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Post global financial crisis multiplex financial network structure longevity: Does it predict re-globalization? Empirical investigation for 234 countries

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Abstract

Research background: International capital flows show decreasing trend after each financial crisis as countries become unwilling to invest in risky counterparties. Recent discussions over structural changes within the global financial network suggest that its structure may be still undergoing some changes. Uncovered weaknesses of over-connectedness with unstable unally countries during global financial crisis were further highlighted by recent Covid-19 pandemic. However, previous research suggest that important structural changes happened after global financial crisis. Thus, such situation raises a question whether post global financial crisis multiplex network structure is long-term and is it exhibiting re-globalization pattern as suggested by re-globalization megatrend.

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Purpose of the article: The main objective of the paper is to assess post global financial crisis multiplex financial network structure longevity and to identify whether it exhibits re-globalization pattern.

Methods: Multiplex financial network mapping, network topological analysis and structure longevity methods were employed to evaluate network connectedness, topological structural properties of multiplex financial network and its' structure longevity. 5-layer multiplex financial network was mapped for different types of capital flows for each layer: net direct and portfolio investments in debt, equity and net banking assets for each year in the post global financial crisis period 2009–2020. Each network layer employed bilateral data from up to 234 countries of the world. Next step of research employed a set of network-level measures defining topological features of each network in the period of 2009–2020 in order to capture the trend of structural changes and evidence of re-globalization. The final stage analyzes multiplex financial network structure by layer and country longevity.

Findings & value added: Analysis reveals that stock (positions) multiplex financial network aggregate connectedness, i.e., density and value, increased during post- global financial crisis period until Covid-19 pandemic period, thus, suggesting that globalization in terms of stock is continuing. Topological structural properties of multiplex financial network changed as number of strongly and weakly connected countries decreased and more countries became included in network. Longevity analysis of layer and country structure within multiplex financial network reveal that banking and debt investments are increasing since 2018, while equity part is decreasing. Developed countries, i.e., the United Kingdom and Germany, decrease in multiplex financial network structure, while developing, especially from Asia region (i.e., Hong Kong SAR, China and Singapore) increase. Such empirical results support the re-globalization megatrend in terms of investment type and counterparty structure as highlighted by most recent scientific discussion showing that it started early after global financial crisis. Research also uncovers some regional trends of Asia region increasing in investment network structure, while Europe decreasing. As developing countries attract more and more investment and further develop, global cost saving and, thus, returns from global investment into these countries may be decreasing, resulting in lower gain from globalization. Our analysis may facilitate investment strategy decisions by suggesting that even though gains from globalization might be decreasing, instead of localization, countries could follow ally investment strategy to manage the risk of over-dependency from unstable counterparty while preserving globalization wealth.

Introduction

A historically unique build-up in aggregate financial flows was observed prior to the global financial crisis (hereinafter – GFC) (Minoiu & Reyes, 2011). The composition of international investment flows before GFC had the tendency of significantly increased banking sector positions and portfolio investments while the share of foreign direct investments (FDIs) in total financing of countries decreased. Cross-border financial investment flows have been expanding rapidly since mid-1990s as the stocks of foreign assets and liabilities have increased from about 75–77 percent of world GDP in

1995 to around 200 percent of world GDP by 2007 reaching its peak. However, global cross-border capital flows have declined 65% since 2007 peak during post-GFC period. This decline of flows was referred to in previous literature as indication of possible deglobalization happening in global financial network. Discussions were ongoing that globalization might have reached a 'natural' equilibrium. However, another strand of literature argues that even though international investment flows decreased after GFC it would be wrong to conclude that financial globalization is over (Lund *et al.*, 2017), because more risk-sensitive, rational, and ultimately more resilient version of global financial integration might be present. This trend of stock positions increasing slower than before GFC has been referred to as slowbalization (Kandil *et al.*, 2020; Ghauri *et al.*, 2021; Garcia-Herrero, 2022).

Researchers suggest that disruptive events, which followed after GFC, i.e., BREXIT, Covid-19 pandemic and war in Ukraine, further strengthened end of high-speed globalization (Ghauri *et al.*, 2021), which might have started already after GFC, rather than uncovering some new trends. Historically, globalization slow-down megatrends were already observed during the interwar era and increase in globalization speed during postwar rebound. However, latest scientific discussions highlight the process of deep change in globalization, phenomenon has been currently referred to as re-globalization, which is necessary as a new approach to globalization and its risk management (Paul, 2021; Madhok, 2021; Scott & Wilkinson, 2021; Bishop & Payne, 2021; Clift & Robles, 2021). Thus, some changes in the speed and structure of global financial flows and countries interdependence appear possible, mostly influenced by risk management policies.

Global financial system was analyzed extensively after GFC in 2008 (Bremus & Fratzscher, 2015; Lambert *et al.*, 2015; Tonzer, 2015; Ghosh, 2017). Shifts in the structure of cross-border capital flows and the stock of foreign investment by types of investment, the changing roles of countries as measured by centrality and connectedness, are also observed in global financial system (Lane & Milesi-Ferretti, 2017; Lund *et al.*, 2017). International financial centers are the most highly integrated into the global system, but China and other developing countries are becoming more and more connected (Lund *et al.*, 2017) and less dependent on major economies (Cerutti & Zhou, 2017). Recent studies suggest that global financial system structural reconfiguration might have been further highlighted by BREXIT and most recent Covid-19 pandemic (Naimy *et al.*, 2023; Ghauri *et al.*, 2021). Recent Covid-19 pandemic again exhibited drawbacks of high intercon-

nectedness and dependency, especially with one particularly risky or unstable counterparty resulting in cross-border investments being shifted either home (reshoring), somewhere else in the region (nearshoring) or to ally countries (friend shoring). Researches, which followed after Covid-19 pandemic focused on cross-border financial network vulnerabilities to shocks from certain countries (Madhok, 2021; Ghauri *et al.*, 2021; Garcia-Herrero, 2022). Even though each crisis impact on global financial system structure is discussed in previous literature, but overall structure longevity analysis covering entire post-GFC period in re-globalization context reveals a gap in empirical literature. Thus, we aim to identify whether multiplex financial network connectedness, topology, layer and country structure longevity exhibit changes during post-GFC period in current context of re-globalization.

This research analyzes post GFC financial sector network structure longevity in the context of re-globalization using multiplex financial network approach. Network analysis, which is a method generally used in physics, has been recently altered with an extension of multilayers that allow one to encode multiple types of edges, multiple subsystems, and other complications (Del Rio-Chanona *et al.*, 2020). Multiplex financial network structure longevity seems a generally understudied area. Korniyenko *et al.* (2018) in their research aim to study interconnectedness of the global financial system, but from the perspective of its susceptibility to shocks. Del Rio-Chanona *et al.* (2020) constructed a multiplex global financial network of three layers for different types of financial assets and focused on systematically important countries identification as well as shock propagation within multiplex network. Thus, even though multiplex financial network structure is analyzed in previous literature, its' longevity taking into account entire post-GFC period in recent context of re-globalization has not been yet addressed.

If these structural changes in global financial network happened influenced only by GFC, they could represent a temporary response to increased systemic risk within network. However, if these changes appear to be long lasting, thus some it might show some deep changes and the formation of a new paradigm, i.e., pattern of re-globalization. Hence, if the latter case appears to be true, structure patterns of global financial network may reveal new qualitative state of global financial network development with regard to its stability and diversification. Shedding light on longevity

of post-GFC multiplex financial network structure in context of re-globalization is a key contribution of this research.

Firstly, we build multiplex financial network based on 5 different types of financial assets: net direct investment in equity, net direct investment in debt, net portfolio investment in equity, net portfolio investment in debt, and net banking loans and deposits. We raise 4 hypotheses to test network connectedness, topology, layer and country structure changes during post-GFC period until Covid-19 pandemic period.

Secondly, we explore multiplex financial network topology as captured by connectedness and topological network measures in order to identify whether deglobalization or continuing, but slower globalization could be observed. Also, topological analysis could help to reveal some potential deep structural changes happening in multiplex financial network.

Finally, we evaluate structural changes and their longevity, by computing multiplex financial network layer and country structure and analyzing its long term trend over post-GFC period.

When it comes to the results, we find that globalization in terms of stock is continuing. Topological structural properties of multiplex financial network changed. Longevity analysis of layer structure reveals that banking and debt investments are increasing since 2018, while equity part is decreasing. Country structure reveal that developed countries, i.e., the United Kingdom and Germany, decrease in multiplex financial network structure, while developing, especially from Asia region (i.e., Hong Kong SAR, China and Singapore) increase.

