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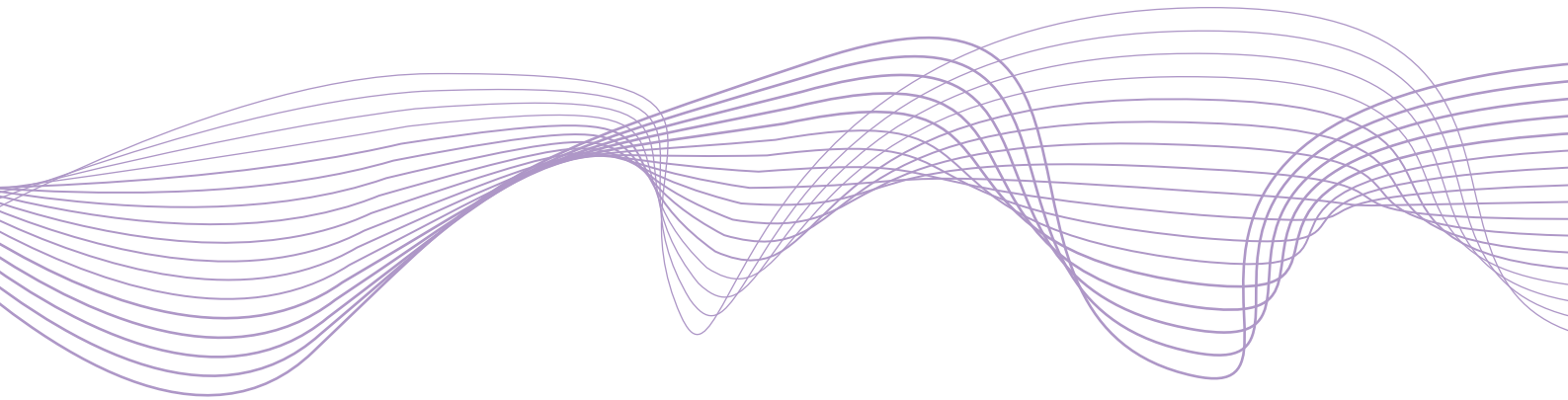
# Networks of counterparties in the centrally cleared EU-wide interest rate derivatives market

by
Paweł Fiedor
Sarah Lapschies
Lucia Országhová



ESRB
European Systemic Risk Board
European System of Financial Supervision

**Abstract**

We perform a network analysis of the centrally cleared interest rate derivatives market in the European Union, by looking at counterparty relations within both direct (house) clearing and client clearing. Since the majority of the gross notional is transferred within central counterparties and their clearing members, client clearing is often neglected in the literature, despite its significance in terms of net exposures. We find that the client clearing structure is very strongly interconnected and contains on the order of 90% of the counterparty relations in the interest rate derivatives market. Moreover, it is more diverse in terms of geography and sectors of the financial market the counterparties are associated with. Client clearing is also significantly more volatile in time than direct clearing. These findings underline the importance of analysing the structure and stability of both direct and client clearing of the interest rate derivatives market in Europe, to improve understanding of this important market and potential contagion mechanisms within it.

**Keywords:** systemic risk, interconnectedness, financial networks, interest rate derivatives, central counterparties, client clearing, EMIR data
**JEL Codes:** G10, L14, G23

# 1 Introduction

This paper analyses the centrally cleared interest rate derivatives (IRD) market in the European Union (EU). The IRD market is one of the largest segments of the derivatives markets in Europe as well as globally[1]. Moreover, it is an important market for hedging purposes for a large number of counterparties. By performing a network analysis, we find interesting structural properties of the IRD market as well as stability stemming from this structure. Moreover, we provide evidence about the importance of studying holistically both direct (house) and client clearing segments of the central clearing.[2] Client clearing on the IRD market has not been analysed in detail previously, presenting a significant gap in the understanding of derivatives market in Europe. With this analysis, we aim to partially fill this gap.

We concentrate on trades cleared through central counterparties (CCPs) for numerous reasons. First, CCPs have become systemically important infrastructures, playing a key role in managing post-trade risks in financial markets. The Group of Twenty (G20) post-crisis reform programme has led to the introduction of a central clearing obligation for standardised over-the-counter (OTC) derivatives in major jurisdictions, including the European Union (EU). With the increased use of central clearing, CCPs are intended to cover most of the OTC derivatives markets for standardised products. Currently, on the order of 60% of the notional traded in the IRD market in the EU is centrally cleared. This number is expected to increase in the coming years, with mandatory clearing gradually coming into force for further categories of counterparties in the EU. Second, the structure of the centrally cleared IRD market in the EU is expected to evolve, with further groups of counterparties becoming obliged to clear standard OTC derivatives via CCPs in the coming years, in particular small financial counterparties and non-financial counterparties. The analysis shows that around

[1]See Triennial Central Bank Survey of foreign exchange and OTC derivatives markets in 2016: `http://www.bis.org/publ/rpfx16.htm`

[2]Direct clearing occurs when a clearing member (CM) of a central counterparty (CCP) clears trades through this CCP. Client clearing is the service provided by the CM to its client under which said clearing member agrees to clear that client's trades through a CCP.

90% of counterparties in the interest rate swaps market in the EU had not yet been directly linked to a CCP in early 2016 [12]. As such, it is important to monitor how the structure evolves. Third, while wider use of CCPs for OTC derivatives is believed to improve market resilience by lowering counterparty risk and increasing transparency, CCPs are not a sufficient condition to ensure the resilience and efficiency of the derivatives markets [5]. As such, it is necessary to understand the structure of these markets, and their implications for financial stability.

To our knowledge, this paper represents the first analysis covering the whole centrally cleared IRD market in the EU. It is also the first paper, which distinguishes clearly between direct (house) clearing and client clearing in a comprehensive network study of the derivatives market. In other words, this paper accounts for all open centrally cleared IRD trades in the EU. Thus, the contribution of the paper is the first look at the structure of the IRD market that is comprehensive both in terms of market coverage and inclusion of indirect clearing, which significantly alters the conclusions of risk analysis on this market.

We provide evidence that the client clearing side dominates the IRD market in terms of the number of relations between counterparties and their interconnectedness. It is also more volatile in terms of the composition of counterparties than direct clearing. In order to better understand the structure, we differentiate market participants by country of domicile and type of institution (whether these are G16 dealers[3], banks, insurance undertakings, pension funds, or other entities). This analysis shows that client clearing is also significantly more diverse in terms of geography and sectors and that the geography and sectors of risks change significantly if client clearing is accounted for. In other words, ignoring the client clearing side would mean missing a large portion of the ultimate risk-takers, and it would lead in particular to missing certain features of risk distribution both in terms of geography and in terms of sectors. To further illustrate the importance of client clearing, we note that only by

[3]An industry group comprising the 16 largest derivatives dealers: Bank of America, Barclays, BNP Paribas, Citigroup, Crédit Agricole, Credit Suisse, Deutsche Bank, Goldman Sachs, HSBC, JPMorgan Chase, Morgan Stanley, Nomura, Royal Bank of Scotland, Société Générale, UBS, and Wells Fargo.

analysing the client clearing side we are able to understand the relation of insurance undertakings and pension funds with the IRD market in the EU, an issue of great importance to financial stability [13]. Moreover, as the data published by CCPs under the CPMI-IOSCO public disclosure framework has revealed, a few CCPs across the EU provide almost exclusively client clearing services via their clearing members. More generally, the network of positions beyond immediate counterparties makes a significant difference to the rank ordering of the systemic importance of institutions, thus client clearing affects the systemic risk ranking of CCPs even though these are not directly linked [2]. For example, if a single CCP would clear all IRD trades for insurance undertakings in the EU, then this would be significant to the systemic nature of such a CCP. However, this information would be missed in an analysis of direct clearing, since all insurance companies in the EU clear their derivative contracts indirectly via a clearing member (only 7 pension funds are clearing members of a CCP). As such, we believe that the understanding of the client clearing, often neglected in studies of centrally cleared derivatives markets, is crucial for understanding financial stability, and contagion effects within the financial system. Further, we perform an analysis of the stability of these networks (access to the clearing hub) with regards to the removal of various institutions from the market (due to the constraints in both data and understanding of the possible behaviour in case of default, we assume withdrawing from clearing and not counterparty defaults), in particular the withdrawal of the most interconnected counterparties, as to further probe the effects of the structure of both house and client clearing on financial stability.

The networks describe the counterparty relations of all CCPs authorised (European CCPs) or recognised (third-country CCPs) by the European Securities and Markets Authority (ESMA) to their clearing members (CMs), as well as the counterparty relations between CMs and their clients. We analyse the set of outstanding IRD contracts at the end of Q3 2016 and at the end of Q4 2016. To create the networks, we use a supervisory

dataset established by the European Market Infrastructure Regulation (EMIR),[4] containing transaction-level data on all open IRD trades that fall into the purview of regulators in the EU.

The analysed networks describe the existence of contractual links between counterparties, but do not quantify these links. In this binary setting, the networks represent only the existence of intermediation chains between counterparties, not their market or notional value. Such networks are more stable since establishing a counterparty relationship is a non-trivial legal process, and often requires economic guarantees. The International Swaps and Derivatives Association notes that "Membership criteria may be significantly different across CCPs, preventing in practice the porting of such portfolios. Equally, documentation cannot be set up quickly enough" [17]. The latter part is valid also for contractual relationships between clearing members and clients, underlining the importance of our analysis. Further, a binary network can be constructed in a robust manner from the supervisory datasets, contrary to networks based on market valuation or notional values of contracts. However, they are not suitable for all types of analysis. As the aim of the paper is to analyse the market structure and systemic risk issues stemming from the structure of counterparty relations (and not the precise state of contractual obligations), the binary networks allow for a more robust analysis of this type (this is partially due to lessened technical burden on dealing with double reporting, which would add to the uncertainty of the results, and partially due to better fit of the intermediation chains for the questions being answered in this paper). However, it is important to keep in mind the limitations of this approach.

The structure of the paper is as follows: Section 2 provides a brief review of relevant literature, Section 3 provides an outline of the importance of client clearing and Section 4 describes the data used in this study, including the cleaning procedure. Section 5 discusses the results, while Section 6 concludes and presents the way forward.

[4]Regulation (EU) No 648/2012 of the European Parliament and of the Council of 4 July 2012 on OTC derivatives, central counterparties and trade repositories, OJ L 201, 27.7.2012, p. 159.

# 2 Literature Review

There are two strands of literature relevant to this work, namely work based on granular, transaction-level datasets on derivatives and work connected to the systemic risk and structure of centrally cleared markets.

Our analysis builds upon the experiences of researchers working on the same dataset [1]. This paper provides a first look into interest rate swap data (IRS) in the EU, covering not only centrally cleared transactions, but also bilateral trades. The authors narrowed their analysis to plain-vanilla fixed-for-floating 6M Euribor IRS, which makes less than a quarter of the notional of all IRD in the EU (based on data at end-2015). Further, they have only based their analysis on data from DTCC, one of the six registered trade repositories (TRs) in the EU. However, due to their narrower setup, they are able to operate on gross notional values. Thus, by looking at exposures (instead of market structure) they provide complementary information to our paper. In particular, they find that a set of dealers predominantly intermediate between end-customers. Since most of the activities to match end-buyers and end-sellers balance out, these dealers only take small net positions vis-à-vis interest rate risk despite maintaining large gross portfolios. This provides a clear motivation for the importance of the analysis of the client clearing landscape, despite the fact that most of the gross notional have been exchanged on the house clearing side.

Further, it is worth noting that in Refs. [7, 8] the authors analyse various aspects of Credit-Default-Swap (CDS) contracts and markets based on the same dataset. Finally, in Ref. [6] the authors analyse foreign exchange derivatives in detail, also based on a granular dataset. The experiences of the authors working on the same dataset but different asset classes was of great help in designing this study.

Complementary to the dataset used in our study, there is also work based on the 2016 BIS Triennial Central Bank Survey results. In a recent analysis, the authors investigate recent developments in the global OTC IRD markets [11]. The authors analyse turnover, effects of regulatory reforms and drivers of trading dynamics in the OTC market. Their analysis does

not concentrate on the market structure, however, which is where our analysis fits in.

Another strand of literature deals with the systemic risks associated with central clearing. The salient features of the derivatives markets, including easy access to synthetic leverage (defined as the build-up of off-balance sheet exposures through derivatives), make these markets prone to systemic risk. This has become apparent during the recent global financial crisis. Since then, CCPs play a dominant role in derivatives markets, mostly due to regulatory requirements for central clearing of certain OTC derivative classes. As such, there is a clear need for transparency, both to supervisors and market participants. In Ref. [5] the authors discuss the implications of derivatives markets shifting focus towards CCPs. The introduction of CCPs is not considered a sufficient condition for efficiency and resilience of OTC derivatives markets. They argue the importance of complementing the introduction of CCPs with improvements in trading and settlement infrastructure, part of the landscape of which is becoming visible in our analysis. In Ref. [15] the author notes the importance of comprehensive coverage of central clearing in the derivatives markets, and that the regulation of OTC derivatives should allow the monitoring of the market to be as comprehensive as possible. In Ref. [16] the authors note the financial stability issues related to the regulation and supervision of CCPs, and advocate for a more integrated regulatory approach. In this light, our analysis hints at the need for more thorough inclusion of client clearing in the EMIR. Finally, in Refs. [3, 14] the authors discuss the transparency implications for IRD markets, for instance that the increased transparency primarily benefits uninformed traders.

Client clearing is also discussed in the literature. In Ref. [10], based on a dataset including CDS positions, the authors estimate the impact of the introduction of central clearing in the CDS market on collateral demand of market participants. In order to study multilateral netting benefits, they also included client clearing in their model. Surprisingly, client clearing appears to reduce system-wide collateral demand under the assumption that clearing members are reusing a share of the collateral they receive from their clients due to cross-counterparty netting and diversification effects. This underlines that client clearing has a

significant effect on the analysis of centrally cleared derivatives market.

# 3 Client Clearing

There are reasons why most attention has been paid to the interconnectednes between CCPs and their CMs in the literature so far. As highlighted by ESMA, there is a high concentration in the IRD market in the EU, with a small number of counterparties accounting for a large number of overall volume [12]. From around 6000 counterparties in the OTC interest rate asset class, the largest 50 counterparties account for 95% of the OTC IRD volume, measured by outstanding notional amounts. Furthermore, the 500 largest counterparties represent 99.4% of the activity. This indicates that a small number of counterparties account for a large fraction of the total volume. Moreover, these large counterparties link to the CCPs as clearing members. We know, for instance from the public disclosure of CCPs based on an internationally agreed framework of CPMI-IOSCO, that client clearing accounts for an amount on the order of 10% of notional traded. Thus, it would seem natural to concentrate on house clearing.

We believe however that it is important to study central clearing in a holistic way, including the client clearing links. First, a major part of the gross notional traded between CCPs and their largest CMs (in particular the G16 dealers) is spurious as they do not create significant net risk exposure [7, 8]. Instead, these large institutions operate as intermediaries. While clients tend not to be of systemic nature on individual level, they may be systemic as a group, which our analysis renders plausible and consistent with the data. Second, as we show in this paper, the counterparty relations between CMs and their clients create much richer networks of interconnections than house clearing. Moreover, the clients modify our understanding of the geography and sector of risks in the IRD markets. These structures are thus important as potential channels of contagion, keeping in mind that all these institutions are further interconnected among themselves, with other parts of the financial system and

the real economy through other asset classes in the derivatives market, as well as through entirely other exposures. Further, the actions of a CCP with regard to its risk management framework may have an economic (and in the worst case - procyclical) impact not only on CMs but also on clients, who are linked to the CCP via clearing members. Therefore, studying the relations and interconnectedness between CCPs, CMs, and clients could help to deepen the understanding of the structure underlying these effects. As pointed out by the ESRB report [4], there is no legal framework for the level of margins and haircuts in transactions between clearing members and clients in the EU. Hence, there are no provisions in place to limit the procyclicality of margin and haircut requirements in client clearing activities. Due to this being a potential source of systemic risk, it is important to study the extent of client clearing in the EU. Finally, we note that data from the CPMI-IOSCO public quantitative disclosure framework for CCPs for the first quarter of 2016 indicates that some CCPs in the EU, e.g. CME Clearing Europe Ltd and ICE Clear Netherlands B.V., provide mostly clearing services that are passed to the client clearing side through their clearing members. As such, an analysis ignoring client clearing would not account properly for risk stemming from the operations of these important financial market infrastructures. Thus, we believe more attention should be paid to the structure and resilience of the client clearing part of the centrally cleared derivatives market. This study is a first attempt to shed light on the market structure of the client clearing side based on the full picture of the centrally cleared IRD market in the EU.

# 4 Data & methodology

The EMIR, which is a European legislation regulating the use of OTC derivatives, CCPs, and TRs includes requirements for reporting of the derivative contracts. According to EMIR, all counterparties to derivative contracts located within the EU must report the details of their contracts to one of the TRs registered by the ESMA. At the time of writing this paper, there

were six registered TRs, refered as CME, DTCC, ICE, KDPW, Regis-TR and UnaVista throughout this paper[5]. The full EU-wide dataset (data on all open IRD trades that fall into the purview of regulators in the EU, be it through the involvement of a counterparty from the EU, the use of euro as the currency of denomination, or the underlying) from all registered TRs is available to the European Systemic Risk Board (ESRB) and the ESMA, while partial datasets are disseminated to over 60 supervisory bodies in the EU. In this paper, we use the dataset as provided to the ESRB. The dataset gathered for the analysis is novel in multiple ways. First, the analysis is based on transactions gathered from all six TRs registered in the EU. To our knowledge, this is the first time that the data for the whole centrally cleared ecosystem for the IRD in the EU has been aggregated. Previous analyses concentrated on the reports coming from DTCC alone (as it covers a majority of the reporting for the bilateral IRD trades), or combining two or three TRs [1, 7, 6]. Second, we provide a clear distinction between house and client clearing. Although it is a crucial distinction to both regulators and market participants, this has been rarely analysed in the literature.

