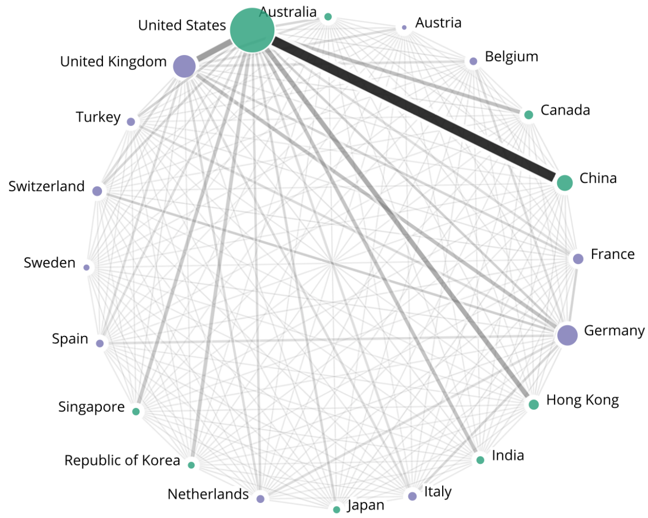
Of the five countries whose ranks changed the most, only Central African Republic increased in importance. The country whose importance decreased the most was Angola, followed by El Salvador, whose rank dropped sharply in early 2015, corresponding to a sharp spike in the murder rate there. Yemen also had a notable drop in rank in early 2015, corresponding to the beginning of the Yemeni Civil War. The centrality of the remaining country in the top five, Guernsey, was relatively stable until early 2016, when it began to steadily decline.

6 Visualizing the Current State

Due to the large number of countries in the payment networks, it is difficult to visualize all of the countries and links between them in a static image. Figure 4, which shows the maximum spanning tree of the most recent network, gives an overview of the most important countries and counterparty relationships, but space constraints make some countries and links difficult to distinguish. In this section we present more detailed visualizations of the sub-networks formed by the 20 countries whose links comprise 50% of traffic. In April 2018, these countries form a complete network, with each country sending and receiving messages from each other country. Figure 9 shows the network of countries whose links make up 50% of traffic in the most recent network as well as the similar visualization from our previous paper, with the 18 countries whose links made up 50% of traffic in July, 2013. The countries are arranged alphabetically, with node size scaled by the volume of messages sent and received, link width and darkness scaled by total message volume between the two linked countries, and node color matching the community classification shown in Figure 6. We see that the set of countries comprising



(a) July, 2013.

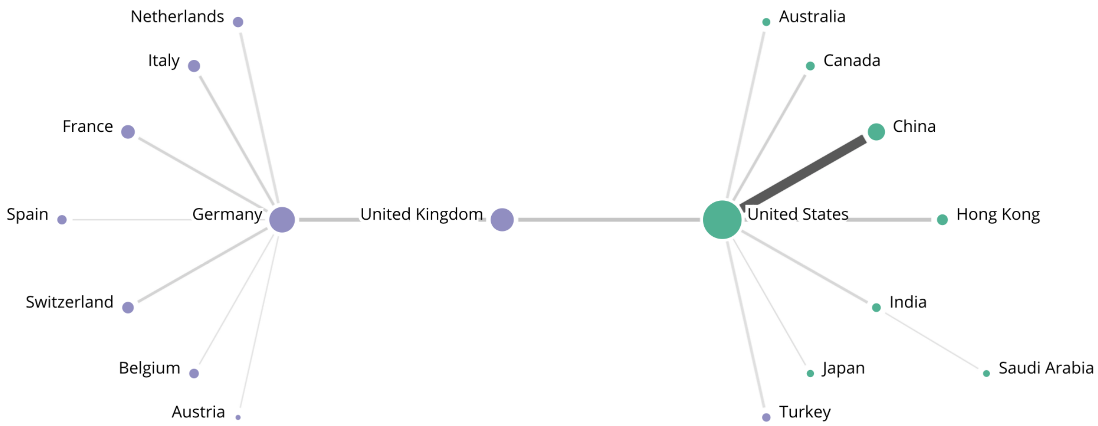


(b) April, 2018.

Figure 9: Countries comprising 50% of message traffic in July, 2013 and April, 2018. Data Source: SWIFT BI Watch.

50% of traffic has been fairly stable over the past five years, with the only changes being the addition of Singapore, South Korea, and Sweden in the current network, and the absence of Saudi Arabia. The strongest bilateral relationship continues to be between the United States and China

As in our previous paper, we also calculate the maximum spanning tree of the countries whose links make up 50% of traffic, shown in Figure 10 for both the July, 2013 and April, 2018 networks. We see a similar structure in both trees, with the countries clustered into two groups, one containing only European countries and the other containing primarily North American and Asian countries, with the United Kingdom linked to both clusters. In the current network Austria, Belgium, and Sweden, are linked to the United Kingdom rather than directly to the European cluster, and the Netherlands has moved from the European cluster to the United States-centered cluster. Nodes are colored according to the community classification shown in Figure 6; we see that, with the exception of Turkey in both networks and the Netherlands in the April, 2018 network, the clustering within the maximum spanning tree aligns with the countries' community classification. The United Kingdom's position in the center of the tree suggests that it continues to act as a bridge between the two communities.