Our results support the re-globalization megatrend in terms of investment type and counterparty structure as highlighted by most recent scientific discussion showing that it started early after GFC.

Our paper is structured as follows. Section 2 presents a brief literature review. Section 3 discusses the multiplex network-based methodology, logics of the research and hypotheses. It also provides the description of empirical data used. In Section 4, we analyze the empirical results of the study. Section 5 discusses the results. Finally, Section 6 concludes.

Literature review

Financial sector, which includes the main global industries such as banking, insurance companies, investment funds etc. interacting through trans-

fer of funds, has undergone the process of financial liberalization and integration during the past decades leading to the formation of highly complex global financial system. Countries, banks and other financial institutions acting as sources and receivers of cross-country capital flows become interconnected through foreign financial linkages. Foreign assets and liabilities being transferred include Foreign Direct Investment (FDI), portfolio equity securities, portfolio debt securities, loans, currency and deposits, trade credit, reserves and other investments (Garcia-Herrero, 2022; Cartas & Harutyunyan, 2017), thus influencing financial globalization. Financial globalization, defined as increased global linkages through cross-border financial flows (Garcia-Herrero, 2022; Yeyati & Williams, 2011), and improvements in technology has contributed significantly to increased complex interconnections among financial sector participants, creating global financial system network. Financial system globalization has reached its peak by 2007 due to significantly increased banking sector positions and portfolio investment. Build-up in aggregate financial flows observed prior GFC has undergone a dramatic reduction in global cross-border capital flows compared to 2007 peak, as a result of insolvency problems, which started in advanced countries, but has spread via chain reactions over interconnected financial institutions.

The financial sector network, its structural changes and systemic risks due to high interconnectedness became a popular research topic after GFC (Garcia-Herrero, 2022; Ghauri *et al.*, 2021; Paul, 2021; Madhok, 2021; Scott & Wilkinson, 2021; Bremus & Fratzscher, 2015; Lambert *et al.*, 2015; Tonzer, 2015; Ghosh, 2017) when network methodology became widely applied in finance and indispensable for systemic risk and interconnectedness analysis. Researches were focusing on structural changes, identification of systemically important countries, as well as network resilience in case of contagion (Lambert *et al.*, 2015; Tonzer, 2015; Ghosh, 2017). Various financial institutions were identified as 'too big to fail' (TBTF) or 'too interconnected to fail' (TITF) based on their relevance (centrality) in a network rather than simply its size, thus, taking into account interrelations within the network (Martínez-Jaramillo *et al.*, 2014), which would not be possible to do without network analysis. Research on global cross-border capital flows after GFC has revealed that they have declined 65% since 2007 peak during post-GFC period. This decline of flows was referred to in previous literature as indication of possible deglobalization happening in global financial network. If globalization could be defined as increased connectedness within network,

deglobalization reveals a contrary trend, i.e., decreased connectedness (number of connections within network). As revealed by other research, global stock of foreign investment relative to GDP has changed little since 2007 and even more countries are participating in global financial network (Lund *et al.*, 2017). Even though international investment flows decreased after GFC, subsequent research argues that financial globalization in terms of stock of foreign investment is not over (Lund *et al.*, 2017), but rather a more risk-sensitive, rational, and ultimately more resilient version of global financial globalization is emerging. This trend of stock positions increasing, but just at a slower pace than before GFC has been referred to as slowbalization (Kandil *et al.*, 2020; Ghauri *et al.*, 2021; Garcia-Herrero, 2022) in previous literature. Thus, slowbalization could be understood as increased connectedness of global financial network, but at a slower pace compared to pre-GFC period.

Discussion regarding globalization suggest that important structural shifts are needed as a new approach to globalization (Garcia-Herrero, 2022; Paul, 2021; Madhok, 2021; Scott & Wilkinson, 2021; Bishop & Payne, 2021; Clift & Robles, 2021). Influenced by risk management policies, some changes in the structure of global financial flows and countries interdependence appear possible. This process is being referred to as re-globalization and its' need seems to be further highlighted by BREXIT and most recent Covid-19 pandemic. If slowbalization concept focuses on the slow-down of connectedness increase in a network-based context, re-globalization could be identified as a change in types, amounts and counterparties of foreign investments, which would reveal change in structure of global financial network. In order to manage excessive risks with one particularly risky or unstable counterparty, cross-border investments are being shifted either home (reshoring), somewhere else in the region (nearshoring) or to ally countries (friend shoring). However, presently, previous studies have not yet attempted to identify empirically whether structural changes, which happened after GFC are long-term and follow same pattern, or there are some changes with regard to post-GFC period events, thus representing a gap in empirical literature.

There is no widely accepted methodology to determine structure, its changes and its longevity in a network (Korniienko *et al.*, 2018). Network analysis of its' structure is mostly based on graphical network analysis (mapping and visualization) and topological analysis of various network measures related to number of nodes, edges, density, average in-degree /

out-degree, in-strength / out-strength, density, assortativity, clustering coefficient, dominance, reciprocity, interconnectedness, centrality (betweenness, closeness etc.) measures (Rahmede *et al.*, 2018; Del Rio-Chanona *et al.*, 2020; Silva *et al.*, 2016). Network visualization involves the representation of a network as nodes and edges, which facilitates the identification of patterns and structures of the network. Topological network structure analysis also focuses on most important and central nodes of whole network and compares various network measures of separate countries in network to reveal network structure and to compare it over time. Centrality measures such as degree centrality, betweenness centrality, and closeness centrality are used to identify the nodes with most influence in the network (Kostoska, 2020; Wang & Sun, 2021).

Recently, multilayer (or multiplex) network method has been started to be applied as an upgrade of previously applied monolayer networks in study fields like economics and finance (Del Rio-Chanona *et al.*, 2020; Korniyenko *et al.*, 2018), medicine (Kinsley *et al.*, 2020), data science (Tuninetti *et al.*, 2021) etc. Multilayer networks are an extension of ordinary (i.e., monolayer) networks that allow one to encode multiple types of edges, multiple subsystems, and other complications (Del Rio-Chanona *et al.*, 2020). Recent literature on multiplex financial networks in finance mostly focus on intra-layer and inter-layer propagation of contagions in multiplex financial networks (Del Rio-Chanona *et al.*, 2020). Multiplex network structure is analyzed fragmentally and mostly focuses on comparison of various whole network indicators similarly to monoplex networks. However, multiplex network analysis allows to take into account different layers thus revealing important features of certain financial investment network types. Bardoscia *et al* (2021) highlights that, different layers of a multiplex network are not structurally similar. For instance, Korniyenko *et al.* (2018) calculates basic structural multiplex network measures (diameter, edge density, mean geodesic distance, reciprocity, global clustering coefficient and mean local clustering coefficient) for 2009 and 2015 years to compare the global financial network structure. Their study finds that the structure of the global financial network has changed since GFC, impacted by European bank's deleveraging and higher corporate debt issuance. The most central countries remain the US and the UK, individual European countries have relatively low impact for shock propagation, but network is highly susceptible to shocks from the entire euro area. The rising role of Asian countries (China, Hong Kong SAR) is also noticeable.

Del Rio-Chanona *et al.* (2020) use MultiRank algorithm as a centrality measure for multiplex networks created by Rahmede *et al.* (2018) and find that several major European countries (Germany, Italy, Spain, France) decrease in rank and that several major Asian countries (Singapore, Hong Kong SAR, China) increase in rank since 2008. Bonaccorsi *et al.* (2019) also in their study use multiplex PageRank (MultiRank) and the multiplex hub and authority scores (MultiHub and MultiAuth) centrality measures to analyze the structure and evolution of multiplex network with 19 layers and 112 nodes to study the structure and evolution of the network. Bonaccorsi *et al.* (2019) results reveal that Yemen, the United Arab Emirates Ecuador and Paraguay, based on their multiplex ranking, are becoming more central.

Another measure that has been used to analyze different layers of the multiplex network, i.e., its structural changes, is average path length measure (Artime & De Domenico, 2021). This measure is used to assess the average distance between the nodes in the multiplex network. For example, Artime and De Domenico (2021) used the average path length measure to analyze the interdependencies between different layers. Artime and De Domenico (2021) find that aggregated versions of multiplex networks tend to overestimate robustness.