The EMIR data is reported on a granular (transaction) level. It covers all derivatives classes, including IRD[6]. Importantly, not only OTC, but also exchange-traded derivatives (ETD) contracts are being reported. The EMIR data also include both bilateral and centrally cleared trades. As the reporting obligation in the EU is broad, covering the majority of counterparties in the derivatives market, we obtain a comprehensive picture of the market. However, the reports provided by individual TRs are not identical, which represents an additional challenge for obtaining a common dataset. Depending on the TR, a number of variables on the order of 90 are reported for each transaction[7]. The dataset identifies counterparties, and contains details of the contract and its execution, valuation, and clearing.

[5]Formally CME Trade Repository Ltd., DTCC Derivatives Repository Ltd., ICE Trade Vault Europe Ltd., Krajowy Depozyt Papierów Wartościowych S.A., Regis-TR S.A., and UnaVista Limited.

[6]Other derivatives classes are credit, commodity, equity and foreign exchange, with a residual classified as others.

[7]See the implementing technical standard with regard to the format and frequency of trade reports: `http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:352:0020:0029:EN:PDF`

We analyse the IRD market in the EU, as it is one of the largest segments of the derivatives market. Moreover, it is an important market for hedging purposes for a large number of institutions. We use the raw trade state reports gathered from TRs on 30 September 2016 and 31 December 2016. Through this paper, we report results for end-2016, while we use the September 2016 dataset to study changes over time. There is no particular significance behind choosing the above dates. There is however a difference in terms of the scope of the clearing obligation for IRD denominated in G4 currencies (EUR, USD, JPY and GBP), with the mandatory clearing for Category 2 entering into force on 21 December 2016 in the EU.[8] Contrary to other large jurisdictions, such as the US, the EU has opted for a gradual introduction of mandatory clearing, with a phasing-in period for different groups of counterparties of several years. Moreover, the mandatory clearing for IRD trades denominated in other European currencies (such as NOK, SEK and PLN) has only started in 2017, thus beyond the timespan of this paper.[9] The slow phasing-in allows us to analyse the changing structure of the mandatory clearing in different points in time.

Following the literature based on the same dataset, we apply a cleaning procedure to the raw state reports from the TRs on the two given dates, namely 30 September 2016 and 31 December 2016. The cleaning procedure discards erroneous observations. It also discards any observations outside the scope of our analysis, e.g. contracts that are not IRD, or contracts that are not centrally cleared. We start by extracting only IRD data, discarding all other asset classes of derivatives, and we continue by removing all non-centrally cleared IRD contracts. Overall, we study all trades cleared by a CCP that has been either authorised[10] (for EU-domiciled CCPs) or recognised[11] (for third-country-domiciled CCPs) by the ESMA.

[8]Commission Delegated Regulation (EU) 2015/2205 of 6 August 2015 supplementing Regulation (EU) No 648/2012 of the European Parliament and of the Council with regard to regulatory technical standards on the clearing obligation, OJ L 314, pp. 13-21.

[9]Commission Delegated Regulation (EU) 2016/1178 of 10 June 2016 supplementing Regulation (EU) No 648/2012 of the European Parliament and of the Council with regard to regulatory technical standards on the clearing obligation, OJ L 195, pp. 3-10.

[10]`https://www.esma.europa.eu/sites/default/files/library/ccps_authorised_under_emir.pdf`

[11]`https://www.esma.europa.eu/sites/default/files/library/third-country_ccps_recognised_under_emir.pdf`

A list of the 17 CCPs present in the study can be found in the Annex. Thus, we only consider trades reported with Legal Entity Identifiers (LEIs) as specified in the Annex in the field called 'CCP.'

After merging the data for centrally cleared IRD transactions from all TRs, we continue with the cleaning procedure. To clean the resulting dataset we remove erroneous observations. First, we remove observations where counterparties are not described by a valid Legal Entity Identifier. Then we remove observations with implausible gross notional values (lower than 1,000 EUR), and observations with missing notional or market value (a missing observation suggests that the trade has been cancelled). We also remove observations with clearly misreported counterparty sides and execution timestamps.

Then, we merge this dataset with foreign exchange rates from OANDA[12] (this is only used for Fig. 1 below). Further, we merge this dataset with other datasets available at the ESRB. We use Bureau van Dijk Orbis[13] in order to assign counterparties to one of the following six groups: G16 dealers, banks (which are not belonging to the G16), CCPs, pension funds and insurance companies, other financial institutions (such as mutual and hedge funds), and non-financial institutions. We also use GLEIF data[14], which allows us to obtain the country of domicile of all counterparties.

Granular reporting for such an important market implies large datasets. In relation to the centrally cleared open IRD contracts dataset, after the above-specified cleaning procedure we were left with over 4 millions of observations, out of over 30 millions reports on open IRD (both OTC and ETD) trades in total (these contain duplicates as all counterparties to a contract have a reporting obligation, the duplicates do not affect the creation of networks reported later – see below). These 4 millions observations are later translated into a network of 7,336 institutions with 12,195 counterparty relations, 90.29% of which are between clearing members and clients. Conversely, the bilateral (non-centrally cleared) interest rate trades

[12] https://www.oanda.com/

[13] http://www.bvdinfo.com/en-gb/our-products/company-information/international-products/orbis

[14] https://www.gleif.org/en/lei-data/global-lei-index

also consist of 4 millions of observations after the cleaning procedure, but the market is much less concentrated. The network resulting from the bilateral trades would consist of 72,924 entities with 113,730 links between them. This part of the market deserves a future separate analysis. Those large numbers are to a certain degree remnants from the times when central clearing was not yet both popular and obligatory. If we look only at trades executed in 2016, we would only get over 700 thousand observations, which would underlie a network of 19,192 entities with 33,412 links between them. Restricting the centrally cleared transactions to only ones executed in 2016 would not reduce the number of entities in the network significantly, and reduce the number of counterparty relations by about one third.

Combining information from all TRs is technically challenging. The number of contracts used in our study (the sample size) is $4,157,339$. Most of the contracts have been reported by UnaVista and DTCC. There is probably a large overlap in reporting between various trade repositories due to the double reporting standard. The remaining four TRs provide significantly fewer non-deduplicated contracts than the first two, however these TRs are largely used by CCPs and counterparties in certain jurisdictions. Ignoring them would mean that we would be left with no or partial information for some EU Member States. We believe therefore that combining data from all TRs is necessary to have the full picture of the European IRD market.

Let us briefly present some summary statistics of the resulting set of contracts. Given the binary setting in which we operate, it was not necessary to deduplicate the list of contracts. Therefore, the summary statistics below should be treated as a mere indication and not a detailed insight. First, in Fig. 1 we present the density distribution of notional value (in EUR) of the studied contracts. We cannot infer detailed conclusions from this, in line with the above discussion, but we see that most of the IRD trades have a gross notional on the order of tens or hundreds of millions of EUR. The distribution of gross notional values approaches normal distribution, but is multimodal, due to the preference of counterparties to trade in round numbers. Second, in Table 1 we present the number of contracts by currency in which

they are denominated[15]. This shows the rough position of each currency in the EU-wide IRD market. The euro and the US dollar dominate this market, as would be expected. Third, in Fig. 2 we present number of observations per maturity year. We see a declining trend, with jumps in major tenors (10, 20, 30 years in residual maturity). There are also some trades reported as maturing in 2016, presumably in error (although it may be for economic reasons such as that these have not yet been settled properly by end-2016), however, these do not change the results of the forthcoming analysis significantly. The reason why we do not discard these trades is that as we are interested in counterparty relations, and even if these contracts have been closed and should not be reported as open on 31 December 2016, they nonetheless indicate that these counterparties have a trading relationship.

Table 1: Number of contracts (after the cleaning procedure) by currency. Data for 31 December 2016.

| Currency | # of contracts | Currency | # of contracts | Currency | # of contracts |
|---|---|---|---|---|---|
| EUR | 1,230,280 | CHF | 85,997 | MXN | 24,208 |
| USD | 1,038,767 | NZD | 82,675 | DKK | 17,890 |
| GBP | 545,209 | PLN | 82,381 | BRL | 4,854 |
| JPY | 290,727 | ZAR | 70,069 | KRW | 4,576 |
| AUD | 204,648 | HKD | 58,493 | Other | 99 |
| SEK | 98,894 | NOK | 57,364 | | |
| CAD | 91,065 | HUF | 46,339 | | |
| SGD | 87,918 | CZK | 34,886 | **Total** | **4,157,339** |

From each of the observations, we extract the counterparties of the reported transaction and whether they are between CCPs and clearing members (house clearing), or between clearing members and clients (client clearing). Thus, we end up with two sets of links between counterparties: one for links for house clearing, and one for links for client clearing. All these links are unweighted, so that they do not contain information about notional or market value traded between counterparties. They do not even quantify the number of open contracts between counterparties, and only the existence of a counterparty relationship between them.

[15]As the networks created for IRD trades denominated in Thai baht (THB), Chilean peso (CLP), Malaysian Ringgit (MYR), Colombian peso (COP), Chinese renminbi (CNY), & Isreali shekel (ILS) are based on a very few contracts, we will not be reporting results for them later in the paper.

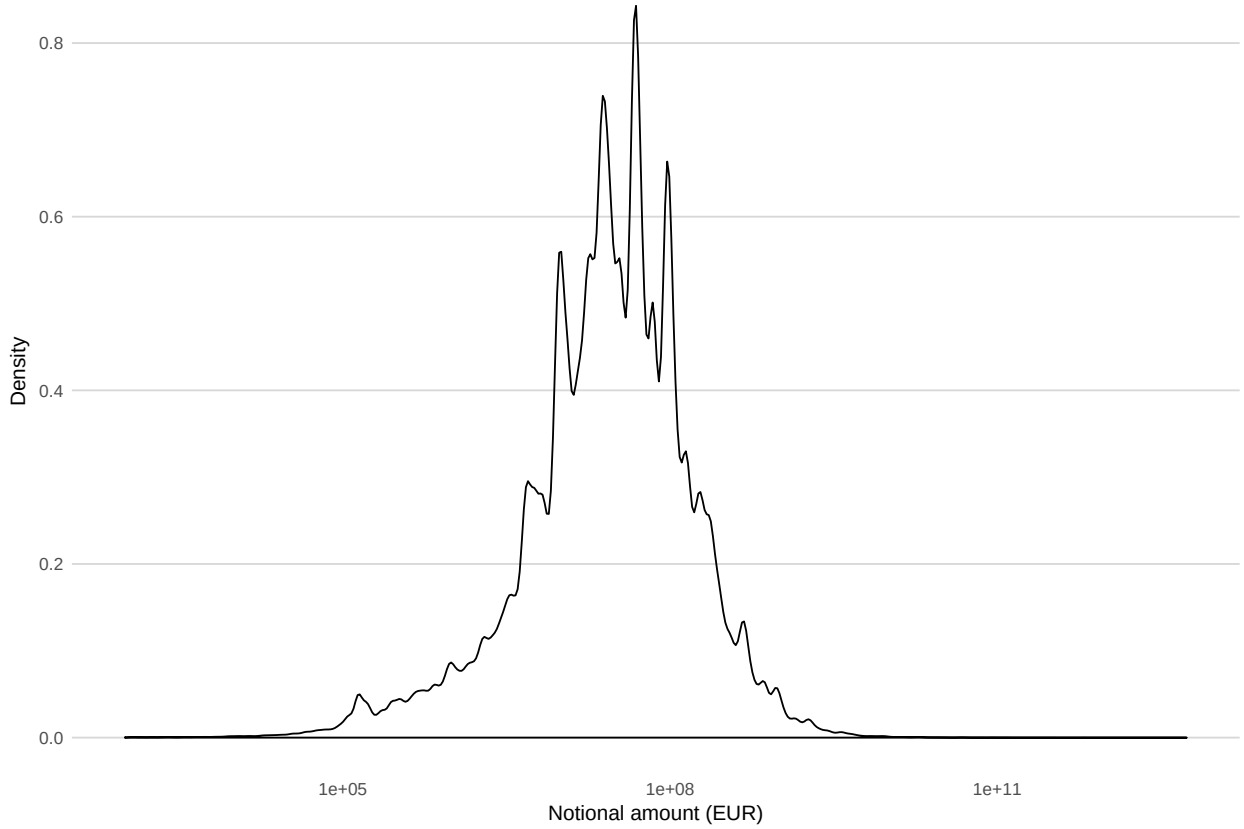



Figure 1: Density of the notional (in EUR) for the studied contracts (after the cleaning procedure). This figure should be only used as an indication of a characteristic scale of the notional of IRD contracts, and the approximate distribution. Data for 31 December 2016. As the cleaning procedure hasn't been tuned to deal with notional values neither detailed analysis nor strong conclusions should be derived from this figure. We observe that most contracts are on the order of tens and hundreds of millions of EUR of gross notional.

As such, if we encounter two different transactions between given counterparties within a specific network, the link is the same as it would be if there was only one transaction between these counterparties. We create full networks for all open IRD contracts, and separate networks for all currencies in which those contracts are denominated, and also separate networks for all years in which these contracts are maturing. For example, a network for the euro will only consist of links between counterparties which have open IRD contracts denominated in EUR between them. All counterparties (nodes) in the resulting networks have assigned their LEI, country of domicile, and type of institution. All links between counterparties (edges) have assigned whether they are related to house clearing (between

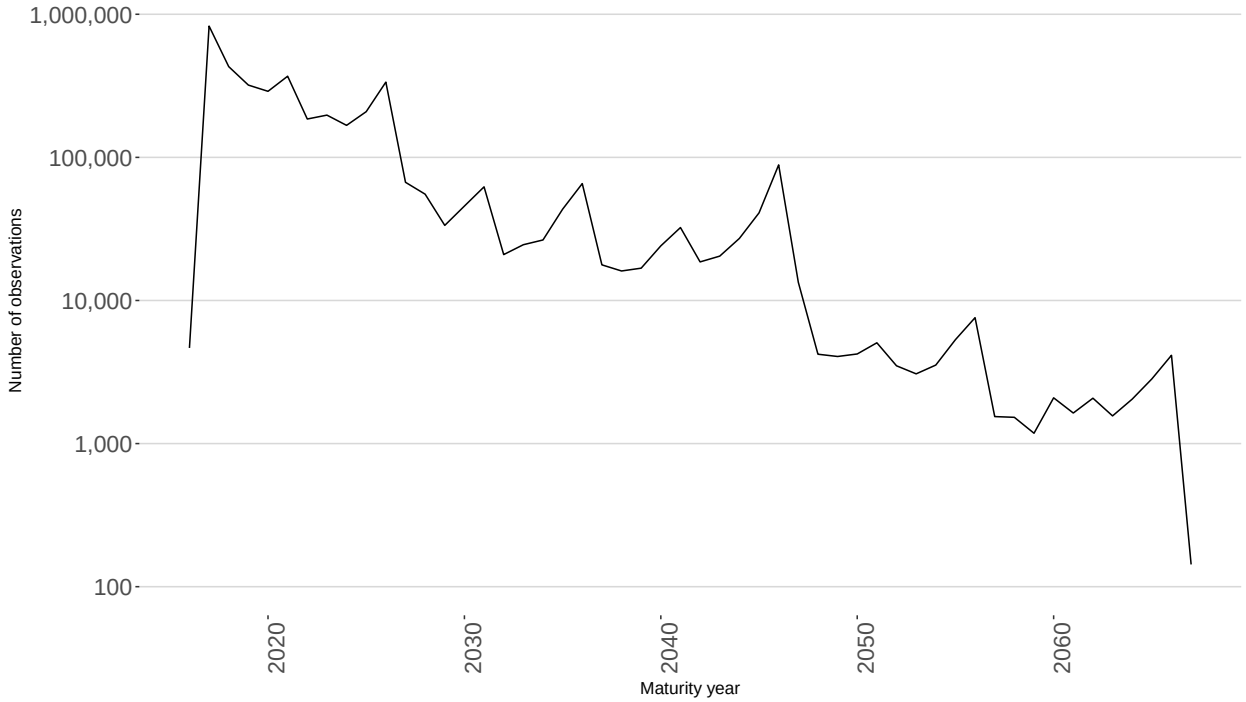



Figure 2: Number of transactions by maturity year within the studied contracts (after the cleaning procedure). Data for 31 December 2016. As the cleaning procedure hasn't been tuned to deal with notional values, this figure gives the general impression of the shape of the distribution of IRD contracts across maturities, but neither detailed analysis nor strong conclusions should be derived from it. We observe that the number of observations decreases steadily with increase in maturity, with the exceptions of major tenors, where we observe jumps.

CCPs and their clearing members) or client clearing (between clearing members and their clients).

# 5 Results & discussion

In this Section we present the empirical results, that is the structure of the EU-wide network of counterparty relations for house clearing (between CCPs with their clearing members), and the counterparty relations for client clearing (between clearing members with their clients). Later in the section, we analyse the stability of these networks with regards to the removal of counterparties.

To start with, in Fig. 3 we present the full network of counterparties in the centrally cleared IRD market in the EU for 31 December 2016. In red we can see the counterparty relationships between clearing members and their clients, and in green links between CCPs and their clearing members. Types of institutions are not presented visually, both for reasons of visibility and confidentiality. The network is presented only for illustrative purposes, and is analysed and presented more in detail below. At this point we can already see that the client clearing side dominates the structure of counterparty relations in the IRD market in the EU, contrary to what one would find looking at the gross notional values. However, as we note above, gross notional values exchanged are not necessarily indicative of the net positions taken by counterparties within the house and client clearing sides. As such, we believe that the client clearing side is important in this market, as will be further evidenced below.

## Types of institutions in the networks

Now, we turn to the analysis of the structure of the centrally cleared IRD market in the EU and the types of counterparties. To start with, in Table 2 we present the number of institutions (nodes) in the analysed networks by their type. In the second column, we present values for the full network (house and client clearing), in the third just the house side (CCP-CM), and in the fourth just the client side (CM-Client). It is worth noting that the sum of institutions present in the house and client clearing does not equal the sum of institutions in the full network, given the double role of clearing members played in the two networks. We observe that other financial institutions dominate both the house clearing and the client clearing, followed by the banks, given the number of these types of institutions in the networks. CCPs are not participating in the client clearing part of the market, while G16 dealers are very active in both networks. In relative terms, G16 dealers are the most active type of institutions in the house clearing, followed by banks and non-financial entities (94%, 30% and 14% respectively from the different types of entities present in the full network).