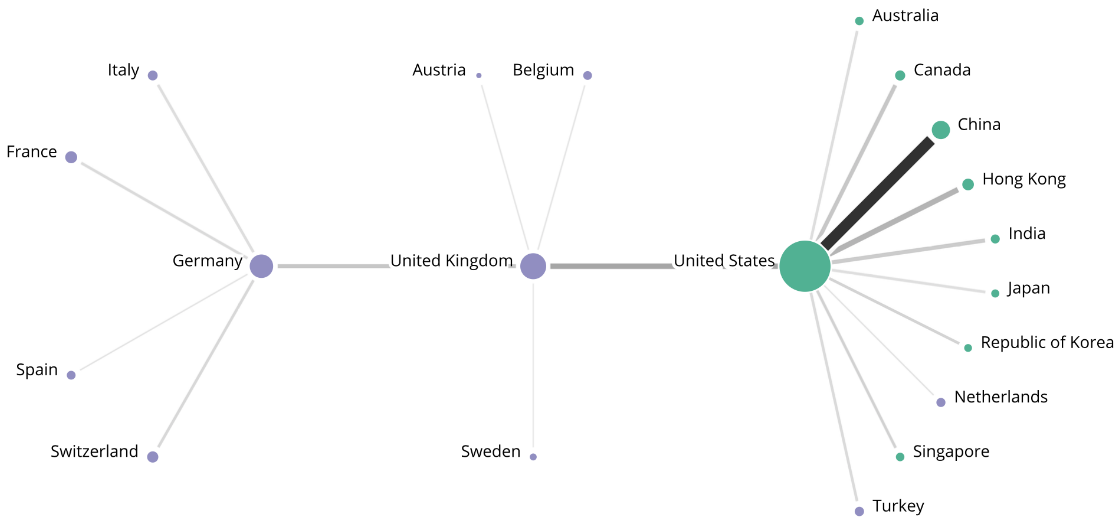


Figure 10: Upper figure: Countries comprising 50% of message traffic in July, 2013, maximum spanning tree. Lower figure: Countries comprising 50% of message traffic in April, 2018, maximum spanning tree. Data Source: SWIFT BI Watch.

7 Within-Country Traffic

So far we have only considered international traffic, i.e., traffic between countries. Now we present a brief exploration of within-country (i.e., domestic) traffic. Figure 11 shows the seasonal-trend decomposition of monthly within-country traffic. Although the overall (increasing) trend and seasonal variation are comparable to what we saw in Figure 3 for between-country traffic, there are two notable differences here. First, in addition to a dip in message traffic around the time of the financial crisis of 2008-09, within-country traffic shows another notable dip in 2015 which is not present in the between-country traffic. Second, in the approximately three years since the second dip, within-country traffic has grown at a notably faster rate than in previous years, a trend not seen in the between-country traffic. In addition, the average yearly growth rate over the entire period of available data is higher for within-country traffic (11.2% per year) than between-country traffic (8.4% per year). We note that, because this analysis is limited to those countries present in all months of available data, the growth in domestic traffic seen here is not due to growth in the number of countries using SWIFT for domestic traffic, but rather growth of existing domestic volumes in countries already using SWIFT.