Thus, overall, multiplex network structure analysis is mostly based on graphical mapping and topological network measures comparison. Further, structural changes within the network are analyzed deeper by focusing on various country level network measures, most important and central nodes and correlations between them. Even though global financial system network structure, connectedness and resilience was analyzed extensively after GFC in 2008, post-GFC global financial system network structure longevity have not been addressed extensively in re-globalization context, thus representing a gap in empirical literature.

Research methods

Logic, methods and hypotheses

This research is performed in 3 stages for identification of multiplex financial network, topological analysis post-GFC global multiplex financial network connectedness and topological measures, and its structure longevity.

The first stage refers to graphical mapping analysis of global financial multiplex network. The second stage uses topological network measure analysis and third stage employs structural analysis methods, as presented in Table 1.

Stage 1 is aimed at mapping of global multiplex financial networks. In this study, we build 5-layer multiplex financial network based on 5 different types of financial assets: net direct investment in equity, net direct investment in debt, net portfolio investment in equity, net portfolio investment in debt, and net banking loans and deposits. We build networks for stock (positions) to capture the effect of overall position outstanding. Each country in the dataset is a node within the network. Directional links between nodes represent net cross-border investment claim positions outstanding from country j to country i . Links exist for strictly positive net positions, i.e., cross-border investment assets of a reporting country are higher than cross-border investment liabilities vis-à-vis another country ('net assets') channeled through financial system between the source and the destination country. All negative positions ('net liabilities') are replaced with zeros and ignored in the analysis, which is in line with the research of Minoiu and Reyes (2011). Missing data and data gaps were filled using mirror statistics. In a network, an edge from node i to node j in layer α indicates that country i has a net asset of type α in country j . Network is presented by the following matrix (adapted from Paltalidis *et al.*, 2015):

$$X^t = \begin{pmatrix} x_{11} & \cdots & x_{1j} & \cdots & x_{1N} & a_1 \\ \vdots & \ddots & \vdots & \ddots & \vdots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots & x_{iN} & a_i \\ \vdots & \ddots & \vdots & \ddots & \vdots & \vdots \\ x_{N1} & \cdots & x_{Nj} & \cdots & x_{NN} & a_N \\ l_1 & \cdots & l_j & \cdots & l_N & \end{pmatrix} \quad (1)$$

Thus, a country's total net assets are given by the sum of its row (assets minus liabilities) using the formula below:

$$a_j = \sum_{i=1}^N x_{ij}, \quad j = 1, \dots, N \quad (2)$$

A monolayer network $G = (V, E)$ consists of a set V of nodes and a set $E \subseteq V \times V - V$ of edges that connect the nodes to each other and, in contrast to monolayer networks, multilayer networks include 'layers' (which are used to encode different types of edges), node-layer tuples (i, α) that represent

node i on layer α , and both intra-layer and inter-layer edges. Diverse relationships between nodes are represented by intra-layer edges, which connect node-layer tuples within a layer, and inter-layer edges, which connect node-layer tuples from different layers. Such diversity of a financial sector network participants and their relationships create a very complex network structure and complex interconnections.

We construct multiplex financial network, which includes 5 layers, which are used to encode different types of edges and represent diverse relationship between nodes by intra-layer edges, which connect node-layer tuples within a layer, no inter-layer edges, which connect node-layer tuples from different layers, exist in our networks. In global financial multiplex network, each node represents a country and each layer represents an asset type (i.e., net investment in equity, debt and bank loans and deposits).

After that, mapping of the network is performed resulting in visual images of cross-border financial networks. Visual images of cross-border financial networks are drawn using network analysis software Arena3D, which allows to visually map different layers of global financial sector network.

In total, using these data sets, for each year, we construct 6 networks: (i) cross-border net direct investments in equity; (ii) cross-border net portfolio investments in equity; (iii) cross-border net portfolio investments in debt assets; (iv) cross-border net direct investments in debt assets; (v) cross-border net bank loans and deposits and (vi) aggregated network of bilateral international financial positions defined as a sum of the five individual networks as exhibited in Figure 1. 12 years are covered by analysis (2009-2020) resulting in total of 72 networks.

Stage 2 is aimed at revealing the results of multiplex network topological analysis. We aim to identify whether multiplex financial network connectedness and topological network measures exhibit changes during post-GFC period. Network connectedness is measured by network nominal value, network value as a percentage of world GDP and network density (actual connections divided by total possible connections). Network topological analysis include network measures: weak and strong component, mean distance, diameter, connected nodes, transitivity, clustering coefficient, efficiency and hierarchy. Weak components denote nodes which do not have two-way directed path between them, strong components denote nodes which do have two-way directed path between them. Mean distance is the average geodesic distance between pair of nodes in a network, while

diameter denotes the largest geodesic distance between pair of nodes in a network. Connected nodes represent connected nodes divided by total number of nodes. Transitivity is the ratio of total number of transitive triads to the total number of transitive and intransitive triads. Clustering coefficient is the ratio of the number of connections observed to the number of the maximum possible connections between its neighbor nodes. Efficiency of a network is inversely proportional to the distance of network (where distance is the shortest path between pair of nodes). Therefore, the bigger the distance between nodes, the less efficient their communication is. Hierarchy measure separates a network into distinct layers, where each layer has a series of functions that define its role in the network. The more such layers in a network, the higher its' hierarchy. These topological measures are calculated and compared over the period of analysis to reveal changes in connectedness and topological structure of global financial network.

In *Stage 3*, we aim to analyze network structure longevity by layer and country. We calculate network structure by layer and compare it over period of analysis to reveal some structural changes and evaluate its longevity. We also calculate network structure by country from debtor (in-degree) and creditor (out-degree) perspectives. We use weighted in-degree and weighted out-degree network measures, which represent value of total links emanating from particular country (weighted out-degree) and value of links leading to particular country (weighted in-degree) and calculate such measures for countries, which have highest structure proportion.

For Hypothesis 1 testing we use ANOVA multiple comparison test for statistical significance analysis, where p-values are calculated using the formula for each pair (Shein-Chung *et al.*, 2002):

$$p - value = \frac{\bar{x}_1 - \bar{x}_2}{\frac{\sigma}{\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}} \quad (3)$$

where \bar{x}_1 is first year period mean, σ – standard deviation, \bar{x}_2 – second year period mean, n_1 – number of observations of first sample period, n_2 – number of observations of second sample period. For Hypothesis 2, 3 and 4 testing, we use Paired t test for statistical significance analysis, where p-values are calculated using the same Formula 3.

We focus our empirical research on post-GFC period, as GFC period was analyzed extensively in prior literature. We aim to analyze whether

financial sector network structural changes, which happened after GFC are long-term, which might indicate a shift in structure of globalization.

We construct several hypotheses to be tested during *Stage 2* and *Stage 3*. Firstly, discussions in previous research are ongoing regarding the change in cross border financial positions with regard to financial globalization. According to Bremus and Fratzscher (2015), connectedness within the global financial network has decreased since 2007–2008 GFC and cross-border foreign claims have not increased significantly during the recovery of the economy. On contrary, Lund *et al.* (2017) argues that financial globalization in terms of stock of foreign investment is not over, but rather a more risk-sensitive, rational, and ultimately more resilient version of global financial globalization is emerging. This trend of stock positions increasing, but just at a slower pace than before GFC has been referred to as slowbalization (Kandil *et al.*, 2020; Ghauri *et al.*, 2021; Garcia-Herrero, 2022) in previous literature. To test it, the first research hypothesis is formulated as follows:

Hypothesis 1: Multiplex financial network aggregate connectedness increased during post-GFC period until Covid-19 pandemic period.

We calculate aggregate and by layer network density and value (nominal and as percentage of GDP) in 2009 and compare it with post-GFC aggregate network density to check whether global financial sector network connectedness, as measured by network density and value, increased until Covid-19 pandemic period. In case at least one of indicators used, i.e., density, nominal value and value as % of GDP, for at least one year mean comparison differs significantly from base 2009 year, hypothesis 1 is accepted.

Secondly, we aim to analyze network topology. Previous research reveals shifts in the structure of the stock of foreign investment (Lane & Milesi-Ferretti, 2017; Lund *et al.*, 2017) and that network topology has changed (Korniyenko *et al.*, 2018; Del Rio-Chanona *et al.*, 2020). Hence, the second research hypothesis is formulated as follows:

Hypothesis 2: Multiplex financial network topology changed during post-GFC period until Covid-19 pandemic period.