Also of note is the fact that one of the G16 dealers does not have direct counterparty relation with any CCP in the IRD market within the EU. Interestingly, banks appear more prevalent in the client clearing side. This is perhaps due to small banks not having direct access to the CCPs. It is also apparent that insurance undertakings and pension funds as well as non-financial counterparties mostly operate within the client clearing side (in relative terms, only 2% and 9% respectively of these types of institutions in the full network are involved in the house clearing).

Table 2: Number of institutions (nodes) in the analysed networks by their type. In the second column we present values for the full network (house and client clearing), in the third just the house side (CCP-CM), and in the fourth just the client side (CM-Client). We observe that other financial institutions are present in the greatest number both the house clearing and the client clearing. At the same time, insurance undertakings & pension funds mostly operate within the client clearing side.

| Type of institution | Full | House | Client |
|---|---|---|---|
| CCP | 17 | 17 | 0 |
| G16 | 16 | 15 | 16 |
| Bank | 608 | 184 | 591 |
| Other financial | 5,438 | 492 | 5,246 |
| Insurance & pension | 420 | 7 | 419 |
| Non-financial | 86 | 12 | 82 |
| Total | 6,585 | 727 | 6,354 |

Having established the types of institutions present in the networks, we now turn our attention to what are the pairs of the types of institutions most prevalent in the studied networks. In Table 3 we present the total number of counterparty relations in the house clearing (between CCPs and their clearing members) by counterparty type, number of clearing members of each type, and average number of counterparty relations with CCPs of a clearing member of each type. Most active in terms of overall number of relations are other financial institutions, followed by banks and G16 dealers. In terms of links per institutions the G16 dealers clearly lead, having on average links with over 6 CCPs. Further analysis would be useful to inquire in detail about the further breakdown within these categories, in particular other financial institutions. We see that insurance undertakings and pension

funds, as well as non-financial companies have less often direct access to CCPs. Banks have more counterparty relations with CCPs than dealers, but this is due to many more banks outside of G16 dealers. It is worth noting that there are six cases where a CCP is a clearing member of another CCP. In Table 4 we present the total number of counterparty relations between clearing members and their clients by counterparty type. The most common relationship occurs between other financial institutions, and also between these and G16 dealers. Banks are also active vis-à-vis most counterparty types.

Table 3: Total number of counterparty relations between central counterparties and their clearing members by counterparty type. We also present the number of clearing members by type and number of links per an entity of a given type in the house clearing network. Most active in terms of overall number of relations are other financial institutions, followed by banks and G16 dealers. In terms of links per institutions the G16 dealers clearly lead, having on average links with over 6 CCPs. We see that insurance undertakings and pension funds, as well as non-financial companies have very little in terms of direct access to central counterparties.

| Type (CCP) | Type (CM) | # of links | # of Type (CM) | Links per CM |
|---|---|---|---|---|
| CCP | Other financial | 690 | 492 | 1.40 |
| CCP | Bank | 286 | 184 | 1.55 |
| CCP | G16 | 93 | 15 | 6.20 |
| CCP | Non-financial | 15 | 12 | 1.25 |
| CCP | Insurance & pension | 7 | 7 | 1.00 |
| CCP | CCP | 6 | 17 | 0.35 |

## Persistence of the networks

Next, we turn to the analysis of persistence of the studied networks over time. It is an important point, as many of the results have different meaning depending on whether the structure we observe is persistent over time, in which case the analysis may be binding in general, or whether it is a state of the market only for the studied day, and as such all the results need to be applied only for the studied period. To this end, in addition to the network we present throughout the paper (for 31 December of 2016), we have created another

Table 4: Total number of counterparty relations between clearing members and their clients by counterparty type, as well as the share of the counterparty relations between institutions of type (1) and type (2) in all counterparty relations of institutions of type (1). The most common relationship occurs between other financial institutions, and also between these and G16 dealers. Banks are also active vis-à-vis most counterparty types. Some pairs with few links removed for confidentiality reasons.

| Type (1) | Type (2) | # of links | Share in Type (1) |
|---|---|---|---|
| Other financial | Other financial | 2,818 | 51.60% |
| Other financial | G16 | 3,121 | 28.95% |
| G16 | Other financial | 3,121 | 72.30% |
| Other financial | Bank | 1,797 | 16.42% |
| Bank | Other financial | 1,797 | 49.37% |
| Bank | G16 | 652 | 18.27% |
| G16 | Bank | 652 | 15.17% |
| Bank | Bank | 419 | 27.97% |
| Insurance & pension | G16 | 305 | 46.79% |
| G16 | Insurance & pension | 305 | 7.27% |
| Other financial | Insurance & pension | 228 | 2.12% |
| Insurance & pension | Other financial | 228 | 34.08% |
| Bank | Insurance & pension | 123 | 3.55% |
| Insurance & pension | Bank | 123 | 18.98% |
| Non-financial | Other financial | 97 | 52.41% |
| Other financial | Non-financial | 97 | 0.91% |
| G16 | G16 | 86 | 4.00% |
| G16 | Non-financial | 54 | 1.25% |
| Non-financial | G16 | 54 | 28.88% |
| Non-financial | Bank | 27 | 16.04% |
| Bank | Non-financial | 27 | 0.84% |

network, which represents a quarter earlier (30 September 2016)[16]. In Fig. 4 we present the percent of edges (counterparty relations) present in the network of counterparty relations in IRD markets at both the end of Q3 and the end of Q4 of 2016 and those present at both times (Jaccard index [18]), within the total number of unique counterparty relations present in either period, divided by currency of denomination, for the full network of CCPs, clearing members, and their clients, for the network of CCPs and their clearing members, and for the network of the clearing members and their clients. For the major currencies the changes

[16]Since we are analysing stocks of open trades the choice of particular dates should not matter significantly. But it is worth noting that end of quarter is the time when financial conglomerates optimise their balance sheets for reporting purposes, which could potentially skew some of the results.

seem to be on the order of 20% for the relations between CCPs and their clearing members, and 30% for the relations between clearing members and their clients. This is natural, as we would expect that clearing members are clearing consistently, smaller clients would change their hedging needs more often. Further, in Fig. 5 we present the same information divided by the year of maturity. We observe that the network of counterparty relations is most volatile in time for the nearest two years of maturity (on the order of 70-90% for the counterparty relationships between clearing members and their clients). Then it remains quite stable across other maturities (at about 15% for counterparty relationships between CCPs and their clearing members, and about 30% for the relationships between clearing members and their clients), except for major tenors (10, 20, 30 years), and the year behind the major tenors (11, 21, 31) – for these the percentage of changes is significantly higher. As most of the changes seem to happen in the relationships between clearing members and their clients, thus regular monitoring of the client clearing aspect may be prudent. We also observe the same situation for the nodes (institutions present in the network), so we skip the presentation of this aspect.

All in all, we find that the structure of the market for the end of quarter 3 and 4 of 2016 is similar, despite the introduction of the clearing obligation for Category 2 of counterparties for G4 IRD contracts between the two periods. Since the results for the two chosen days (30 September 2016 and 31 December 2016) look very similar, in the interest of space, we do not reproduce all of the charts for two periods and show charts for 31 December 2016 only. Nonetheless, we believe that for particular enquiries it may be necessary to study changes over time carefully, in particular with the possible changes to the market structure related to the gradual introduction of the clearing obligation for both IRD derivatives denominated in G4 and other European currencies.

## Degree distributions

We continue the analysis with a careful look at the degree distributions. In Fig. 6 we present degree distributions of (a) the full network, (b) the house clearing network, (c) the client clearing network. While the network of counterparty relations between CCPs and their clearing members is characterised by a two tier structure (core and periphery, both reasonably close to distinct power laws), divided around degree of 10 counterparty relationships, the network of clearing members and their clients shows a three tier structure (inner core, outer core, and periphery – divided by degrees of around 10 and around 100). Since the client clearing domininates the whole network, (a) & (c) are similar. This is quite natural as in the house clearing network we would expect two tiers, one comprised of the CCPs who deal with many clearing members, and one comprised of clearing members who deal with a limited number of CCPs. If we would only consider the house clearing side it would be clear that only the core tier would be important to the resilience of this market. Contrary to this, in the network representing the client clearing side (and the whole market) we observe three tiers: one for large dealers and large CCPs – those who deal with a very large number of clients and clearing members, one for relatively well-connected dealers, banks, and smaller CCPs, and finally one for clients and smaller clearing members. Thus, analysing the client clearing side is important, as ignoring it would lead to completely different understanding of the derivatives market – as the structure of the house and the client clearing sides are markedly different.

To complement the above discussion of the three tier structure of the centrally cleared IRD market in the EU, in Fig. 7 we present the same network as in Fig. 3, but this time we colour the institutions to classify them into the three tiers: institutions in the inner core are presented in red, outer core in blue, and periphery in green. We can see how the inner core of the market is creating the backbone of the network. Both the outer core and the periphery are much less pronounced, and are not readily visible in this visualisation. This underlines the importance of the institutions present in the inner core of the network, that

is both large CCPs and the G16 dealers. Importantly, this structure would not be clearly visible if we ignored the client clearing side.

To complete the discussion of degree distributions, we also present these for networks of parts of the IRD market, divided by either the currency of denomination of the contracts, or the maturity of the contracts underlying the analysed networks. In Fig. 8 we present degree distributions of (a) the full network of IRD denominated in arbitrarily chosen major currency, (b) the full network of IRD denominated in arbitrarily chosen minor currency, (c) the full network of IRD with an arbitrarily chosen short maturity year, (d) the full network of IRD with an arbitrarily chosen long maturity year. The degree distribution of the network of a major currency IRD closely resembles this of the full network. The network of a minor currency IRD very closely resembles a scale-free network, and does not have a tiered structure. The network with short maturity appears to have a two tier structure, with the break between tiers around degree of 100, while the network for contracts with long maturity appears not to have a tiered structure, and is somewhere between power law and log-normal distribution. This underlies the fact that while for the whole centrally cleared derivatives market in the EU the above analysis holds, it does not necessarily hold for markets of IRD denominated in specific currencies. Thus, while the above is useful for financial stability analyses of the whole European derivatives market, it is not necessarily useful for analysing particular pockets within this market. These can be analysed carefully using the same dataset and methodology, but due to space constraints we concentrate on the analysis of the whole network in detail.

## Currency and maturity of the contracts

Having established that the client clearing side affects the structure of the centrally cleared IRD market in the EU, we turn to the structure of the market by the currency of denomination and year of maturity of the contracts, having in mind both the house and the client clearing sides. In Fig. 9 we present the distribution of edges (counterparty relations) be-

tween CCPs and their clearing members (CCP-CM), and clearing members and their clients (CM-Client) across maturities of the IRD contracts. IRD contracts with maturities of up to 50 years have been conducted among counterparties. We observe that the amount of counterparty relations is the highest for short-term IRD, and decreases fast with time, except for major tenors (10, 20, 30 years). Client clearing clearly dominates across most maturities, for the full network the counterparty relations in the house clearing side constitute only 9.5% of all the counterparty relations in the studied market. This differs by maturity, for the maturities close in time this value is lower, while for the long-term IRD the percentage of house clearing is larger. In particular, this value is around 9.5% for IRD maturing in 2017, and rises to about 50-70% for IRD maturing after 2050. In Fig. 10 we present the distribution of edges (counterparty relations) between CCPs and their clearing members (CCP-CM) and clearing members and their clients (CM-Client) across currencies in which the IRD contracts between these counterparties are denominated. There are IRD contracts denominated in 23 different currencies in our dataset, including the euro and six other official currencies in non-euro area EU Member States (out of nine).[17] We observe that the currencies that have the most interconnected counterparty clearing networks for IRD denominated in them are the euro (EUR), the US dollar (USD), and the British pound (GBP), followed by the Japanese yen (JPY). These are also the currencies (refered to as G4 currencies) which are already subject to central clearing for IRD trades for the first two groups of counterparties in the EU. Client clearing dominates house clearing across all currencies, however there is some variation. The share of client clearing among the main currencies is similar, with the house clearing side accounting for about 10% of the counterparty relations. For currencies with smaller IRD markets, the share of house clearing rises to about 35-50%. As such, it is important to keep in mind that the impact of client clearing on the structure of the IRD

[17]Besides the euro (EUR) and the British pound (GBP), IRD trades denominated in Polish zlotys (PLN) and Swedish kronor (SEK), which will be both subject to the clearing obligation for the first two categories of counterparties in the course of 2017, are most frequent from the European currencies, followed by the Czech koruna (CZK), Danish krone (DKK), and Hungarian forint (HUF). IRD trades denominanted in Bulgarian lev (BGN), Croatian kuna (HRK) and Romanian leu (RON) are missing in our dataset. From other EEA currencies, IRD trades in Swiss franc (CHF) and Norwegian krone (NOK) are also present.

market in the EU is not homogeneous across currencies and maturities. Thus, for specific policy and research purposes it may be necessary to analyse particular parts of this market.

## Types of institutions vis-à-vis maturity and currency of contracts

Now, we turn our attention to the average number of counterparty relations of various types of institutions, looked from the perspective of networks based on IRD contracts with specific maturities. In Fig. 11 we present the average degree (solid line) divided by maturity date and type of institution - for the full network of counterparty relations between CCPs, their clearing members, and the clients of these clearing members, at the end of 2016. Please note that we use a logarithmic scale. We observe that CCPs dominate these networks, as we would expect, and on average trade with a similar number of counterparties across all maturity dates (some of the values for higher maturities were removed for reasons of confidentiality, but the level of average degree remains similar for CCPs across all maturities). This is interesting, as we would have expected fewer institutions being interested in long-term IRD contracts. It is apparent that clearing members are large and diversified enough to be able to deal with the whole range of maturities within the IRD market in Europe. The distribution is skewed to the right as the 75th percentile is at the same level as the average. Then, for G16 dealers we observe the number of their counterparty relations decrease significantly with the maturity date. The distribution is similarly skewed as for CCPs, with some very strongly interconnected dealers. This pattern suggests the role of G16 dealers in the client clearing with smaller institutions. These institutions are less interested in long-term IRD contracts, thus justifying the observed negative slope. A similar pattern, although on a much smaller scale, can be observed for banks and other financial institutions – presumably for similar reasons. In Fig. 12 we present the average degree (solid line) divided by maturity date and type of institution - for the network of counterparty relations between CCPs and their clearing members (house clearing), at the end of 2016. Please note that we use a logarithmic scale. We observe that the house clearing side is clearly dominated by CCPs,

which on average trade with a similar number of counterparties across all maturity dates (some of the values for higher maturities were removed for reasons of confidentiality, but the level of average degree remains similar for CCPs across all maturities). The distribution is skewed to the right as the 75th percentile is at the same level as the average. Thus, we can infer that there is a small number of very large CCPs driving the average above the 75th percentile. Then for G16 dealers we observe the number of their counterparty relations decrease significantly with the maturity date, this time – in contrast to the full network – the relative interconnectedness of these dealers is smaller on average than CCPs – showing that they are mostly connected to their clients. This should be looked at together with the previous figure including the client clearing – we observe that G16 dealers have fewer counterparty relations with clients for longer maturities, but also fewer connections with CCPs for longer maturities, presumably due to lower demand from clients. The distribution is similarly skewed as for CCPs, with some very strongly interconnected dealers. A similar pattern, although on a much smaller scale, can be observed for banks and other financial institutions. Importantly, we can observe that virtually no insurance undertakings & pension funds are clearing members of the CCPs, showing the importance of client clearing to this important sector. Similar results appear for non-financial companies, as one would expect.

Having looked at the intersection of maturities and types of institutions, we turn to the intersection of the currency of the underlying IRD contracts and types of institutions within the networks. In Fig. 13 we present the average degree (number of counterparty relationships of a given institution) by currency in which the IRD constituting the counterparty relationship is denominated and type of institution, for the full networks (CCPs, clearing members, and their clients). We observe that G16 dealers dominate, and in particular have a significant number of counterparty relationships on average for IRD denominated in the euro, the British pound, and the US dollar (if CCPs were plotted they would be significantly above other categories but often below G16 dealers - especially in the case of major currencies). This is due to the dominance of client clearing in the whole network, as pre-

sented above – client clearing is done to a large extent through G16 dealers. Interestingly, for the less prevalent EU currencies (such as CZK, DKK, PLN, and SEK) it is the CCP dominating the structure of the clearing network instead of the dealers, signaling a limited amount of client clearing for these. This raises a question of whether there is much less interest in hedging in these currencies, whether it is smaller banks dealing with these instruments regionally, or whether there is little interest in using centrally cleared IRD contracts by small institutions in the first place (and opting for bilateral relations instead). It would be interesting to analyse the market structure in the future, following the introduction of the clearing obligation for PLN and SEK in the course of 2017 for the first two categories of counterparties. Further, in Fig. 14 we present the same information for the networks of CCPs and their clearing members (the house clearing side). The CCPs are not presented due to reasons of confidentiality. If we plotted the CCPs, they would often be an order of magnitude higher than the other categories, thus we would observe that the richness of structure of the full network with client clearing is gone, and CCPs clearly dominate this side of the clearing network. This is more or less what we would expect, although very small number of counterparty relations of G16 dealers within this network on average is surprising. This means that G16 dealers concentrate on one or two CCPs for their business in specific currencies – an issue of interest for the stability of the market, especially the client clearing part. On the one hand, this underlies the importance of client clearing for analysing full implications of interconnectedness in this market, but on the other hand it also shows that we need to stress that CCPs remain the major contributors to the structure of this system. Finally, in Fig. 15 we present the same information for the networks of clearing members and their clients. We observe that for client clearing the importance of the G16 dealers is overshadowing any other type of institutions. If there are systemic risks or contagion mechanisms in the client clearing structure, these will be either contained within or amplified by the G16 dealers, as such they deserve close attention. It is interesting that no other type of institutions are on average heavily interconnected within the client clearing side, with the

exception of non-financial firms in the IRD market denominated in the Australian dollar (AUD), a peculiar development in itself.