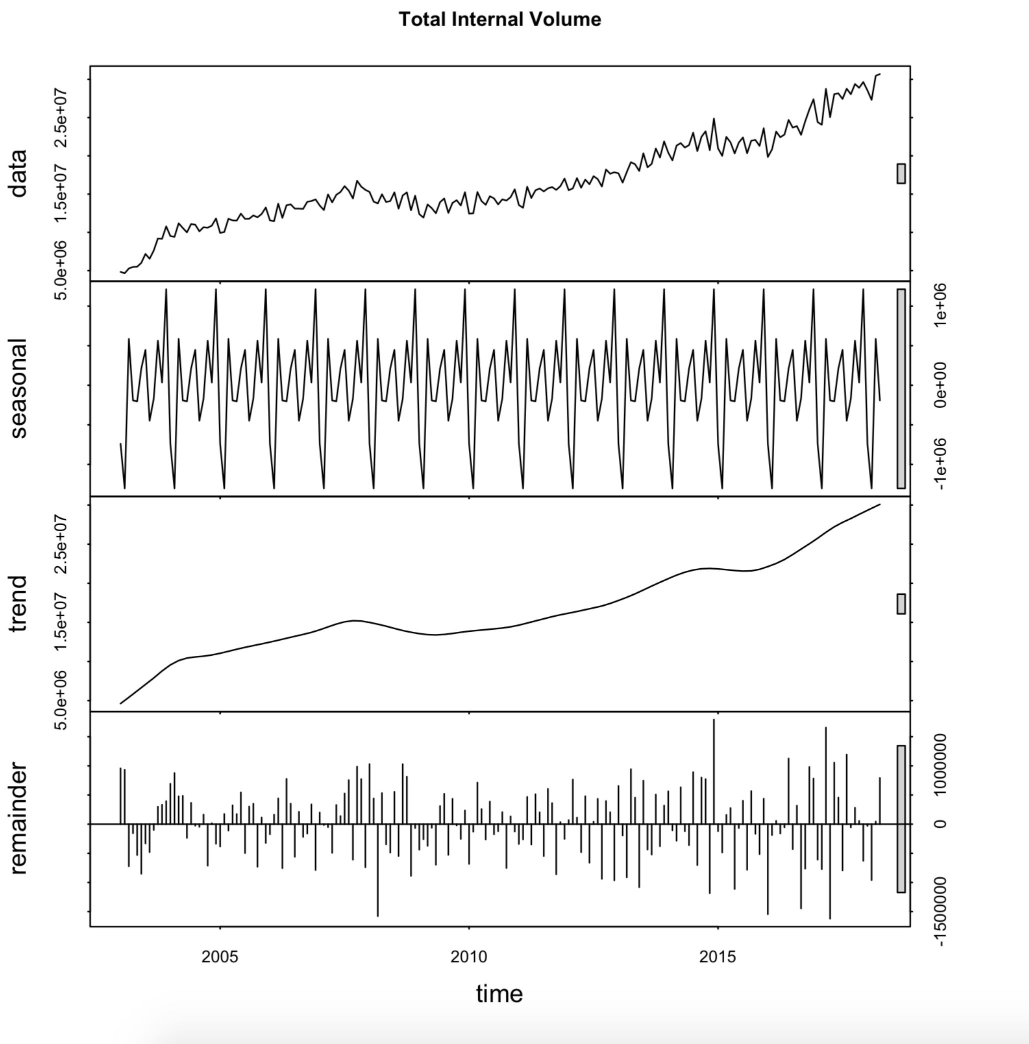


Figure 11: Seasonal-trend decomposition of domestic message volume. Data Source: SWIFT BI Watch.

Although the overall trend is increasing within-country traffic, there are a few countries whose internal traffic decreased during the period of study. Limiting to those countries that averaged at least one internal message per month, Iran saw the largest decrease in internal traffic (-18.4% annually), followed by Greece (-8.4%), Azerbaijan (-7.4%), Slovenia (-5.9%), and the Faroe Islands (-5.5%)[2]. The countries whose internal traffic increased the most were Chile (277%), Honduras (256%), Malaysia (170%), Tanzania (162%), Malawi (100%), and Zimbabwe (100%).

[2]The remaining countries whose internal traffic was decreasing overall are Argentina, Finland, Cuba, Oman, and Germany, all with less than 5% annual decrease.

8 Conclusions

Here we have provided a brief analysis of the networks formed by monthly MT 103 message volumes aggregated at the country level. We found that overall traffic continues to grow and that countries remain globally connected in the payment networks throughout the period of analysis. This, despite changes in the geopolitical landscape and regulatory pressure.

We observed that the networks have an approximate core-periphery classification and a stable community structure, with the most important communities corresponding roughly to 1) the Americas, China, India, Australia, southeast Asia, and parts of Africa and the Middle East; 2) Europe, plus northern and southern Africa; 3) the former Soviet Union; 4) West Africa; and 5) Caribbean islands. The most recent data available show some evidence of the development of additional regional communities, and changes in specific countries' community membership mirrors shifts in the trading relationships that reflect wider geo-political developments.

We also found that the decline in the number of counterparty relationships (links), first reported in our 2014 paper, has continued during the past five years. The countries that have lost the most links tend to be offshore financial centers. This decline is counterbalanced by two other observations. First, traffic between the largest financial centers has increased. The five most important global financial centers – the United Kingdom, the United States, China, Hong Kong, and Singapore – and their underlying corridors have gained strength. The United States continues to be the most important country in the network, and although China continues to be one of the most significant countries, its relative importance has not changed considerably during the period of study. Second, the traffic within countries has increased faster and stronger than traffic between countries over the same period.

The previous observations show that countries globally exchange more and more messages, and suggest that the payment networks' structure has reorganized to maintain all the countries connected. In the current structure, payments go to larger hubs first before reaching their final destination using larger corridors. This is illustrated by two effects. First, we measured an approximate core-periphery structure for the network, with the core set of countries acting as hubs connecting the rest of the network. Second, the increase of traffic within countries hints at those payments that first reach a domestic hub before transiting to larger hubs.

We hope this work encourages continued research on global payment networks, and on financial networks in general.

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