In case at least one of network topology measures used differ significantly between 2009 and 2020 year, hypothesis 2 is accepted.

Next, we focus our analysis multiplex financial network layer structure and its longevity. Previous research reveals shifts in the structure of the stock of foreign investment by types of investment. According to Lane and Milesi-Ferretti (2017), cross-border FDI positions have continued to expand, unlike positions in portfolio instruments and other investment after GFC. A reduction in cross-border lending was compensated by 16% increase of FDI comparing 2007 and 2016 (Lund *et al.*, 2017). To test it, the third research hypothesis is formulated as follows:

Hypothesis 3: Multiplex financial network layer structure changed during post-GFC period until Covid-19 pandemic period.

In case at least for one of layers, mean comparison between year groups 2009–2011 and 2018–2020 differ significantly, hypothesis 3 is accepted. Finally, we aim to analyze multiplex financial network country structure longevity. Previous research shows that advanced economies and international financial centers are the most highly integrated into the global system, but China and other developing countries are becoming more and more connected (Lund *et al.*, 2017) and less dependent on major economies (Cerutti & Zhou, 2017). Thus, fourth hypothesis is formulated as follows:

Hypothesis 4: Multiplex financial network countries' structure changed during post-GFC period until Covid-19 pandemic period.

This fourth hypothesis would aim to test countries' structure longevity within multiplex financial network considering period from post-GFC until Covid-19 pandemic. In case at least for one of countries used, mean comparison between year groups 2009–2012 and 2017–2020 or 2009–2014 and 2015–2020 differ significantly, hypothesis 4 is accepted.

Data

5-layer multiplex financial network is built based on 5 different types of financial assets: net direct investment in equity, net direct investment in debt, net portfolio investment in equity, net portfolio investment in debt, and net banking loans and deposits for the period 2009–2020 for a total sample of 234 countries including territorial entities that are not states as

understood by international law and practice, i.e., dependent territories, see Table 2.

Data of net direct investments in equity and debt positions data is gathered from Coordinated Direct Investment Survey (hereinafter — CDIS) database published by International Monetary Fund (IMF). Direct investment arises when an investor resident in one economy makes an investment that gives control or a significant degree of influence over the management of an enterprise that is resident in another economy (DataBank, The World Bank, 2022).

Portfolio equity and debt investment net positions data is gathered from Coordinated Portfolio Investment Survey (hereinafter — CPIS) database published by International Monetary Fund (IMF). Portfolio investment is defined as cross-border transactions and positions involving equity and debt securities, other than those included in direct investment or reserve assets (DataBank, The World Bank, 2022).

Banking loans and deposits is gathered from Bank for International Settlements database. The main part of foreign positions consists of standard cross-border loans issued by banks in a reporting country vis-à-vis banks and non-bank institutions in a recipient country. We choose to work with the residence base data (Locational banking statistics (hereinafter — LBS) by residence) to be able to match the BIS banking statistics with the IMF's CDIS and CPIS survey data by country to go beyond the analysis of bank data only.

Private financial flows — equity and debt — account for the bulk of development finance. Equity flows comprise foreign direct investment (FDI) and portfolio equity. Debt flows are financing raised through bond issuance, bank lending, and supplier credits (DataBank, The World Bank, 2022). Data availability and gaps, as well as the fit of the data for the analysis of global financial interconnectedness and shock propagations has been discussed in length in Cerutti and Zhou (2017), Kubelec and Sa (2010), Milesi-Ferretti and Tille (2011b), Lane and Milesi-Ferretti (2017).

Limitation of this research is that it includes only positive cross-border banking claim positions, i.e., net positions of a reporting country vis-à-vis another country ('net assets') were used. All negative positions ('net liabilities') were replaced with zeros and ignored in the analysis in line with the research of Minoiu and Reyes (2011). However, as pointed out by Minoiu and Reyes (2011), the network of negative positions could reveal interesting patterns in capital movements.

Research is limited by the data period available, i.e., post-GFC period from 2009 until 2020 could only be covered in this research as latest data of 2021–2023 is not yet available. Future research could include 2021–2023 period data into analysis allowing to better identify Covid-19 pandemic influence on global financial network, to analyze the war in Ukraine impact on global investment network structure and to check whether post-GFC structure tends to maintain its longevity over these periods. As Covid-19 pandemic and war in Ukraine has affected global financial network worldwide, data analysis including these periods could enhance the research and could reveal some further changes in re-globalization pattern.

Our methodology is limited by data availability and gaps, which are caused by cross-border financial sector investment claim positions data not provided by some countries or suppressed due to confidentiality reasons. 129 countries report for CDIS their inward and outward direct equity and debt positions. For remaining countries mirror data from reporting countries is used. In this research, we used outward positions as more countries report their outward positions than inward. 93 countries report for CPIS their asset and liability positions of debt and equity. The remaining non-reporting countries have mostly only their liability data (mirrored from reporting countries assets). In certain cases, where either asset or liability position data was not provided, no net asset data was calculated. Therefore, for non-reporting countries, mirror data from reporting countries was used where possible. 43 countries report their Locational banking statistics for BIS throughout 2009–2020. For non-reporting countries or reporting, but for which data was not provided, mirror data was used where possible. Overall number of countries included in network constitute 234 and was limited by data availability as per databases.

Results

Stage 1. Multiplex financial network mapping

Initially, multiplex global financial networks in 2009 and 2020 consisting of 5 layers (net direct investment in equity, net direct investment in debt, net portfolio investment in equity, net portfolio investment in debt, and net banking loans and deposits) are mapped. Refer to Figure 2 for graphical drawing of multiplex global financial networks. Bank loans and deposits

(BIS) layer appears to have changed the least comparing 2009 and 2020 as the number of countries within this layer increased by +3. Number of countries in 2020 increased in every layer (net direct investment in equity (CDIS equity) by +9, net direct investment in debt (CDIS debt) by +24, net portfolio investment in equity (CPIS equity) by +9, net portfolio investment in debt (CPIS debt) by +17). However, increase is the highest in CDIS debt layer where +24 countries joined the network. In terms of network connections, even though they increased in all layers, biggest increase in average degree is in net direct investment in equity (CDIS equity) layer, i.e., from 15.55 in 2009 to 24.44 in 2020. The lowest increase in average degree is observed in net portfolio investment in equity (CPIS equity) layer by +1.9 (from 9.51 in 2009 to 11.41 in 2020). Network value as a percentage of world GDP for aggregated network also increased from 83.3 % in 2009 to 101.9 % in 2020. Overall, increase in network countries and connections comparing 2009 and 2020 is observed in all layers of multiplex global financial network as well as in aggregate global financial network. Also, network value as a percentage of world GDP increase for aggregate network comparing 2009 and 2020 is observed, suggesting increase in connectedness within global financial network.

Stage 2. Topological analysis of multiplex network

Step 2.1. Analysis of multiplex financial network connectedness

For measuring the level of connectedness in the multiplex global financial network, network's density, network nominal value in US dollars as well as network value as a percentage of world GDP, to capture real increase in network value, measures are calculated for 2009 and 2020. The results of calculations are provided in Figure 3. The results reveal that network density increased in all multiplex global financial network layers as well as in aggregated network. Largest increase in density observed for net direct investment in equity (CDIS equity) layer by +3.8 percentage points (hereinafter — pp), while the lowest for net portfolio investment in equity (CPIS equity) by +0.8 pp. Thus overall, global multiplex financial network connectedness, as measured by number of connections, increased during post-GFC period until Covid-19 pandemic period in 2020. Connectedness in terms of network value also reveals increase in all multiplex global financial network layers as well as in aggregated network. Structurally, CDIS

equity layer has the most connections, which have the largest value. Even though bank loans and deposits (BIS) layer have high network value, its density increased by only +1.1 pp. Portfolio equity and debt investment networks' density increased moderately by +0.8 and +2.2 pp, respectively, while its network value increased by +9.3 and +4.5 trillion of US dollars, respectively. Network value as a percentage of world GDP decreased for bank loans and deposits (BIS) layer by -3.3 pp and for net direct investment in debt layer by -0.3 pp, comparing 2009 and 2020, but increased for all other layers, i.e., net direct and portfolio investment in equity by +13.7 pp and + 7.8 pp, respectively, and for net investment in portfolio debt by +0.9 pp. Such results suggest that somewhat changed financial globalization is continuing after GFC and does not suggest deglobalization trend during post GFC period in terms of net investment stock (positions) network.