## Geography of counterparties

We now turn to the analysis of the IRD market participants by country of domicile. In Fig. 16 we present the average degree (blue bar for EU countries, orange bar for non-EU countries) divided by country of domicile of institutions (CCPs, clearing members, and their clients) – for the network of counterparty relations at the end of 2016. We observe that institutions from large countries such as the United States, Canada, Japan, and Great Britain are on average more connected with other counterparties than institutions from most European countries. This suggests that mostly large institutions from non-EU countries trade in the EU-wide IRD market[18]. In some of the cases, it is the influence of the very small number of the most connected institutions, showing that there exist strongly interconnected institutions at the core of the IRD market. We also observe quite a rich picture in terms of the number of countries which participate in the EU-wide IRD market, particularly with regards to non-EU countries. Further, in Fig. 17 we present the same information for the network of counterparty relations between CCPs and their clearing members (house clearing) at the end of 2016. We observe that the picture here is different from the full network. Although the institutions from the UK are still strongly interconnected on average, there is no longer the effect of some very systemic institutions, showing that the super systemic institutions in these markets from the point of view of interconectedness are the dealers who deal with clients, and not just the CCPs. This, together with the knowledge that CCPs are well-prepared to deal with problems in the financial markets, suggests that client clearing is very significant for financial stability and in particular the contagion channels. Finally, we lose the rich structure in terms of the number of countries participating in the IRD market within

[18]This is conceivably also an issue with the borders of the dataset we are using, it is possible that only the large dealers from the non-EU countries are present in our sample, whereas we are missing some of the client clearing side of those contracts which are within the non-EU countries only and as such not reported to the European authorities.

the EU. As such, ignoring the client clearing side would potentially ignore important aspects of the geography of risk within the derivatives market.

We also present the country profile as above per the type of institutions (we skip CCPs and merge G16 dealers with other banks for reasons of confidentiality). In Fig. 18 we present the average degree (blue bar for EU countries, orange bar for non-EU countries) divided by country of domicile and type of institutions – for the network of counterparty relations between CCPs, clearing members, and clients, at the end of 2016. We observe that the banks with most counterparty relations on average are domiciled in the Great Britain, France, and Australia. For insurance and pension companies these numbers are low across the board. Other financial institutions are on average the most connected in this market if they are domiciled in the United States and Japan. For non-financial institutions, the only notable average number of counterparty relationships is reported for Australian institutions.

Now we turn our attention to the cross-section between currencies in which the contracts underlying the studied networks are denominated, and the country of domicile of the institutions within the studied networks. In Fig. 19 we present the average degree by currency in which the IRD contract is denominated and domicile country of the institution, for the full network (CCPs, clearing members, and their clients). We observe that counterparties from the Great Britain and the United States are persistently strongly interconnected on average across most currencies, showing the importance of the international financial conglomerates operating there, while for instance Canadian institutions are most engaged in the IRD denominated in Canadian dollar (CAD). Further, in Fig. 20 we present the same information for the network of CCPs and their clearing members. We observe that fewer countries of domicile are represented, if we do not take into account the client clearing side, once again showing the importance of client clearing in understanding the precise nature of the interconnectedness stemming from these markets. We also observe that counterparties from Great Britain are once again persistently strongly interconnected on average across most currencies (perhaps due to the number of CCPs domiciled in Great Britain), while for

instance Canadian institutions are most engaged in the IRD market denominated in CAD, Australian institutions in AUD, and so forth. Interestingly, IRD denominated in JPY seem to be traded more (in the sense of the number of counterparty relations) through institutions domiciled in Singapore than Japan, a trend also present in the full picture including client clearing, presented in Fig. 19.

Now, we dive deeper into the geography of counterparty relations, concentrating on the more diverse side of client clearing. In Fig. 21 we present the total number of counterparty relations between clearing members and their clients domiciled in specific countries. We observe that the matrix representing the geography of pairs of clearing members and clients is very sparse, indicating that clearing members from a few jurisdictions only provide client clearing to a larger number of clients. A significant amount of counterparty relations between clearing members and their clients are between clearing members from the Great Britain and clients from Luxembourg. Thus, ignoring client clearing in the analysis of centrally cleared IRD markets would hide the strong interconnectedness of institutions domiciled in Luxembourg. Clearing members from Great Britain have a significant number of counterparty relations with clients from other countries as well. Same goes for clearing members from the United States. In contrast, German clearing members mostly have counterparty relations with German clients, while French clearing members have counterparty relations mostly with French and German clients. Another important note is that the number of counterparty relations is persistent with regards to the country of domicile of the clearing member, in other words there is a significant number of those for clearing members from the United States, the Great Britain, and Germany across most countries of domicile of the clients. In contrast, for most other countries of domicile of the clearing members there is few counterparty relations with clients across all countries. In terms of country of domicile of clients we do not see any strong patterns, except for the fact that clients from Luxembourg are the most active in the IRD market in the EU.

## Clustering of the networks

We now turn to the analysis of clustering of the studied networks, across currencies and maturities. In Fig. 22 we present the percent of edges (counterparty relations) present in both networks of IRD markets for contracts denominated in specific currencies, within the total number of unique counterparty relations present in either network, for (a) the full network (CCP-CM-Client), and (b) the network of CCPs and their clearing members (house clearing). We observe that the client clearing side is significantly more diverse across currencies than the house clearing side. It is difficult to spot any structure in the clustering of networks by currency. Notably, the networks for the major currencies (EUR, GBP and USD) appear to be relatively close to each other, but significantly different from the other networks. This may be caused by the introduction of the central clearing obligation for these currencies. In Fig. 23 we present the same information for contracts maturing in specific years. Many of the zeroes presented are for confidentiality reasons. We observe that the client clearing side is significantly more diverse across maturities than the house clearing side. Maturities closer to each other tend to be closer to each in terms of counterparty relations (values close to the diagonal), while further from the diagonal we observe more diverse pairs of networks. This suggests that it will be relatively simple for institutions to simultaneously clear IRD contracts of similar maturities with the same counterparties (easiness of hedging across a range of similar maturities).

Above, we perform the clustering using the Jaccard index, a relatively simple measure of similarity as a starting point. The presented networks are in fact complex networks, and such simple measures may ignore some useful characteristics in this context. As such, it may be useful to complement this analysis in the future with tools specific to complex networks. For instance, information-theoretic metrics are shown to quantify the distance between pairs of complex networks and can be used to cluster the layers of a multilayer system [9]. Those tools can also help in the process of model selection to figure out which theoretical network formation process fits the observed networks. These tools are computationally intensive

for such large networks, and may not perform optimally for sparse networks, such as the networks for single currencies or single maturity years that we analyse in this paper.

## Stability of the networks

Finally, we turn to the analysis of the stability of the studied networks. This analysis is based on the main network of counterparty relationships between CCPs, clearing members, and clients in the IRD market in the EU. In Fig. 24a we present the average percentage of institutions (in the number of all institutions in the network) that would be disconnected with the main trading network[19] of CCPs, clearing members, and clients, as a result of the removal of a certain number of institutions from the network at random (blue line). The average is calculated based on 1,000 realisations for each number of removed institutions, results for all realisations presented as grey dots (for confidentiality reasons each dot represents an average of 3 realisations). While the average shows a simple, linear relationship between the removal of institutions and the number of other disconnected institutions, the structure of individual results shows a rich diversity of results. To investigate what drives the rich underlying structure of the results, we disentangle these effects by the type of institutions removed from the network, and by side of the clearing (house, client). We also remove the institutions from the largest to the smallest (by their number of counterparty links) instead of random removal, to see the sensitivity of the network to the removal of the most connected counterparties. Thus, in Fig. 24b we present the percentage of institutions (in the number of all institutions in the network) that would be disconnected with the main trading network as a result of the removal of a given number of the largest counterparties (in terms of the number of counterparty relations) from the network (for confidentiality reasons we present the cumulative effect lumped by 3 institutions). Note that the percentage is not strictly increasing in the number of removed counterparties – this is because particular institutions may or may not end up in the main trading hub as defined above, depending on the specific

[19]If the network gets broken up into multiple disjoint subnetworks after the removal of certain institutions, we define the main trading network (or hub) as the subnetwork with the largest number of institutions.

number of removed counterparties (if the number of removed counterparties is high enough). We note that the collective removal of two largest counterparties already has an effect over 4 times larger than the removal of the largest counterparty. Removing further counteparties has diminishing effects.

At this point it is important to note that this analysis is not intended to study the resilience of the market to counterparty defaults. First, it would be very difficult to gauge this question for a number of reasons. We only know of the existence of counterparty relationships but not the exposures. Even if we knew the exposures, we would need to be able to gauge not only the gross notionals, which are also not informative, but net notionals and market values, and – crucially – collateral. As we do not have any information about collateral in the dataset, we are not able to perform such an analysis. We also do not know anything about the macroeconomic situation that could lead to these defaults, and this would significantly alter the results. It would also be difficult to investigate the effects on the confidence of market participants. Second, the default of a CCP would almost always (except for fringe cases with non-default related losses, such as a major cyber attack) be related to the defaults of clearing members, while clearing members and clients can default independently, further adding to the complexity of the situation. As such, we believe that a resilience analysis would be very difficult to perform convincingly. We thus concentrate on an analysis of the stability of the networks and the access to bilateral clearing (and not central clearing) in case some of the counterparties stop clearing the IRD contracts. This will give us a proxy of their systemic importance. The importance of studying stability of existing counterparty relations even in the absence of cascading defaults is underlined by the International Swaps and Derivatives Association, as described in the Introduction. The latter part is valid also for contractual relationships between clearing members and clients, underlining the importance of this analysis.

In order to disentangle the effects on the stability of the clearing structure of the removal of specific types of institutions we perform the same type of simulation as above, but this time

we remove a random sample of a specific type of institutions at a time from the network. In Fig. 25 we present the percentage of institutions (in the number of all institutions in the network) that would be disconnected with the main trading network of CCPs, clearing members, and clients, as a result of a random removal (based on 1,000 realisations, for confidentiality reasons each dot represents an average of 3 realisations) from the network of a certain number of (a) CCPs, (b) G16 dealers, (c) banks, (d) other financial institutions, (e) insurance & pension firms, (f) non-financial institutions. We observe that CCPs have a limited effect on the stability of the counterparty network. Removal of all CCPs would leave over 95% of the counterparties in the market connected. Of course, a removal of CCPs would most likely be a serious threat to financial stability, but assuming that these CCPs would stop offering clearing services in the IRD market in an orderly manner, it appears that most counterparties would remain interconnected through the bilateral connections with each other. This may be particularly relevant to the question of the potential suspension of the central clearing obligation in specific cases. It looks as if the central clearing obligation was suspended in the case where CCPs are not available as the market structure would be able to perform the bilateral clearing reasonably well. This is because the existence of intermediation chains does not depend strongly on the central counterparties. Additionally, it is worth noting that the studied institutions are also interconnected through bilateral relations as well as through other asset classes, which we cannot observe in our analysis. This is of course just a first approximation of the analysis that would need to be performed in the future to answer questions about the suspension of the central clearing obligation. The network is the least stable with regards to the removal of G16 dealers, then banks and other financial institutions. Removal of insurance & pension or non-financial firms does not affect the network structure in any way. In Fig. 26 we present the same information for the network of house clearing (CCP-CM). We observe that for the house clearing side it is just the CCPs that matter in terms of stability of the network with regards to the removal of institutions. This is an obvious consequence of the structure of house clearing. The network

is resilient to the removal of any other types of institutions. This, together with Fig. 25, highlights that the client clearing side has a very strong impact on the analysis of the stability of the structure of the derivatives market. Due to the confidentiality constraints, we do not provide results for the removal of the largest counterparties of a given type.

We also take a look at how stable the access to the main clearing hub is for different cohorts of institutions in the network with respect to removal of clearing members. In Fig. 27a we show the percentage of institutions (in the number of all institutions of a given type in the network) that would be disconnected with the main trading network of central counterparties, clearing members, and clients, as a result of the removal of a certain number of clearing members from the network at random. There, we see that there is a large disparity of results depending on which clearing member is removed, but on average insurance companies & pension funds are the most affected, followed by other financial institutions, non-financial institutions, and banks. Thus there are differences between the effects on various types of institutions, but we also observe that a removal of one clearing member from the clearing structure has a relatively low impact on the systemic scale. A withdrawal of clearing of a single clearing member will not have systemic consequences, but constitutes operational risk that the clients should be aware of and have contingency plans for, as a large share of clients clear all their interest rate derivatives through a single clearing member. It is important to stress that this analysis hints at potential issues with access to central clearing rather than effects of counterparty defaults, in which case the results and the systemic importance in terms of risk would depend strongly on the overall exposures of counterparties. Further, in Fig. 27b we present the same analysis but removing a certain number of the largest clearing members (in terms of the number of counterparty relations). Note that the ratio is not strictly increasing in the number of removed clearing members – this is because the institutions of a particular type may or may not end up in the main trading hub as defined above, depending on the specific number of removed clearing members (if the number of removed clearing members is high enough). We concentrate on the analysis of the removal of

one or the two largest clearing members. The removal of the three largest clearing member has an effect of varying degrees, however. Banks are the least affected by it, followed by non-financial institutions. Insurance companies and pension funds as well as other financial institutions are the most affected by the additional removal of the second largest clearing member from the network.

Finally, we look at the second order connections, to try find a first approximation for market access of the counterparties of various types. In this analysis, we define market access of an institution as the total number of counterparties that neighbours of that institutions are connected with in the network. We ignore central counterparties in this part of the analysis, as these enter the situaton post-trade, and as such would not give much information about market access. For instance, if an institution was a client of two clearing members, one of which was trading with 5 institutions and the other with 8 institutions then the market access, as we define it, for this institution would be equal to 13. The reasoning behind this is that access to clearing members who have more counterparty relations would give an institution more access to potential counterparties in the derivatives market to enter into contracts with than a clearing member who has a limited number of counterparty relations. Thus, in the following analysis, we estimate how the removal of clearing members would affect such market access for various types of institutions. We also show what market access various types of institutions have in the empirical network. This approach has its limitations, we ignore access to counterparties that would happen through longer intermediation chains than two connections in the network, as this would add considerable complexity to the analysis and we believe the current setup gives a reasonable first approximation to what we try to capture. The procedure is the same as above, we remove at random a number of clearing members (100 realisations plotted on the charts), and calculate the market access variable as defined above for all institutions still present in the network. We then aggregate the results by the type of institutions. First, in Table 5, we present the total and average market access in the network we start with. We can see that G16 dealers have by far the highest

average market access, which is consistent with their role as intermediaries. Surprisingly, non-financial companies have, on average, better market access on this market than banks and insurance & pension companies. Other financial companies have the lowest market access on average, even though collectively they have the most market access given the number of these institutions in the network. In Fig. 28a we present the average loss of the market access by type of institution given a random removal of a given number of clearing members from the network (note log scale used). We can see that the loss of market access converges to the average market access for a given type of institution (as in Table 5). This is seen clearly in Fig. 28b, where we present the ratio of the market access lost as a result of the removal of a given number of clearing members to the starting market access (as in Table 5). We can see clearly that there is a linear relationship between the number of clearing members removed from the network and loss of market access, and the nature of this relationship does not strongly depend on the type of institution in question. Thus, the underlying force in this case is the starting market access.

Table 5: Total market access and average market access for the full network of interest rate derivatives in the EU at the end of 2016. market access is defined as the sum of counterparty relations of all neighbours of a given institution.

| Type of institution | Total market access | Average market access |
|---|---|---|
| G16 | 16,899 | 1,056.19 |
| Non-financial | 9,580 | 111.40 |
| Bank | 15,046 | 24.75 |
| Insurance & pension | 9,839 | 23.43 |
| Other financial | 17,160 | 3.16 |

In Fig. 29 we present the same analysis, but instead of removing the clearing members randomly as previously, we remove the clearing members from the largest to the smallest (by the number of counterparty links). In Fig. 29a we present the loss of market access by type of institution given a removal of given number of the largest clearing members from the network (note log scale used). Again, we can see that the loss of the market access depends very much on the average market access for a given type of institution. Thus, we turn to

Fig. 29b, where we present the ratio of the market access lost as a result of the removal of a given number of the largest clearing members to the starting market access. Here, we can see the differences in the effect of the removal of the three largest clearing members on the market access of the various groups of institutions. Other financial institutions would note the lowest effect of around 30%, whereas the other types would all see an effect on the order of 40%. The effects of the removal of the largest clearing member are more diverse, ranging from less than 20% to around 30%. Overall, other financial institutions and G16 dealers seem the least affected by the removal of largest clearing members (for the opposite reasons: while G16 dealers are strongly interconnected and do not depend so much on the other counterparties for their access to intermediation, the other financial institutions are so fragmented that they are not collectively affected in a strong way), while banks are the most affected. This is noteworthy, given the importance of the banking sector to financial stability.

# 6 Conclusion

We have presented a first comprehensive description and analysis of the centrally cleared IRD market in the EU. In particular, we have shown that the client clearing side is rich and important for the analysis of the market structure and stability of the derivatives markets. Our results hint that G16 dealers play a crucial role in the centrally cleared IRD market. This means that for macroprudential reasons there is a need to consider the interplay between banking and financial market infrastructures, which is not trivial not least due to the difference in business models between the two.

Future research should look into the structure of centrally cleared market for other classes of derivative contracts, most notably FX derivatives and the CDS market, taking into account client clearing as in this study. Further, a richer analysis of the clustering of these networks should be performed, to gauge the similarity of network structures of various segments of

the derivatives market in the European Union. Stability, resilience and potential contagion in these networks should be analysed in more detail, particularly using notional and market values of trades between counterparties.