In order to calculate significance of density, network nominal value and network value as percentage of world GDP increase, we take 2009 year as a base year for comparison of layer means with period ranging 2010–2020, to test if density means of all layers for each year differ significantly from 2009. Mean difference test results are provided in Table 3. Mean comparison results reveal that density mean in 2009 is significantly lower compared to all years in the period 2013–2020. In other words, post-GFC network density still exhibited density close to 2009 until 2012, but its density increased significantly from 2013 onwards. Network nominal value mean comparison results reveal that 2019–2020 nominal network value is higher than 2009 from 2019 onwards. However, network real value (i.e., as a percentage of GDP), even though higher than 2009, does not differ significantly in 2010–2020 from 2009. Such results suggest that network value may be significantly affected by inflation. Thus overall, global multiplex financial network connectedness, as measured by number of connections (network density) and network value increased significantly starting from 2013 (density) and 2019 (network value) during post-GFC period until Covid-19 pandemic period in 2020. Therefore, Hypothesis 1 is accepted.

Step 2.2. Analysis of multiplex network topological measures

For the comparison of the multiplex global financial network structure, we calculate topological structure network measures for 2009 and 2020 years. In Table 4, we summarize component and distance measures for weighted and directed networks. As exhibited in Table 4, the number of

weak components decreased in 2020 as compared to 2009 in all layers of multiplex global financial network as well as in aggregate network. Number of strong components also decreased in all layers despite net bank loans and deposits (BIS) layer, i.e., from 51 in 2009 to 54 in 2020. Decreased of weak and strong components in a network suggest that previously weakly connected countries become more connected and vice versa — previously reciprocally connected countries become less connected. Network diameter did not change for BIS, CDIS equity, CPIS debt and aggregated networks, but decreased for CDIS debt and CPIS equity layers. Such results suggest that countries have decreased distance vis-à-vis countries further away from each other in net direct investments in debt (CDIS debt) and net portfolio investments in equity (CPIS equity) layers. Connected nodes' part from all nodes also increased for all layers. Such trends suggest that some structural changes might have happened within multiplex global financial as numbers of strongly and weakly connected countries decreased, i.e., weakly connected countries became stronger and strongly connected — weaker, and more countries became included in network.

Selected network measures of transitivity, clustering coefficient, efficiency and hierarchy are provided in Table 5. Transitivity also increased in majority of layers despite CDIS debt and CPIS equity layers, where it decreased by -0.01 and -0.04, respectively. Clustering coefficient decreased in BIS, CPIS debt and aggregated networks, by -0.02, -0.01 and -0.01, respectively. Increase is observed in CDIS debt and CPIS equity layers, by +0.04, +0.03, respectively. Network efficiency decreased in almost all layers despite CPIS equity, where it remained unchanged. Largest decrease in network efficiency could be observed in CDIS equity and aggregated networks, i.e., -0.04. Hierarchy network measure increased in BIS and aggregated networks in 2020 as compared with 2009, by +0.05, +0.02, respectively. Highest decrease in network hierarchy observed in CDIS equity by -0.07. Thus, overall multiplex global financial network became more transitable and hierarchical, but less clustered and efficient in 2020 comparing with 2009.

In order to check whether topological network structure measures' layer means are different comparing 2009 and 2020, significance statistics are calculated, see Table 6. Analysis reveals that weak components, mean distance, connected nodes to all nodes and efficiency topological network structure measures layer means differ significantly, thus suggesting that

some structural changes happened within multiplex global financial network. Therefore, Hypothesis 2 is accepted.

Stage 3. Analysis of multiplex financial network structure longevity

Step 3.1. Layer structure longevity

Further, we perform multiplex network layer structure longevity over the period 2009–2020 analysis. First, changes in structure for each year is computed, then, layer structure in aggregate network for each year is calculated. Network layer structure for 2009–2020 is provided in Figure 4 bottom right. Yearly changes in structure for each layer are provided in top left (equity), top right (banking) and bottom left (debt). Network structure results reveal that equity layer had increasing trend from 2009 until 2017, but started to decrease from 2018 onwards. On contrary, banking and debt layers had decreasing trend from 2009 until 2017, but started to increase from 2018 onwards. Thus, graphical analysis of layer structure longevity suggests that important changes in layer structure might have started in 2018. In order to test it, we separate year periods into two groups, i.e., 2009–2011 and 2018–2020 and calculate means of structure for each layer. We then calculate mean differences between two year-groups for each layer and its statistical significance. Calculation results are provided in Table 7. Results reveal that structure means between groups 2009–2011 and 2018–2020 differ significantly for equity, debt and banking layers. Thus, overall, multiplex network layer structure changed during post-GFC period starting from 2018 until Covid-19 pandemic period in 2020 with equity decreased in structure, while debt and banking layers increased in structure. Therefore, Hypothesis 3 is accepted.

Step 3.2. Countries' structure longevity

Next, we aim to analyze countries' structural position longevity within multiplex network. We calculate network structure by country from debtor (in-degree) and creditor (out-degree) perspectives. We use weighted in-degree and weighted out-degree network measures, which represent value of total links emanating from particular country (weighted out-degree) and value of links leading to particular country (weighted in-degree). We then calculate countries' with the highest structure debtor (weighted in-degree)

and creditor (weighted out-degree) structure rankings in aggregate network for each year (see Figure 5). As exhibited in Figure 5, network structure ranking results reveal that average countries' weighted in-degree structure had decreasing trend from 2009 until 2014, but started to increase from 2015 onwards. Average countries' weighted out-degree structure had less decreasing trend from 2009 until 2016, but started to decrease more from 2017 onwards. Based on such trend groups, we calculate weighted out-degree and weighted in-degree structure mean differences for selected countries, see Table 8. Results reveal that for Hong Kong SAR, Ireland, Cayman Islands and China, weighted out-degree structure has significantly increased comparing 2009–2012 and 2017–2020 periods and for United Kingdom significantly decreased. Regarding weighted in-degree structure, it has significantly increased comparing 2009–2014 and 2015–2020 periods and for Japan, Ireland, Switzerland, Singapore and China, and significantly decreased for Germany.

Thus, results suggest that developed countries United Kingdom, Germany might be decreasing in multiplex financial network structure, while developing, especially from Asia region (i.e., Hong Kong SAR, China and Singapore) might be increasing. Therefore, Hypothesis 4 is accepted.

Discussion

Our analysis confirms no deglobalization in terms of stock (positions) network aggregate connectedness, i.e., density and value. These results are in line with Lund *et al.* (2017), who identified that global stock of foreign investment relative to GDP has changed little since 2007 and more countries are participating. Thus, even though cross-border capital flows after GFC declined 65 % since 2007, which was referred to as deglobalization, in terms of stock (positions) globalization is still present.

Further, during our analysis, it was identified that multiplex financial network topology changed during post-GFC period until Covid-19 pandemic period. Such trend suggest that some structural changes might have happened within multiplex global financial as number of strongly and weakly connected countries decreased, i.e., weakly connected countries became stronger and strongly connected — weaker, and more countries became included in network. These results are in line with latest scientific discussions highlighting the possible process of deep change in globaliza-

tion, phenomenon has been currently referred to as re-globalization (Paul, 2021; Madhok, 2021; Scott & Wilkinson, 2021; Bishop & Payne, 2021; Clift & Robles, 2021). Our research results are also supported by Korniyenko *et al.* (2018), who using same multiplex financial network method found that the structure of the global financial network has changed since GFC and that the most central countries remain the US and the UK, but the rising role of Asian countries (China, Hong Kong SAR) is also noticeable.

Previous research mostly analyzed network structure from connectedness and network topological measures perspective (Korniyenko *et al.*, 2018), however, network layer and country structure have not been analyzed extensively. Our analysis has revealed that multiplex financial network layer and country structure changed during post-GFC period until Covid-19 pandemic period. Banking and debt investments are increasing since 2018, while equity part is decreasing. Also, developed countries, i.e., the United Kingdom and Germany, decrease in multiplex financial network structure, while developing, especially from Asia region (i.e., Hong Kong SAR, China and Singapore) increase, with change starting significantly in 2015–2017. These results further support re-globalization in terms of investment type and counterparty structure revealing that it might have started during post-GFC period and might be further highlighted by BREXIT and Covid-19 pandemic.