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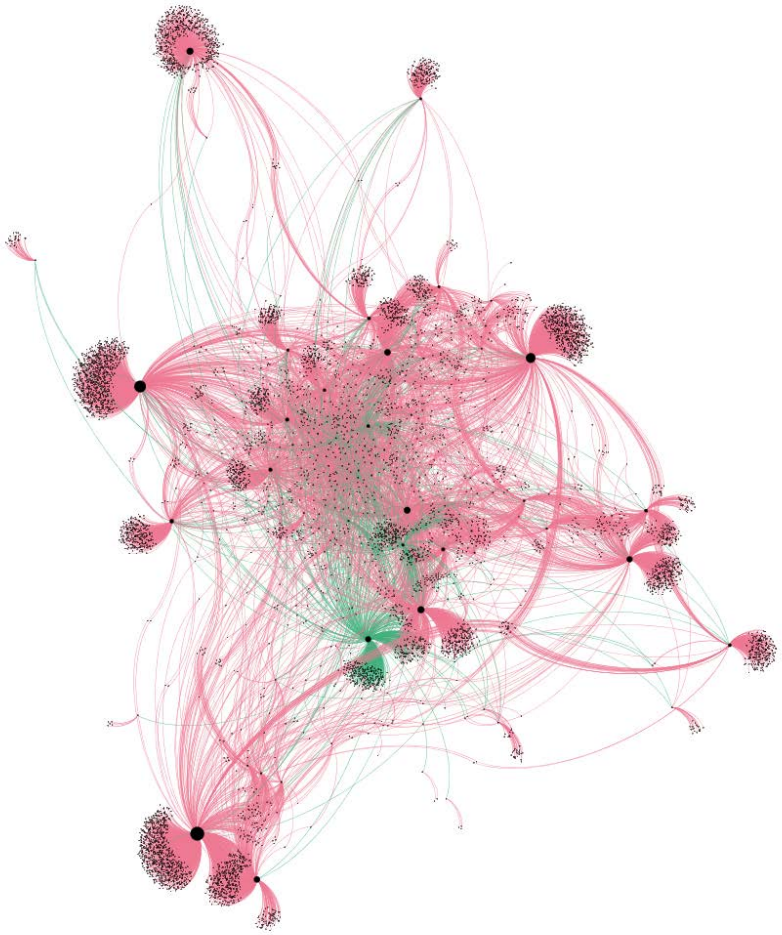


Figure 3: Full network of counterparty relationships. Data for 31 December 2016. Size of nodes relative to their degree (number of counterparty relations). Counterparty relations between CCPs and their CMs shown in green and between CMs and their clients shown in red. We can observe that the client clearing is the dominant part, contrary to networks based on gross notional. This suggests that the structure of the client clearing is significant for financial stability, in particular affecting the stability of the IRD market.

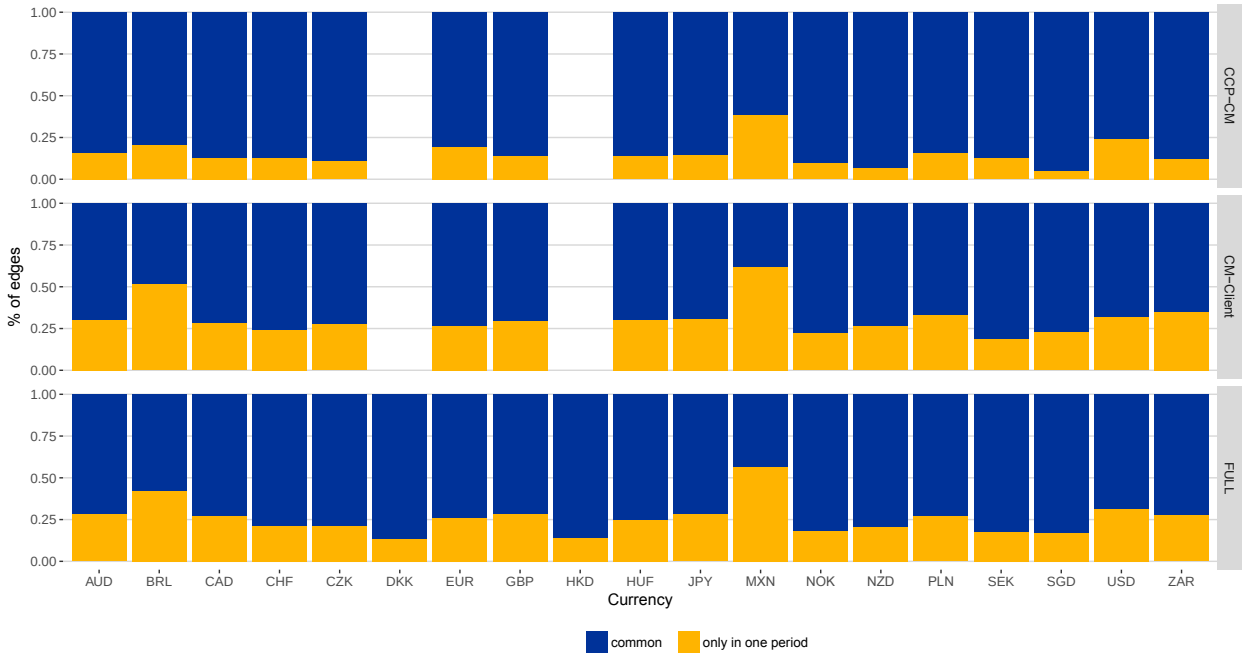



Figure 4: Percent of edges (counterparty relations) present in the network of counterparty relations in IRD markets at both the end of Q3 and the end of Q4 of 2016 and those present at both times (Jaccard index), within the total number of unique counterparty relations present in either period, divided by currency of denomination, for the full network of CCPs, clearing members, and their clients (FULL), for the network of CCPs and their clearing members (CCP-CM), and for the network of the clearing members and their clients (CM-Client). Some values not presented due to reasons of confidentiality. We observe that for some of the less prevalent currencies there are actually no changes between quarters (CLP), for other currencies the changes are substantial (MXN, BRL). For the major currencies the changes seem to be on the order of 20% for the relations between CCPs and their clearing members, and 30% for the relations between clearing members and their clients. As most of the changes seem to happen in the relationships between clearing members and their clients, thus regular monitoring of the client clearing aspect may be prudent. We also observe the same situation for he nodes (institutions present in the network), so we skip the presentation of this aspect.

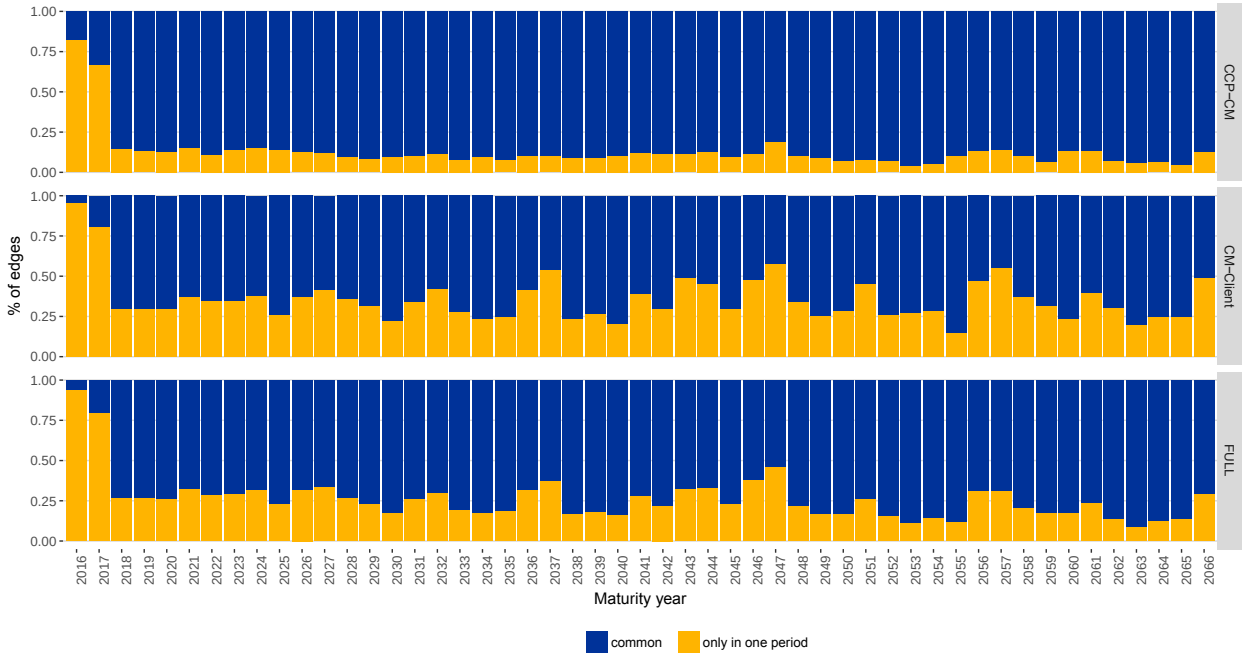
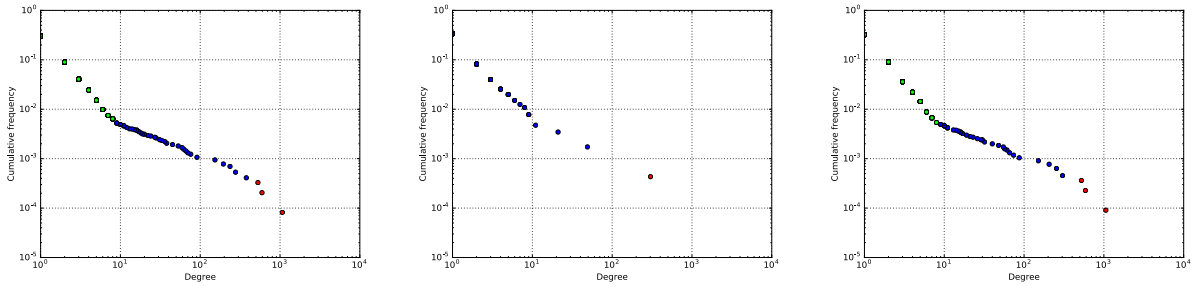



Figure 5: Percent of edges (counterparty relations) present in the network of counterparty relations in interest rate derivative markets at both the end of Q3 and the end of Q4 of 2016 and those present at both times (Jaccard index), within the total number of unique counterparty relations present in either period, divided by maturity of the contract, for the full network of CCPs, clearing members, and their clients (FULL), for the network of CCPs and their clearing members (CCP-CM), and for the network of the clearing members and their clients (CM-Client). We observe that the network of counterparty relations is most volatile in time for the nearest two years of maturity (on the order of 70-90% for the counterparty relationships between clearing members and their clients). Then it remains quite stable across other maturities (at about 10% for counterparty relationships between CCPs and their clearing members, and about 25% for the relationships between clearing members and their clients), except for major tenors (10, 20, 30 years), and the year behind the major tenors (11, 21, 31) – for these the percentage of changes is significantly higher. As most of the changes seem to happen in the relationships between clearing members and their clients, thus regular monitoring of the client clearing aspect may be prudent. We also observe the same situation for he nodes (institutions present in the network), so we skip the presentation of this aspect.




(a) (b) (c)

Figure 6: Degree distributions of: (a) the full network; (b) the house clearing network; (c) the client clearing network. Data for 31 December 2016. The degree distribution is constructed based on average degree of every three institutions (thus each point represent a number of institutions equal to 3 or its multiples), for confidentiality reasons. Inner core in red, outer core in blue, and periphery in green. While the network of counterparty relations between CCPs and their clearing members is characterised by a two tier structure (core and periphery, both reasonably close to distinct power laws), divided around 10 counterparty relationships, the network of clearing members and their clients (which also domininates the whole network, thus (a) & (c) are similar) shows three tier structure (inner core, outer core, and periphery – divided by degrees of around 10 and around 100).

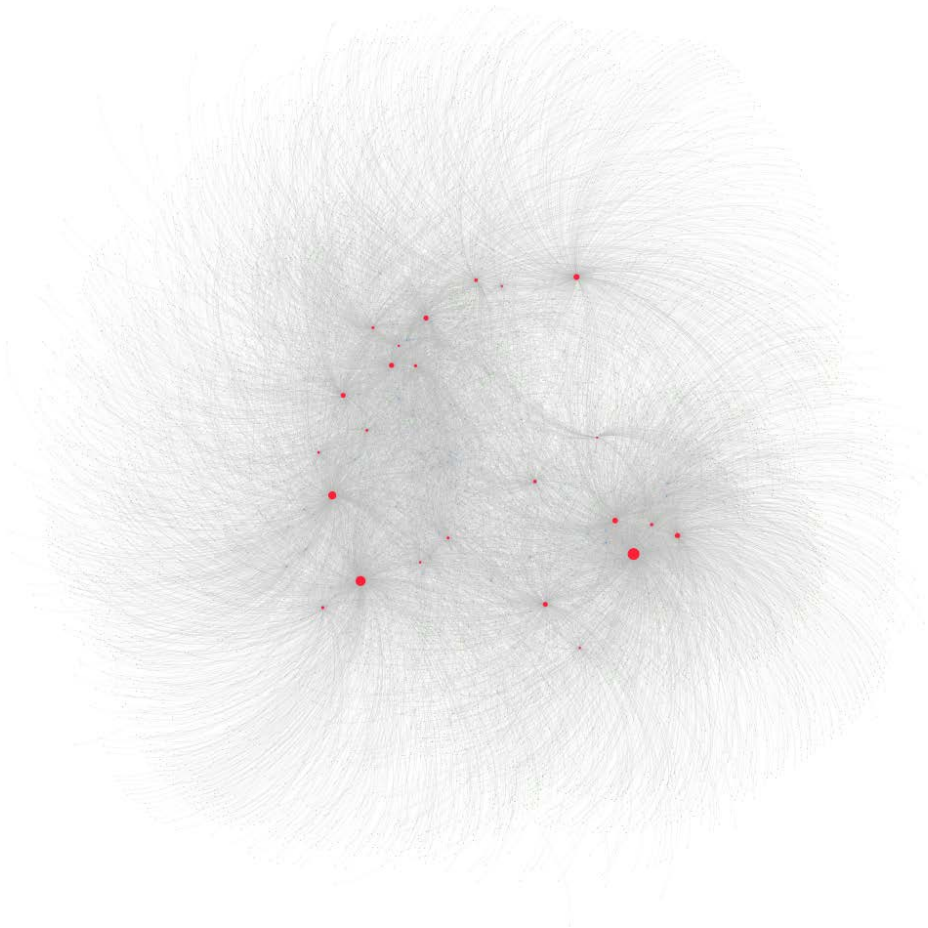


Figure 7: Full network of counterparty relationships between CCPs, clearing members and clients. Data for 31 December 2016. Tiered structure is presented – with institutions in the inner core in presented red, outer core in blue, and periphery in green. The colours for the outer core and periphery (blue and green) are not visible due to the dominance of the inner core (red). We can see how the inner core of the market is creating the backbone of the network.

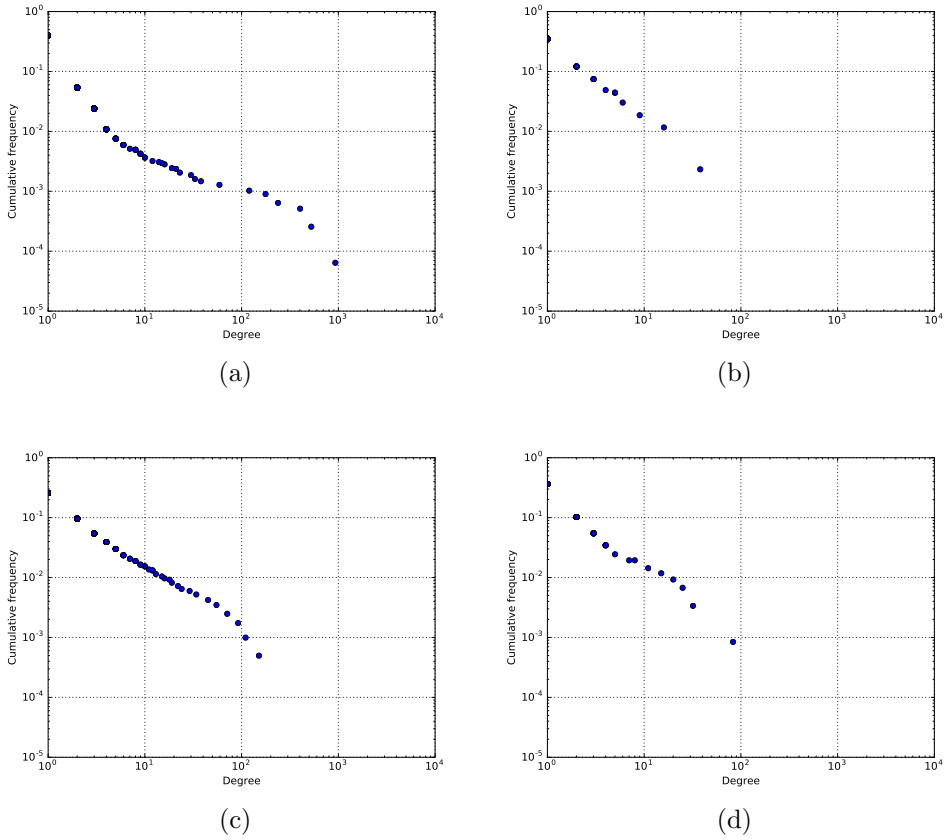



Figure 8: Degree distributions of: (a) the full network of IRD denominated in arbitrarily chosen major currency (Q4 2016); (b) the full network of IRD denominated in arbitrarily chosen minor currency (Q4 2016); (c) the full network of IRD with an arbitrarily chosen short maturity year (Q4 2016); (d) the full network of IRD with an arbitrarily chosen long maturity year (Q4 2016). The degree distribution is constructed based on average degree of every three institutions (thus each point represent a number of institutions equal to 3 or its multiples), for confidentiality reasons. The degree distribution of the network of a major currency IRD closely resembles this of the full network. The network of a minor currency IRD very closely resembles a scale-free network, and does not have a tiered structure. The network with short maturity appears to have a two tier structure, with the break between tiers around degree of 100, while the network for contracts with long maturity appears not to have a tiered structure, and is somewhere between power law and log-normal distribution.

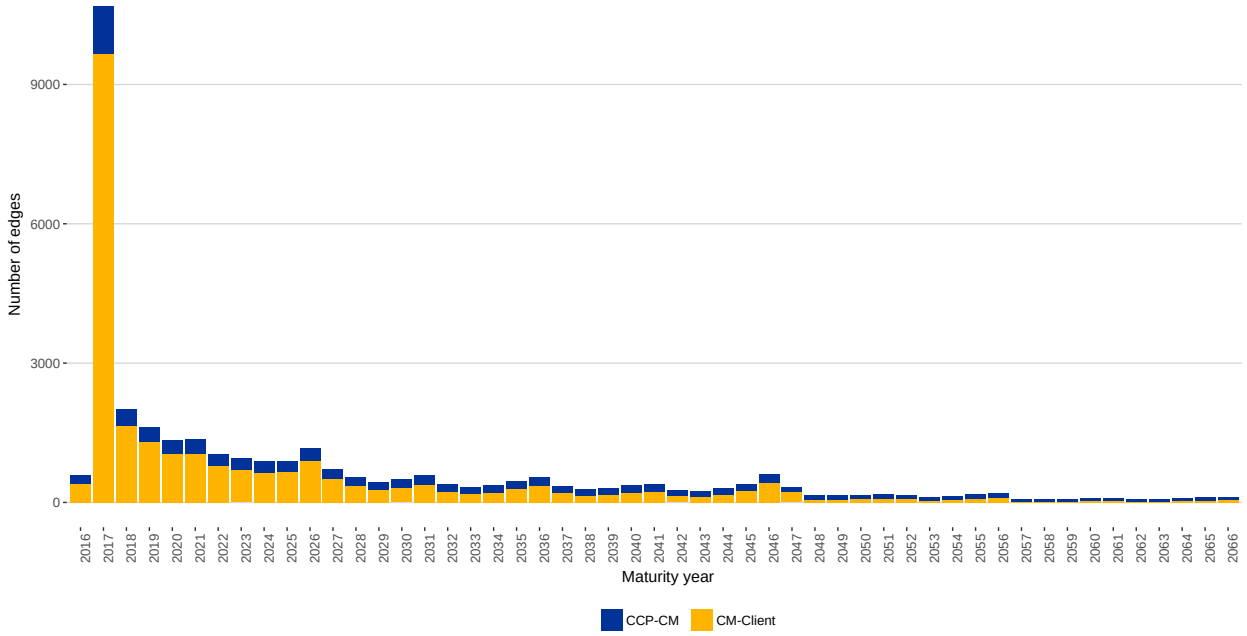



Figure 9: Distribution of edges (counterparty relations) in the full network across maturities. Data for 31 December 2016. We observe that the amount of counterparty relations is the highest for short term interest rate derivatives, and decreases fast with time, except for major tenors (10, 20, 30 years). Client clearing clearly dominates across most maturities, except very long ones.

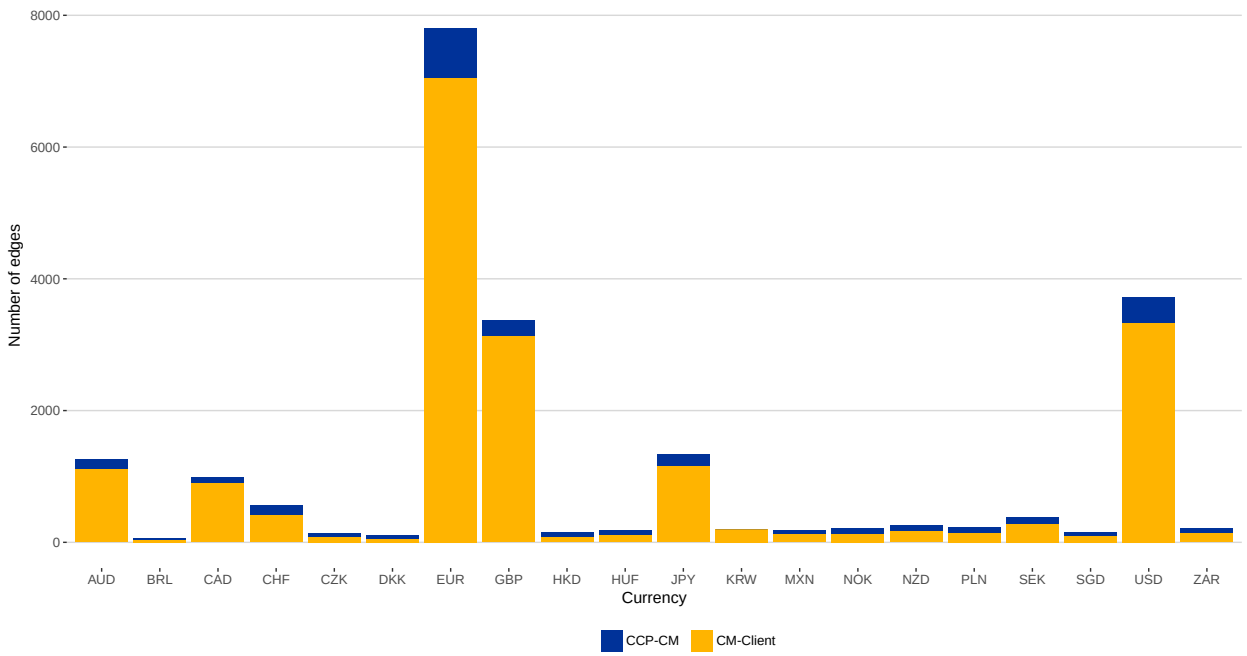



Figure 10: Distribution of edges (counterparty relations) in the full network across currencies. Data for 31 December 2016. We observe that the currencies that have the most interconnected counterparty clearing networks for IRD denominated in them are the euro, the US dollar, and the British pound. Among the main currencies the share of client clearing in these is similar. Client clearing strongly dominates house clearing across major currencies, and tends to be slightly more prevalent than house clearing in other currencies.

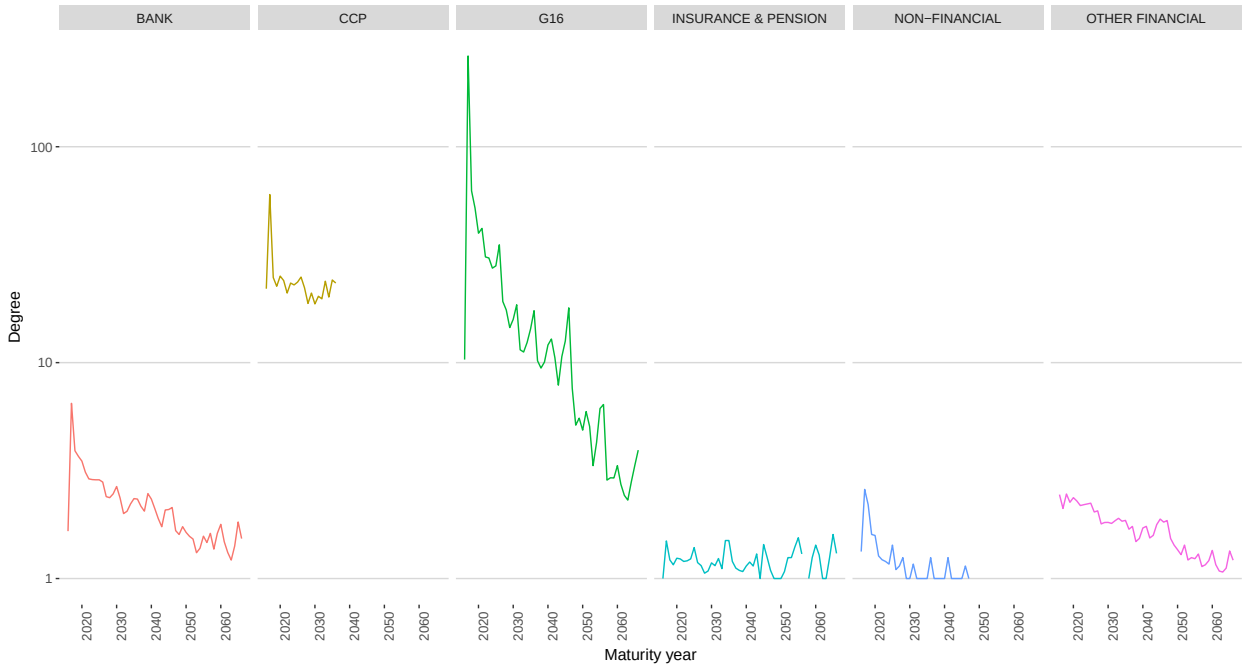



Figure 11: Average degree (solid line) for the full network of counterparty relations at the end of 2016, divided by maturity date and type of institution. A logarithmic scale is used. Missing values due to no observations or confidentiality. We observe that CCPs dominate these networks, as we would expect, and on average trade with a similar number of counterparties across all maturity dates (some of the values for higher maturities were removed for reasons of confidentiality, but the level of average degree remains similar for CCPs across all maturities). The distribution is skewed to the right as the 75th percentile is at the same level as the average. Then, for G16 dealers we observe the number of their counterparty relations decrease significantly with the maturity date. The distribution is similarly skewed as for central counterparties, with some very strongly interconnected dealers. Similar pattern, although on a much smaller scale, can be observed for banks and other financial institutions.

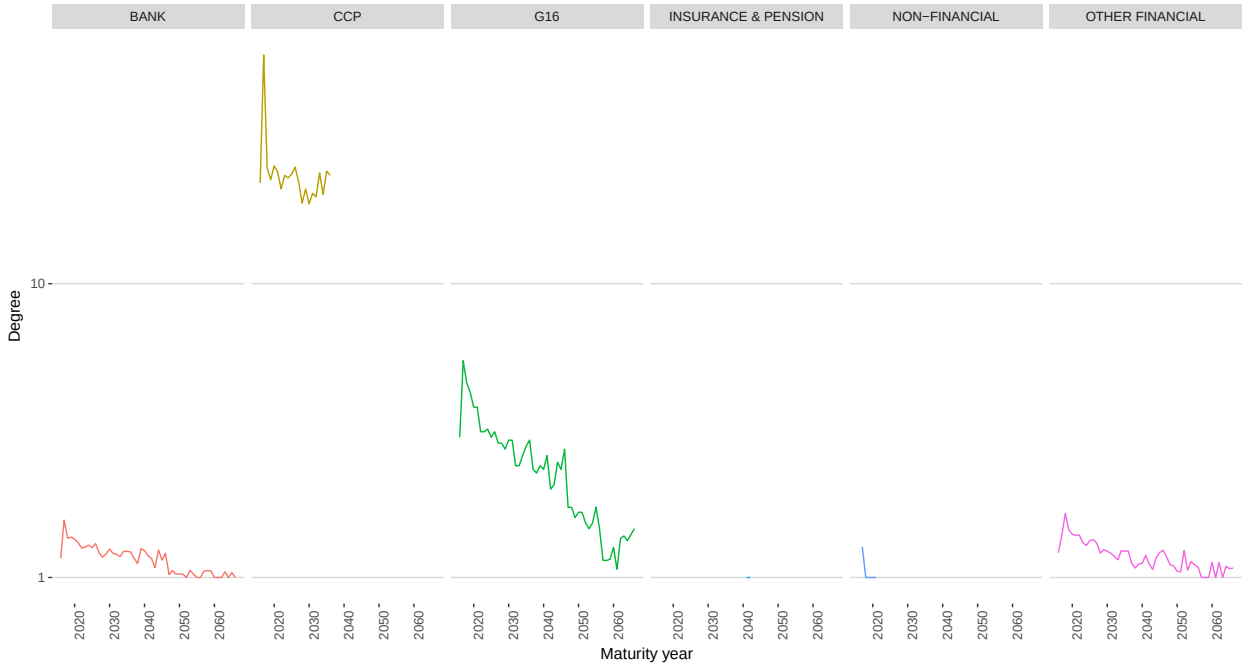



Figure 12: Average degree (solid line) divided by maturity date and type of institution - for the network of counterparty relations between CCPs and their clearing members, at the end of 2016. Please note that we use a logarithmic scale. Missing values due to no observations or confidentiality. We observe that central counterparties on average trade with a similar number of counterparties across all maturity dates (some of the values for higher maturities were removed for reasons of confidentiality, but the level of average degree remains similar for CCPs across all maturities). The distribution is skewed to the right as the 75th percentile is at the same level as the average. Then for G16 dealers we observe the number of their counterparty relations decrease significantly with the maturity date, this time – in contrast to the full network – the relative interconnectedness of these dealers is smaller on average than CCPs – showing that they are mostly connected to their clients. The distribution is similarly skewed as for CCPs, with some very strongly interconnected dealers. Similar pattern, although on a much smaller scale, can be observed for banks and other financial institutions. Importantly, we can observe that virtually no insurance undertakings & pension funds are clearing members of the CCPs, showing the importance of client clearing to this important sector. Similar results appear for non-financial companies.

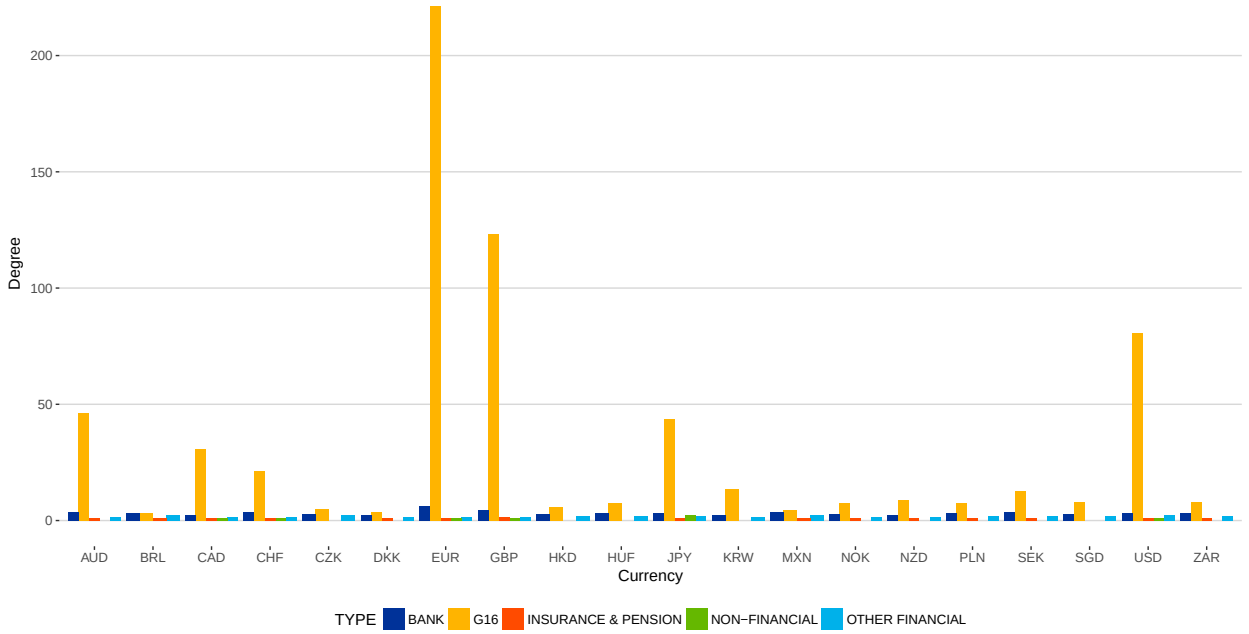



Figure 13: Average degree (number of counterparty relationships of a given institution) by currency in which the IRD constituting the counterparty relationship is denominated and type of institution, for the networks of central counterparties, clearing members, and their clients. Missing values due to no observations or confidentiality (in particular, CCPs are not shown for confidentiality reasons). We note that G16 dealers dominate, and in particular have a significant number of counterparty relationships on average for IR derivatives denominated in EUR, GBP, and USD. Interestingly, for the less prevalent EU currencies (such as CZK, DKK, PLN, and SEK) it is the CCP dominating the structure of the clearing network instead of the dealers, signaling a limited amount of client clearing for these.

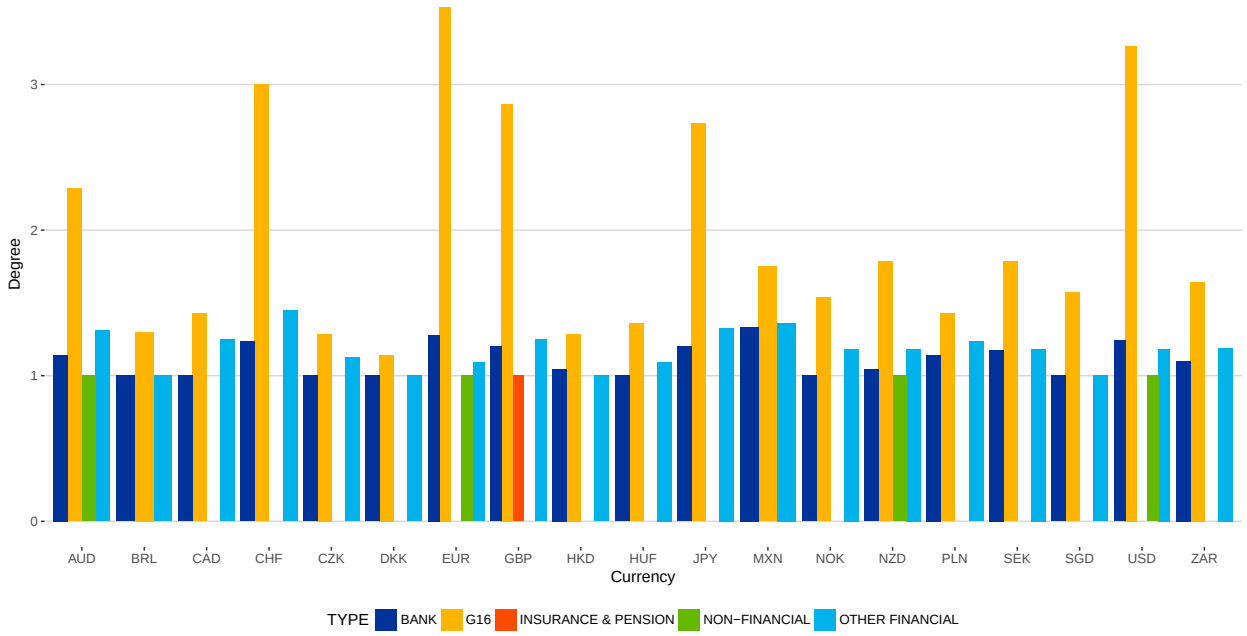



Figure 14: Average degree (number of counterparty relationships of a given institution) by currency in which the IRD constituting the counterparty relationship is denominated and type of institution, for the networks of central counterparties and their clearing members. Missing values due to no observations or confidentiality. In particular, CCPs are not shown due to confidentiality reasons. If CCPs were shown, they would be often an order of magnitude higher than the other categories. We would thus observe that all the richness of the full picture with client clearing is gone, and CCPs dominate this side of the clearing network. On the one hand, this underlies the importance of client clearing for analysing full implications of interconnectedness in this market, but on the other hand it also shows that we need to stress that CCPs remain the major contributors to the structure of this system.