Novelty of our research includes holistic overview of post-GFC multiplex financial network structure longevity due to long period of analysis and a global set of countries. We analyze globalization from its restructurization perspective as a result of re-globalization. We take into account not only connectedness and network topology to reveal structure changes, but also analyze investment type structure and country importance within the network. We add to previous literature by analyzing empirically current re-globalization megatrend.

Our research results imply some important potential strategy recommendations for investors. As developing countries attract more and more investment and further develop, global cost saving and returns from global investment into these countries may be decreasing, resulting in lower gain from globalization. Such trend may influence deglobalization and localization trends, but it may result in lower overall wealth of investors and countries. Thus, in such case ally (friend shoring) investment strategy could help to manage the risk of over dependency from unstable counterparty while preserving globalization wealth. Investment strategies of investors

from small economies could also follow same strategy to preserve gains from globalization, however, these countries may have more limited abilities to follow it, due to dependence and interconnectedness with dominating countries.

Future studies could prolong research period incorporating data from Covid-19 pandemic and war in Ukraine, which could further reveal some interesting re-globalization tendencies. Pandemic has further exhibited drawbacks of high interconnectedness, which were revealed after GFC. Dependency especially with one particularly risky or unstable counterparty might result in cross-border investments being shifted either home (reshoring), somewhere else in the region (nearshoring) or to ally countries (friend shoring). While our research reveals some structural re-globalization shifts in investment and counterparty structure, it also uncovers some regional trends of Asia region increasing in investment network structure, while Europe decreasing. Thus, future research could aim to analyze whether some regionalization patterns are forming within multiplex financial network.

Conclusions

Literature analysis reveal that currently there are many discussions regarding globalization, i.e., whether it is in deglobalization, slowbalization or re-globalization trend. While deglobalization and slowbalization focus on the speed of globalization, re-globalization denotes some deep change in structure of globalization. Even though financial system network structure, connectedness and resilience was analyzed extensively after GFC in 2008, post-GFC global financial system network structure longevity has not been addressed extensively in re-globalization context, thus representing a gap in empirical literature.

In order to analyze multiplex financial network structure and its longevity, we build multiplex financial network based using 5 layers (different types of financial assets): net direct investment in equity, net direct investment in debt, net portfolio investment in equity, net portfolio investment in debt, and net banking loans and deposits for the period 2009–2020 for 234 countries. We measure multiplex financial network connectedness, topological structure and perform layer and country structure longevity analysis.

Analysis reveals that stock (positions) multiplex financial network aggregate connectedness, i.e., density and value, increased during post-GFC period until Covid-19 pandemic period, thus, suggesting that globalization in terms of stock is continuing. Further on, it was identified that multiplex financial network topology changed as number of strongly and weakly connected countries decreased and more countries became included in network. These results support a possible re-globalization as a deep change in structure of globalization.

Longevity analysis of layer and country structure within multiplex financial network reveal that banking and debt investments are increasing since 2018, while equity part is decreasing. Developed countries, i.e., the United Kingdom and Germany, decrease in multiplex financial network structure, while developing, especially from Asia region (i.e., Hong Kong SAR, China and Singapore) increase. These results further support re-globalization in terms of investment type and counterparty structure and reveals that it might have started already during post-GFC period. Research also uncovers some regional trends of Asia region increasing in investment network structure, while Europe decreasing.

Limitations of this research include the data period available 2009–2020. Thus, we are not able to cover fully Covid-19 pandemic and the war in Ukraine data, which would enhance the analysis taking into account the influence of these disruptive events on global financial network. In addition, in our multiplex financial network, we include 5 layer of different investment types, however, future research could include also trade data.

With regard to investment strategy recommendations for dominating and small economies, as global cost saving and returns from global investment into developing countries may be decreasing, in such case ally (friend shoring) investment strategy could help to manage the risk of over dependency from unstable counterparty while preserving globalization wealth.

Our research contributes to previous research by analyzing post-GFC multiplex financial network structure over a long period for a global set of 243 countries using a complex multiplex network method. In addition, we analyze multiplex financial network structure longevity empirically in a recent context of re-globalization. Extensive analysis period and re-globalization context enhances previous research and allows to understand structural changes more comprehensively.

Future research could aim to analyze how re-globalization is influenced by Covid-19 pandemic and the war in Ukraine by extending research period. In addition, future studies could analyze what are the counterparties of main network countries in terms of structure, i.e., whether investments remain within region or are made intra-regionally, which would allow to further investigate possible nearshoring or friend shoring patterns of re-globalization, i.e., to analyze regionalization as a possible scenario of re-globalization.

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Annex

Table 1. Logics of the research

| Stages | <i>Stage 1.</i> Identification of multiplex financial network | <i>Stage 2.</i> Multiplex financial network topological analysis | <i>Stage 3.</i> Analysis of multiplex financial network structure longevity |
|----------------|---|---|--|
| Steps | 1. 1. Multiplex financial network mapping | 2.1. Analysis of multiplex financial network connectedness (Hypothesis 1) 2.2. Analysis of multiplex network topological measures (Hypothesis 2) | 3.1. Analysis of multiplex network layer structure longevity (Hypothesis 3) 3.2. Analysis of multiplex network country structure longevity (Hypothesis 4) |
| Methods | Mapping of networks | Topological network structure analysis | Structure longevity analysis |
| Data | Bilateral cross-border investment claim positions | Global banking network matrices | Global banking network matrices |

Table 2. Main characteristics of research sample

| No. | Layer | Asset type | Countries* | Data source |
|------------|--------------|------------------------------------|-------------------|-----------------------------|
| 1 | BIS | Net bank loans and deposits | 208 | BIS LBS by residence (2020) |
| 2 | CDIS equity | Net direct investment in equity | 227 | CDIS (2020) |
| 3 | CDIS debt | Net direct investment in debt | 213 | CDIS (2020) |
| 4 | CPIS equity | Net portfolio investment in equity | 201 | CPIS (2020) |
| 5 | CPIS debt | Net portfolio investment in debt | 201 | CPIS (2020) |
| 6 | Aggregate | All above aggregated | 234 | BIS, CPIS, CDIS (2020) |

Note:* The terms 'country' and 'economy' do not always refer to a territorial entity that is a state as understood by international law and practice (BIS convention, 2020). Sometimes an economy has a separate physical or legal zone that is under its control, but to which, to some degree, separate laws are applied (e.g., a free trade zone or offshore financial center) (CDIS guide, 2015). Nevertheless, if statistical data for territorial entities that are not states are maintained on a separate and independent basis, such territorial entities are included in the analysis.

Source: Compiled by authors based on BIS LBS by residence (2020), CPIS (2020) and CDIS (2020).

Table 3. Network value, network value as % of world GDP and network density layer mean difference for 2009 compared with 2010–2020 networks

| (I) Year of comparison | (J) Year | Network value, trillion of US dollars | | Network value, % of world GDP | | Network density, % | |
|------------------------|----------|---------------------------------------|---------|-------------------------------|---------|-----------------------|---------|
| | | Mean Difference (J-I) | P-value | Mean Difference (J-I) | P-value | Mean Difference (J-I) | P-value |
| 2009 | 2010 | 0.495 | 1.000 | -0.011 | 1.000 | 0.004 | 0.978 |
| | 2011 | 0.955 | 1.000 | -0.027 | 1.000 | 0.006 | 0.701 |
| | 2012 | 1.675 | 0.997 | -0.016 | 1.000 | 0.008 | 0.202 |
| | 2013 | 2.469 | 0.942 | -0.006 | 1.000 | 0.010* | 0.047 |
| | 2014 | 2.863 | 0.858 | -0.005 | 1.000 | 0.012** | 0.004 |
| | 2015 | 2.923 | 0.842 | 0.013 | 1.000 | 0.016** | 0.000 |
| | 2016 | 3.283 | 0.722 | 0.016 | 1.000 | 0.018** | 0.000 |
| | 2017 | 5.260 | 0.109 | 0.039 | 0.997 | 0.020** | 0.000 |
| | 2018 | 4.747 | 0.207 | 0.010 | 1.000 | 0.021** | 0.000 |
| | 2019 | 5.819* | 0.049 | 0.026 | 1.000 | 0.022** | 0.000 |
| | 2020 | 7.293** | 0.004 | 0.062 | 0.901 | 0.021** | 0.000 |

Note: Significance statistics p-value shown in the table, * and ** denote significance levels of 5 % and 1 %, respectively.