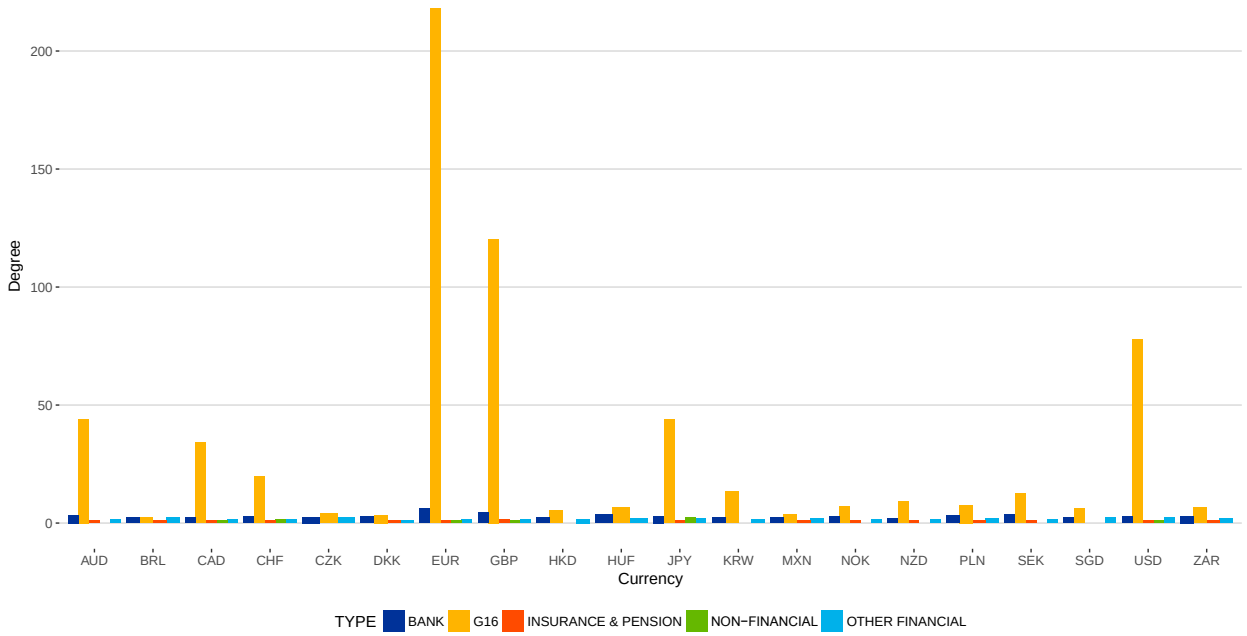



Figure 15: Average degree (number of counterparty relationships of a given institution) by currency in which the IRD constituting the counterparty relationship is denominated and type of institution, for the networks of clearing members and their clients. Missing values due to no observations or confidentiality. We observe that for client clearing the importance of the G16 dealers is overshadowing any other type of institutions. If there are systemic risks or contagion mechanisms in the client clearing structure, these will be either contained within or amplified by the G16 dealers, as such they deserve close attention.

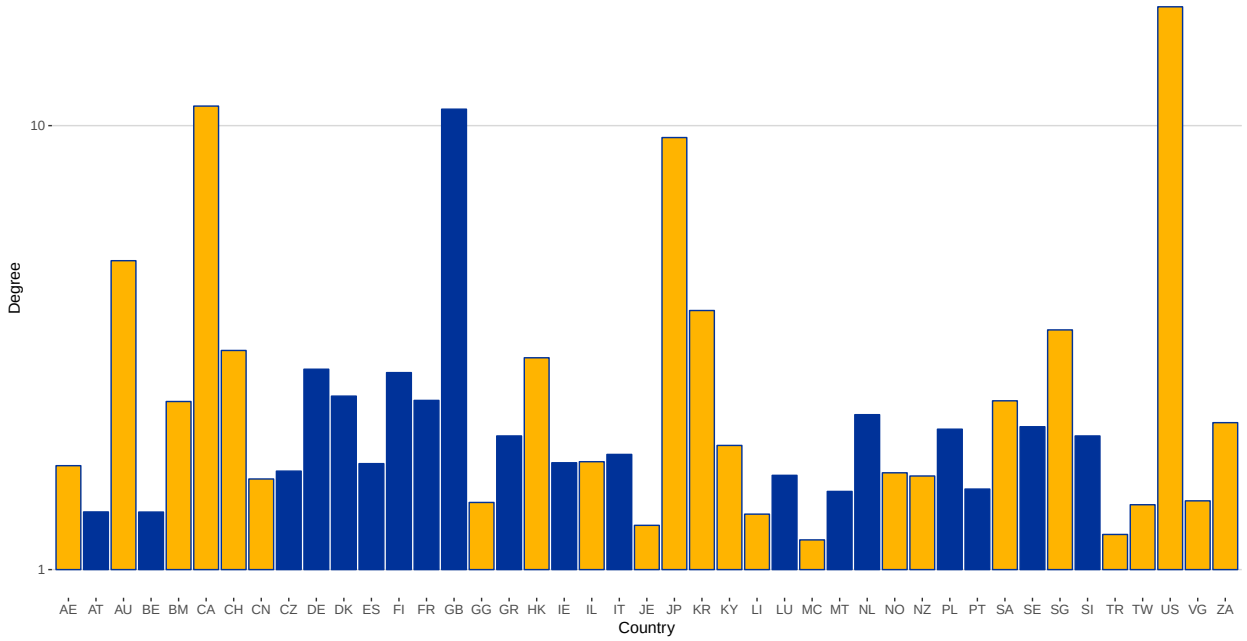



Figure 16: Average degree (blue bar for EU countries, orange bar for non-EU countries) divided by country of domicile of institutions (CCPs, clearing members, and their clients) – for the network of counterparty relations at the end of 2016. We observe that institutions from large non-EU countries such as the United States, Canada and Japan are on average more connected with other counterparties than institutions from most European countries. This suggests that mostly large institutions trade in the EU IRD market. The notable exception is the Great Britain. The institutions domiciled in the Great Britain are on average highly connected with other counterparties. We know this is the influence of the very small number of the most connected institutions, as the 90th percentile is below the average (in contrast with the non-EU countries) – showing that there are strongly systemic institutions, from the point of view of IRD market, in the Great Britain. The 90th percentile is not shown for confidentiality reasons.

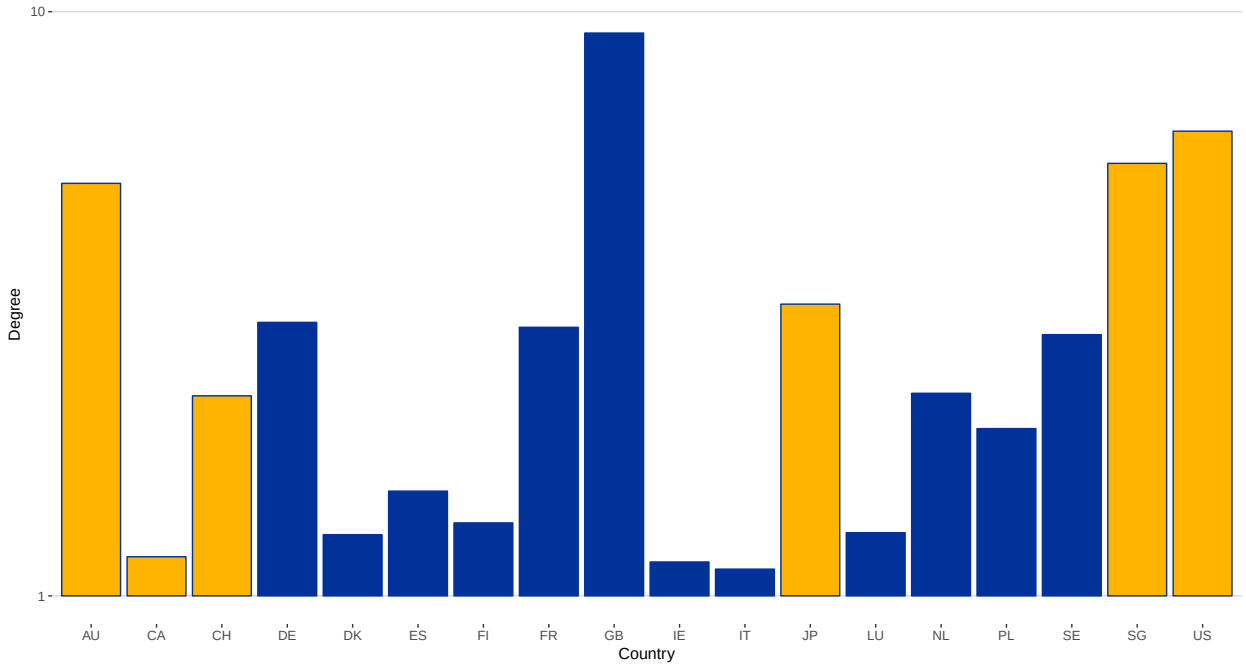



Figure 17: Average degree (blue bar for EU countries, orange bar for non-EU countries) divided by country of domicile of institutions (CCPs, and clearing members) – for the network of counterparty relations between CCPs and their clearing members at the end of 2016. We observe that the picture here is different from the full network. Although the institutions from the Great Britain are still strongly interconnected on average, there is no longer the effect of some very systemic institutions, showing that the super systemic institutions in these markets from the point of view of interconectedness are the dealers who deal with clients, an not just the CCPs. This, together with the knowledge that CCPs are well-prepared to deal with problems in the financial markets, suggests that client clearing is very significant for financial stability and in particular the contagion channels. The 90th percentile is not shown for confidentiality reasons.

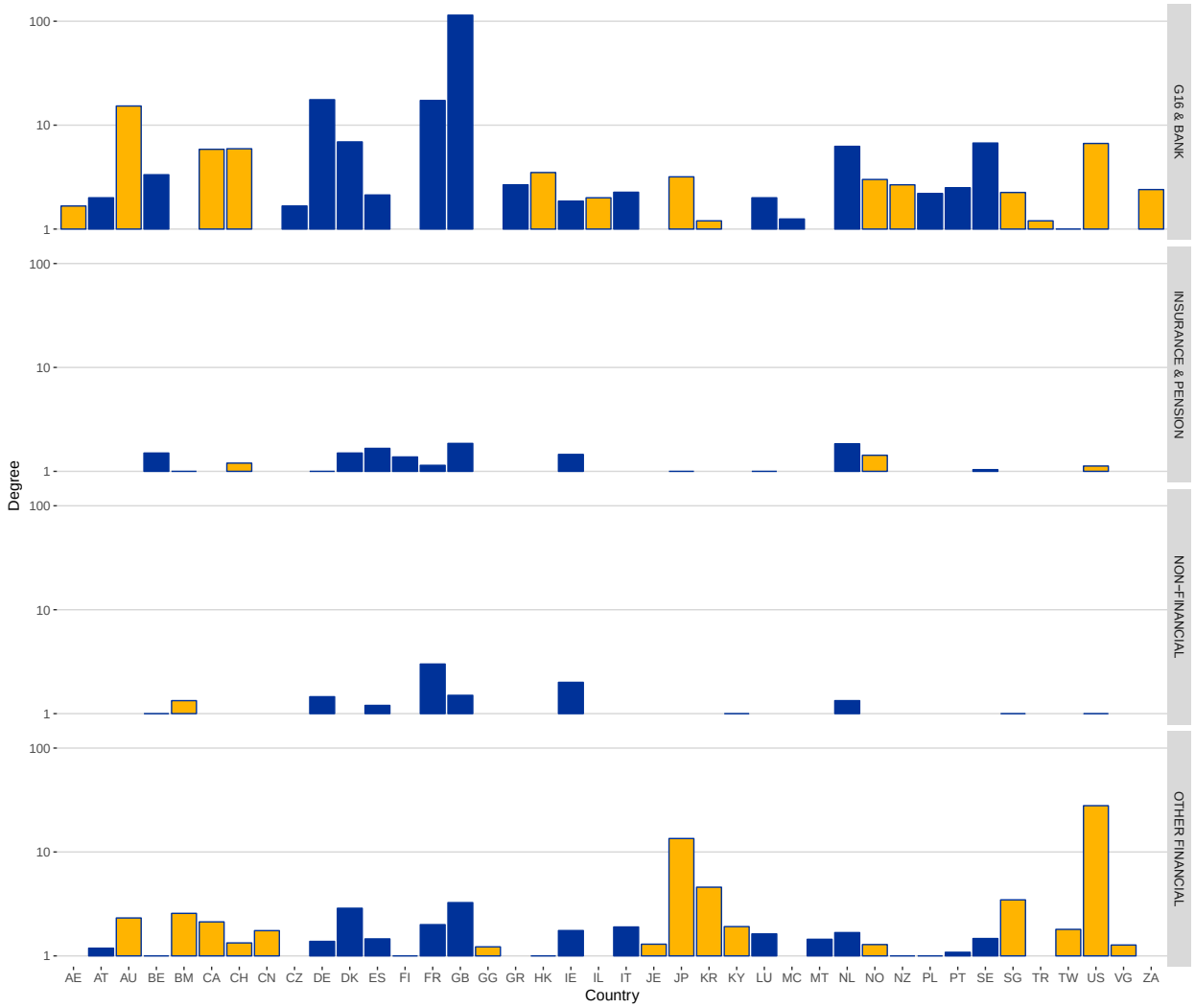



Figure 18: Average degree (blue bar for EU countries, orange bar for non-EU countries) divided by country of domicile and type of institutions – for the network of counterparty relations between CCPs, clearing members, and clients, at the end of 2016. Some categories and/or values not presented due to missing values and confidentiality reasons. We observe that the banks & G16 dealers with most counterparty relations on average are domiciled in the Great Britain, France, and Austria. For insurance & pension companies these numbers are low across the board. Other financial institutions are on average the most connected in this market if they are domiciled in the United States and Japan.

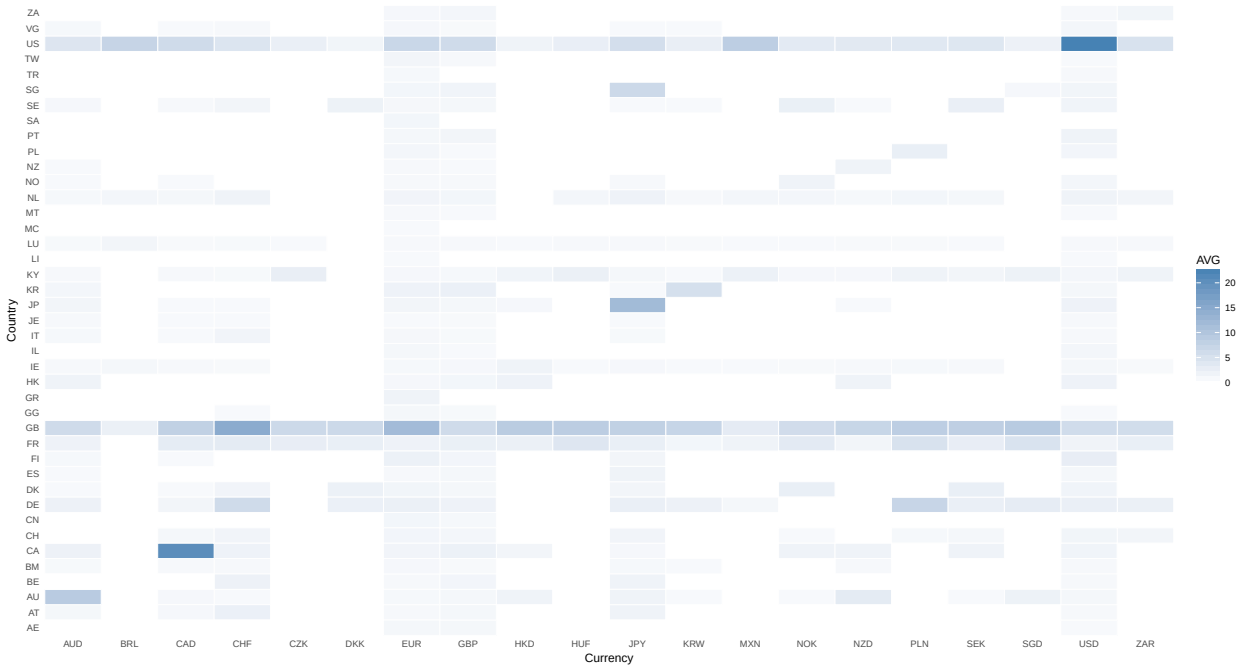



Figure 19: Average degree (number of counterparty relationships of a given institution) by currency in which the IRD contract is denominated and domicile country of the institution, for the network of CCPs, clearing members, and their clients. Zeroes may exist due to no counterparty relationships or for confidentiality reasons. We observe that counterparties from the Great Britain and the United States are persistently strongly interconnected on average across most currencies, showing the importance of the international financial conglomerates operating there, while for instance Canadian institutions are most engaged in the interest rate derivatives denominated in CAD.