Source: Own calculations based on BIS LBS by residence data (2020), CPIS (2020), CDIS (2020).

Table 4. Component and distance measures for 2009 and 2020 networks

| Network | Weak components | | Strong components | | Mean distance | | Diameter | | Connected nodes | |
|-------------|-----------------|------|-------------------|------|---------------|------|----------|------|-----------------|------|
| | 2009 | 2020 | 2009 | 2020 | 2009 | 2020 | 2009 | 2020 | 2009 | 2020 |
| BIS | 33 | 30 | 51 | 54 | 2.19 | 2.11 | 4 | 4 | 0.86 | 0.88 |
| CDIS equity | 23 | 14 | 56 | 39 | 2.16 | 1.99 | 4 | 4 | 0.91 | 0.94 |
| CDIS debt | 49 | 25 | 82 | 57 | 2.41 | 2.16 | 6 | 4 | 0.79 | 0.90 |
| CPIS equity | 57 | 38 | 168 | 161 | 2.24 | 2.11 | 7 | 5 | 0.76 | 0.84 |
| CPIS debt | 56 | 39 | 169 | 159 | 2.03 | 2.03 | 5 | 5 | 0.76 | 0.84 |
| Aggregated | 12 | 4 | 27 | 22 | 1.96 | 1.85 | 4 | 4 | 0.95 | 0.99 |

Source: Own calculations based on BIS LBS by residence data (2020), CPIS (2020), CDIS (2020) and network software Netminer.

Table 5. Network measures for 2009 and 2020 networks

| Network | Transitivity | | Clustering coefficient | | Efficiency | | Hierarchy | |
|-------------|--------------|------|------------------------|------|------------|------|-----------|------|
| | 2009 | 2020 | 2009 | 2020 | 2009 | 2020 | 2009 | 2020 |
| BIS | 0.20 | 0.24 | 0.84 | 0.82 | 0.94 | 0.93 | 0.17 | 0.21 |
| CDIS equity | 0.40 | 0.41 | 0.72 | 0.72 | 0.92 | 0.89 | 0.28 | 0.20 |
| CDIS debt | 0.38 | 0.37 | 0.63 | 0.67 | 0.94 | 0.92 | 0.31 | 0.27 |
| CPIS equity | 0.47 | 0.43 | 0.79 | 0.82 | 0.94 | 0.94 | 0.77 | 0.77 |
| CPIS debt | 0.47 | 0.56 | 0.84 | 0.83 | 0.93 | 0.91 | 0.77 | 0.76 |
| Aggregated | 0.47 | 0.51 | 0.83 | 0.82 | 0.86 | 0.82 | 0.13 | 0.14 |

Source: Own calculations based on BIS LBS by residence data (2020), CPIS (2020), CDIS (2020) and network software Netminer.

Table 6. Topological network structure measures layer mean difference comparison for 2009 and 2020 networks

| | Mean 2009 (I) | Mean 2020 (J) | Mean difference (J-I) | P-value |
|------------------------------|---------------|---------------|-----------------------|---------|
| Weak components | 43.60 | 29.20 | -14.400* | 0.018 |
| Strong components | 105.20 | 94.00 | -11.200 | 0.076 |
| Mean distance | 2.20 | 2.08 | -0.125* | 0.041 |
| Diameter | 5.20 | 4.40 | -0.800 | 0.178 |
| Connected nodes to all nodes | 0.82 | 0.88 | 0.062* | 0.018 |
| Transitivity | 0.38 | 0.40 | 0.020 | 0.426 |
| Clustering coefficient | 0.76 | 0.77 | 0.010 | 0.483 |
| Efficiency | 0.93 | 0.92 | -0.018* | 0.043 |
| Hierarchy | 0.46 | 0.44 | -0.017 | 0.442 |

Note: Significance statistics p-value shown in the table, * and ** denote significance levels of 5 % and 1 %, respectively.

Source: Own calculations based on BIS LBS by residence data (2020), CPIS (2020), CDIS (2020).

Table 7. Descriptive statistics for 2009–2011 and 2018–2020 networks by layer

| | Min | Min | Max | Max | Mean | Mean | Std. Dev. | Std. Dev. | Mean |
|---------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|------------|
| | 2009-2011 | 2018-2020 | 2009-2011 | 2018-2020 | 2009-2011 | 2018-2020 | 2009-2011 | 2018-2020 | difference |
| Equity | 0.493 | 0.613 | 0.633 | 0.628 | 0.570 | 0.620 | 0.020 | 0.010 | -0.106** |
| p-value | | | | | | | | | 0.014 |
| Debt | 0.206 | 0.208 | 0.250 | 0.212 | 0.230 | 0.210 | 0.020 | 0.010 | 0.039* |
| p-value | | | | | | | | | 0.000 |
| Banking | 0.161 | 0.164 | 0.257 | 0.177 | 0.200 | 0.170 | 0.000 | 0.000 | 0.067 |
| p-value | | | | | | | | | 0.037 |

Note: Significance statistics p-value shown in the table, * and ** denote significance levels of 1 % and 5 %, respectively.

Source: Own calculations based on BIS LBS by residence data (2020), CPIS (2020), CDIS (2020).

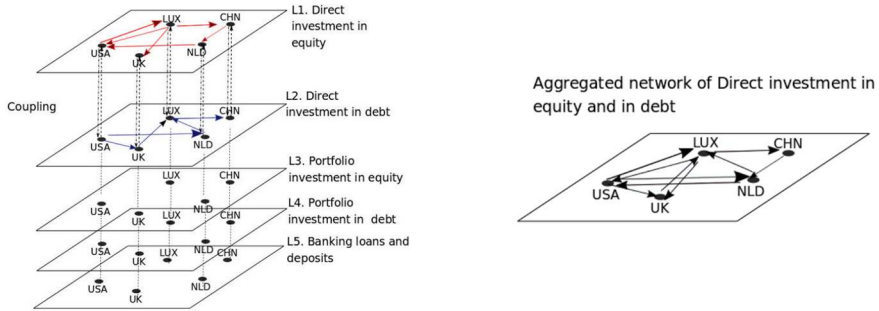
Table 8. Weighted out-degree and weighted in-degree structure period mean difference comparison

| | Weighted out-degree structure | | | | Weighted in-degree structure | | | |
|----------------|-------------------------------|--------------------|-----------------------|---------|------------------------------|--------------------|-----------------------|---------|
| | Mean 2009-2012 (I) | Mean 2017-2020 (J) | Mean difference (J-I) | P-value | Mean 2009-2014 (I) | Mean 2015-2020 (J) | Mean difference (J-I) | P-value |
| United States | 0.046 | 0.044 | -0.002 | 0.966 | 0.035 | 0.042 | 0.007 | 0.856 |
| Luxembourg | 0.080 | 0.099 | 0.020 | 0.055 | 0.070 | 0.081 | 0.011 | 0.092 |
| Japan | 0.089 | 0.085 | -0.003 | 0.060 | 0.019 | 0.024 | 0.006** | 0.004 |
| Netherlands | 0.088 | 0.082 | -0.006 | 0.116 | 0.071 | 0.071 | -0.001 | 0.831 |
| France | 0.087 | 0.066 | -0.021 | 0.103 | 0.04 | 0.036 | -0.003 | 0.069 |
| Germany | 0.081 | 0.069 | -0.012 | 0.092 | 0.038 | 0.028 | -0.010* | 0.012 |
| Hong Kong SAR | 0.030 | 0.043 | 0.013** | 0.000 | 0.022 | 0.028 | 0.006 | 0.108 |
| United Kingdom | 0.067 | 0.042 | -0.025* | 0.012 | 0.093 | 0.086 | -0.007 | 0.165 |
| Ireland | 0.025 | 0.035 | 0.010* | 0.028 | 0.023 | 0.032 | 0.009** | 0.004 |
| Switzerland | 0.032 | 0.03 | -0.001 | 0.230 | 0.027 | 0.029 | 0.002** | 0.002 |
| Cayman Islands | 0.014 | 0.019 | 0.005** | 0.000 | 0.127 | 0.145 | 0.018 | 0.526 |
| Singapore | 0.013 | 0.016 | 0.003 | 0.168 | 0.012 | 0.016 | 0.004* | 0.034 |
| China | 0.010 | 0.013 | 0.003** | 0.001 | 0.031 | 0.038 | 0.007* | 0.050 |

Note: Significance statistics p-value shown in the table, * and ** denote significance levels of 5 % and 1 %, respectively.

Source: Own calculations based on BIS LBS by residence data (2020), CPIS (2020), CDIS (2020).

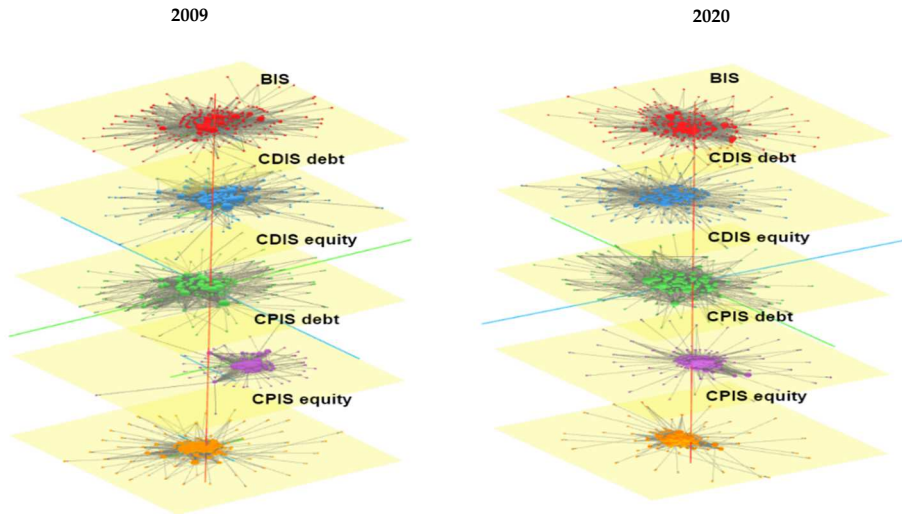
Figure 1. Schematic representation of a multiplex and aggregated networks of the global financial system



Note: On the right, a schematic network example is shown that corresponds to the aggregation of the first two layers (direct investments in equity and debt). When two edges (with same direction) overlap the weights are summed up and a single edge is kept.

Source: Korniyenko *et al.* (2018).

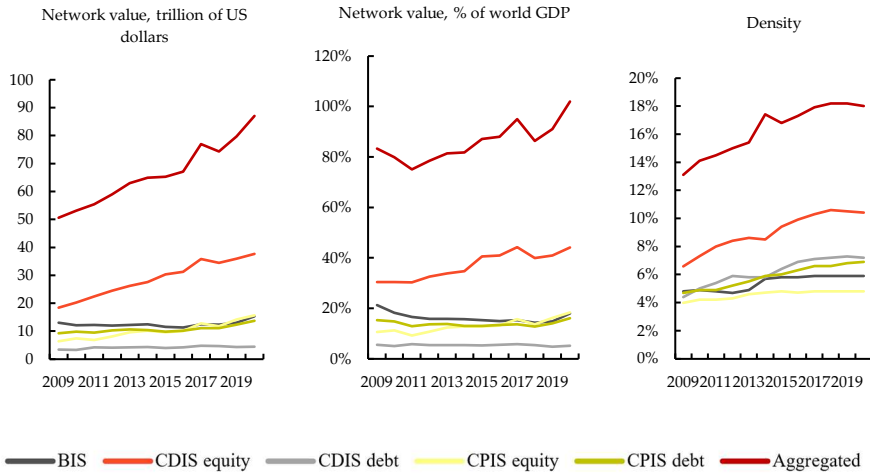
Figure 2. Multiplex 5-layer global financial networks in 2009 and 2020



Note: Node color depends on the layer: red – net bank loans and deposits, blue – net direct debt, green – net direct equity, purple – net portfolio debt and orange – net portfolio equity. Node size depends on the node degree metric (larger nodes – higher node degree metric). Networks are drawn based on Kamada-Kawai algorithm in Arena3D. Networks are directed and weighted.

Source: Own calculations based on BIS LBS by residence data (2020), CPIS (2020), CDIS (2020) and network software Arena3D.

Figure 3. Network value, network value as % of world GDP and network density for layers and aggregate network 2009–2020



Source: Own calculations based on BIS LBS by residence data (2020), CPIS (2020), CDIS (2020) and network software Netminer.

Figure 4. Equity, banking and debt layer structure 2009–2020 and its change, year over year

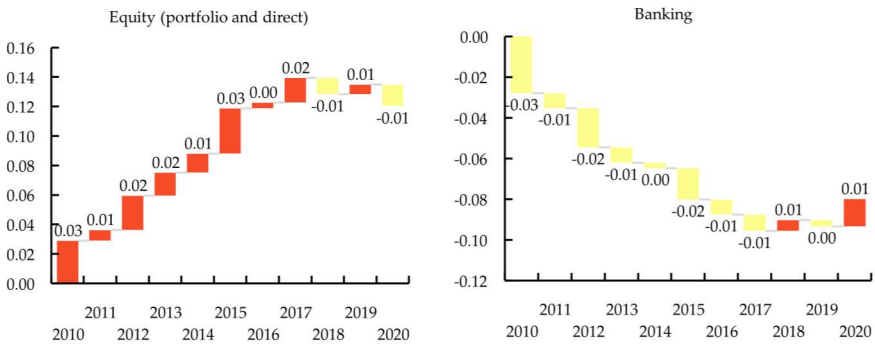
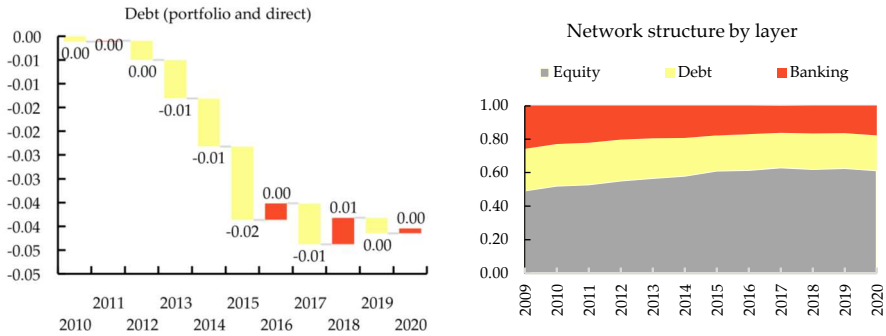
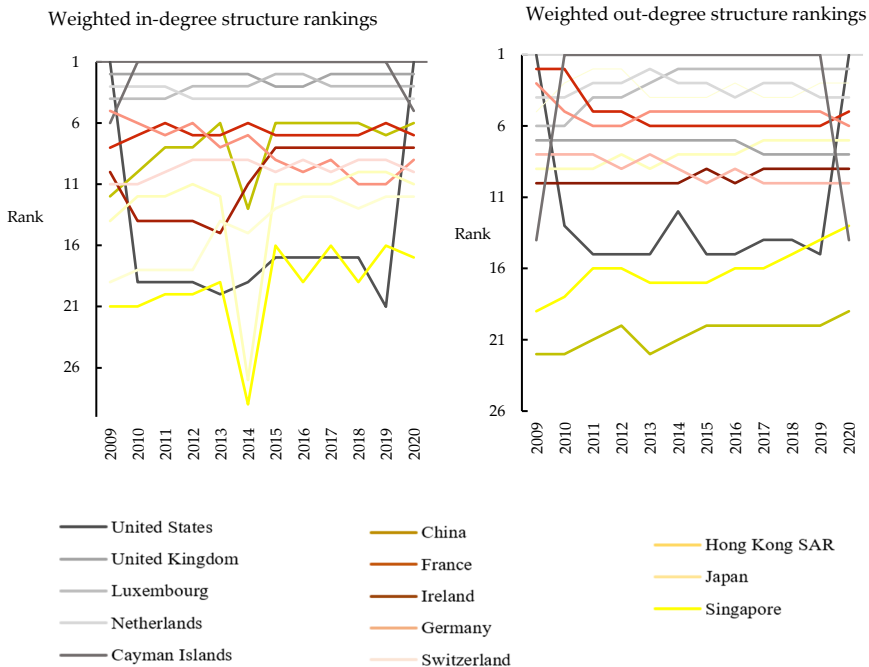


Figure 4. Continued



Source: Own calculations based on BIS LBS by residence data (2020), CPIS (2020), CDIS (2020).

Figure 5. Aggregate network weighted in-degree and weighted out-degree structure rankings 2009–2020



Source: Own calculations based on BIS LBS by residence data (2020), CPIS (2020), CDIS (2020).