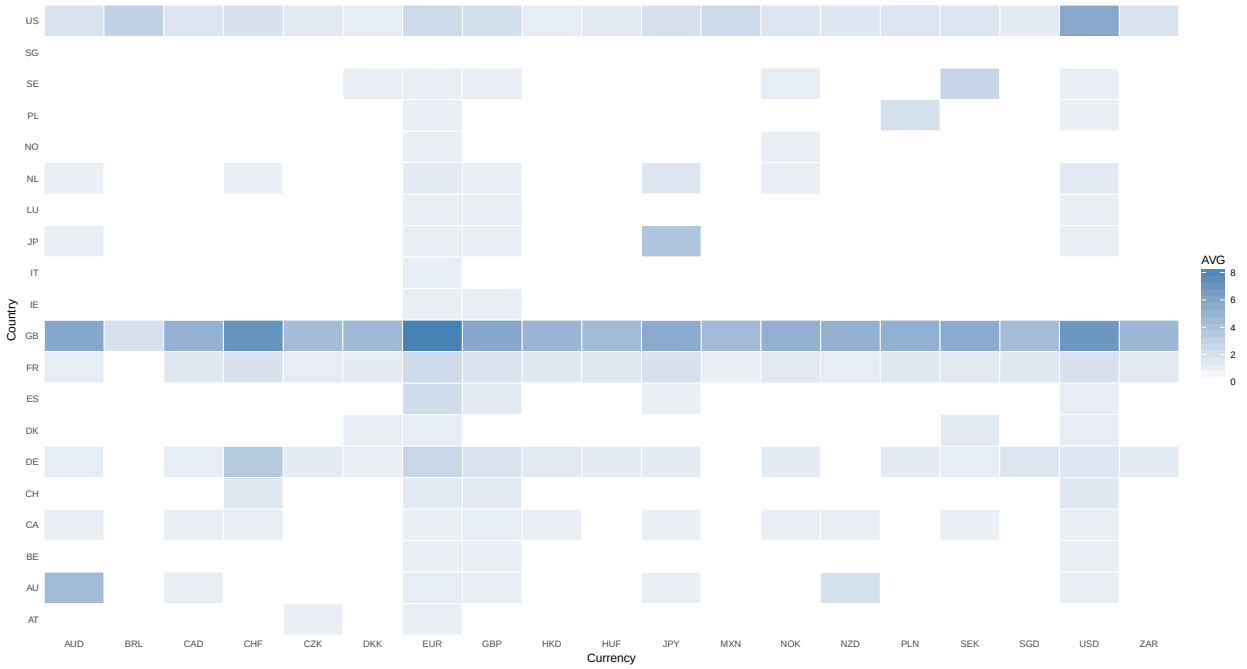



Figure 20: Average degree (number of counterparty relationships of a given institution) by currency in which the IRD contract is denominated and domicile country of the institution, for the network of CCPs and their clearing members. Zeroes may exist due to no counterparty relationships or for confidentiality reasons. We observe that fewer countries of domicile are represented, if we do not take into account the client clearing side, once again showing the importance of client clearing in understanding the precise nature of the interconnectedness stemming from these markets. We also observe that counterparties from the Great Britain are once again persistently strongly interconnected on average across most currencies (perhaps due to the strength of the CCPs domiciled in the Great Britain), while for instance Canadian institutions are most engaged in the interest rate derivatives denominated in CAD, Australian institutions in AUD, and so forth. Interestingly, IRD denominated in JPY seem to be traded more (in the sense of the number of counterparty relations) through institutions domiciled in Singapore than Japan.

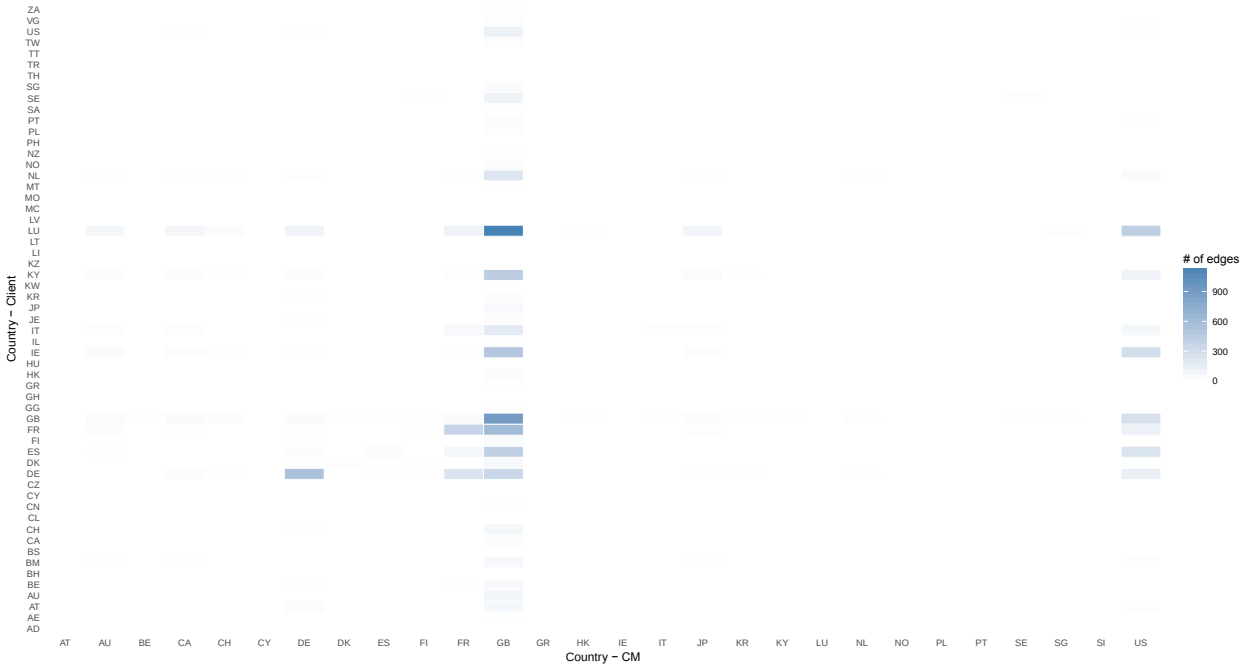
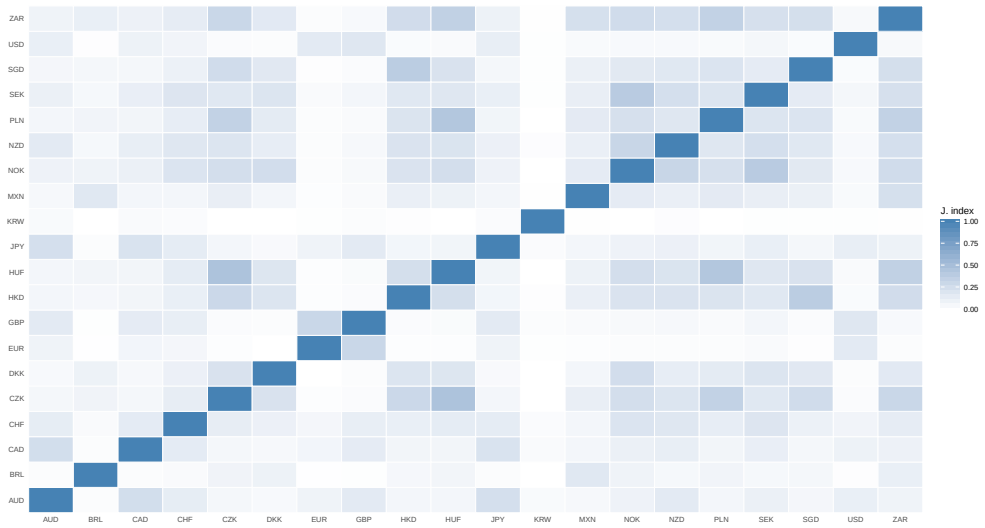
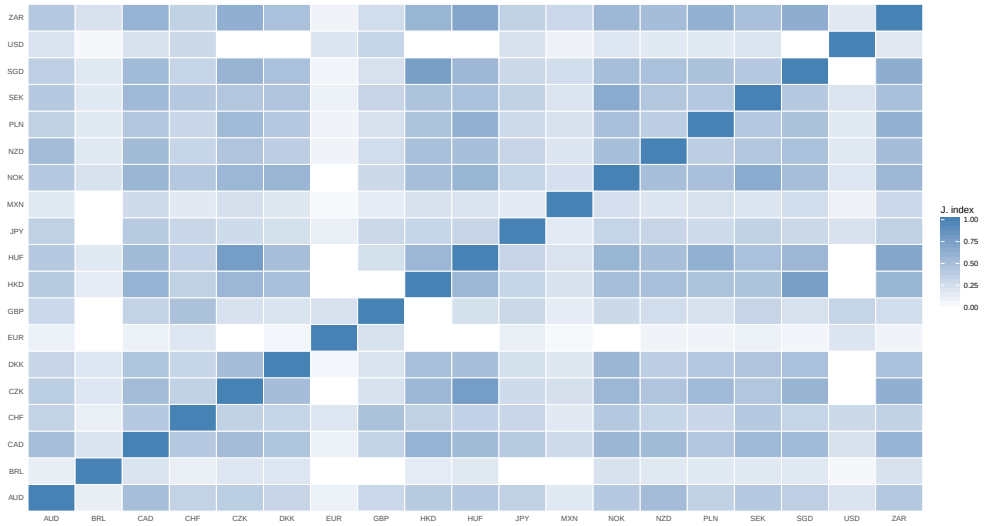



Figure 21: Total number of counterparty relations in client clearing (CM-Client) domiciled in specific countries. Zeroes may exist due to no counterparty relationships or for confidentiality reasons. We observe that the a significant number of counterparty relations between clearing members and their clients are between clearing members from the Great Britain and clients from Luxembourg. Thus ignoring client clearing in analysing centrally cleared IRD markets would hide the strong interconnectedness of institutions domiciled in Luxembourg. Clearing members from Great Britain have a significant number of counterparty relations with clients from other countries as well. Same goes for clearing members from the United States. In contrast, German clearing members mostly have counterparty relations with German clients.

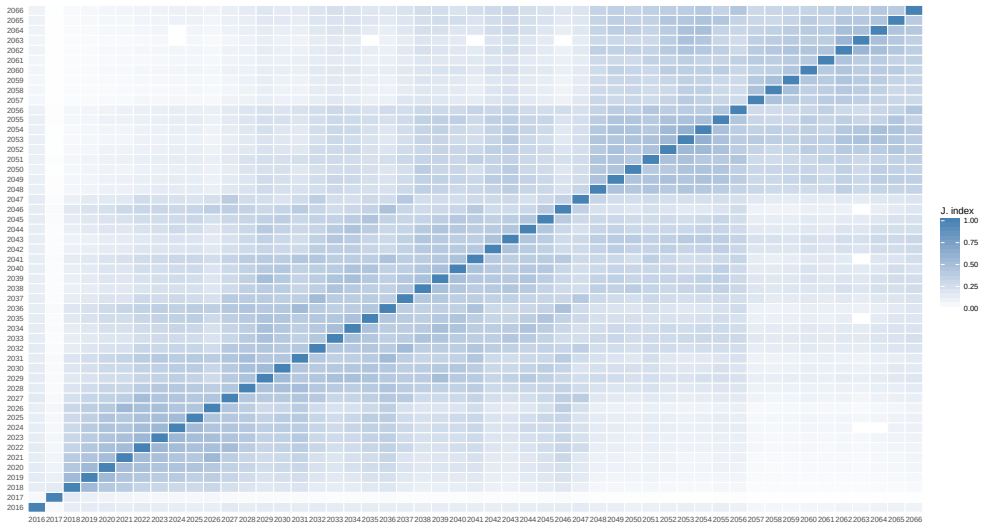



(a)

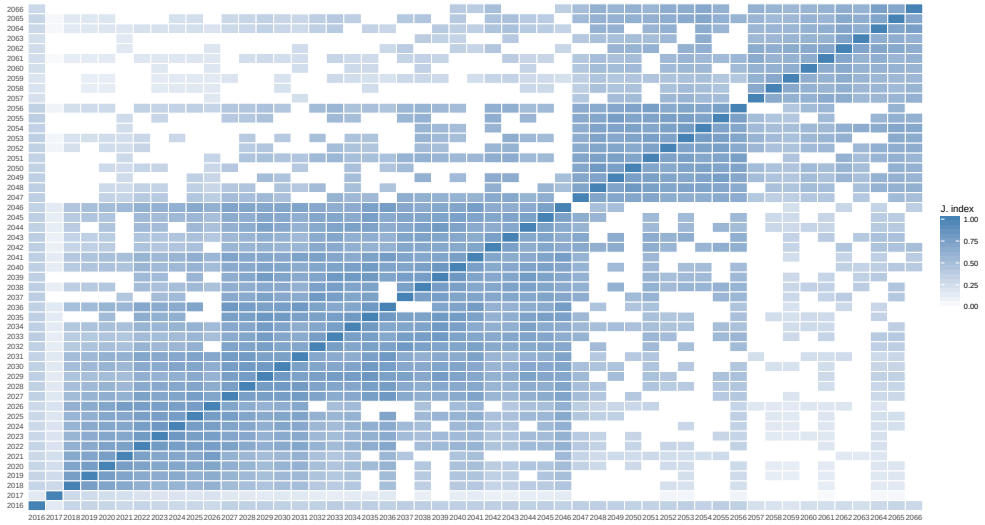



(b)

Figure 22: Percent of edges (counterparty relations) present in both networks of IRD markets for contracts denominated in specific currencies, within the total number of unique counterparty relations present in either network, for: (a) the full network; (b) the network for house clearing (CCP-CM). Zeroes may exist due to no common counterparty relationships or for confidentiality reasons. We observe that the client clearing side is significantly more diverse across currencies than the house clearing side.

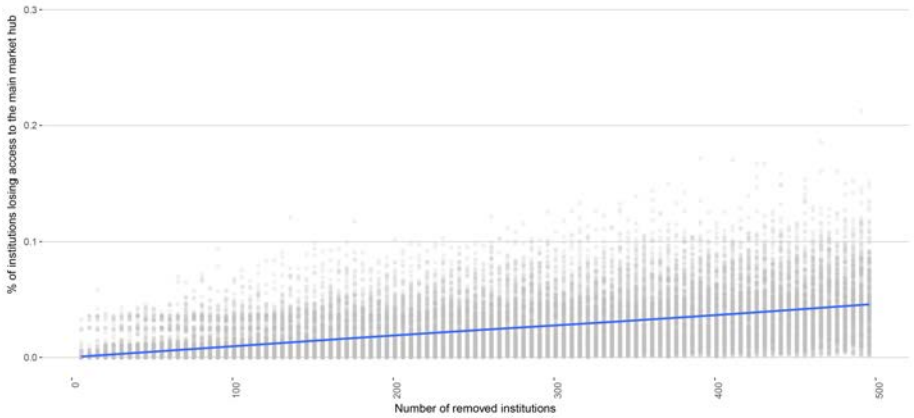



(a)

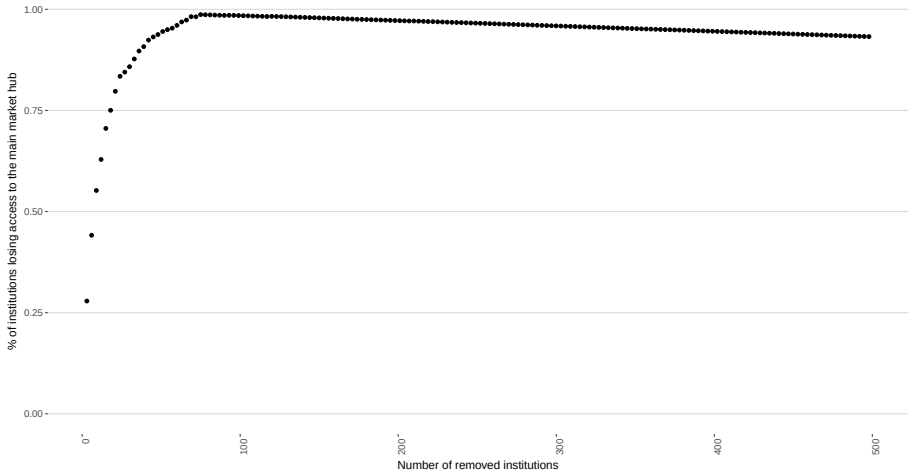



(b)

Figure 23: Percent of edges (counterparty relations) present in both networks of IRD markets for contracts maturing in specific years in the average number of counterparty relations present in either network, for: (a) the full network; (b) the network for house clearing (CCP-CM). Zeroes may exist due to no common counterparty relationships or for confidentiality reasons. We observe that the client clearing side is significantly more diverse across maturities than the house clearing side. Maturities closer to each other tend to be closer to each in terms of counterparty relations (values close to the diagonal), while further from the diagonal we observe more diverse pairs of networks.




(a)




(b)

Figure 24: The percentage of institutions (in the number of all institutions in the network) that would be disconnected with the main trading network of central counterparties, clearing members, and clients, as a result of the removal from the network of: (a) a certain number of institutions at random (blue line). The average is calculated based on 1,000 realisations for each number of removed institutions, results for all realisations presented as dots (for confidentiality reasons each dot represents an average of 3 realisations); (b) a certain number of the most interconnected institutions (for confidentiality reasons we present the cumulative effect lumped by 3 institutions). While the average shows a simple, linear relationship between removal of institutions and the number of other disconnected institutions, the structure of individual results shows a rich diversity of results. While the removal of the largest counterparty from the network has an effect of just over 10%, the collective removal of two largest counteraprties already has an effect of over 40%. Removing further counteparties has diminishing effects.

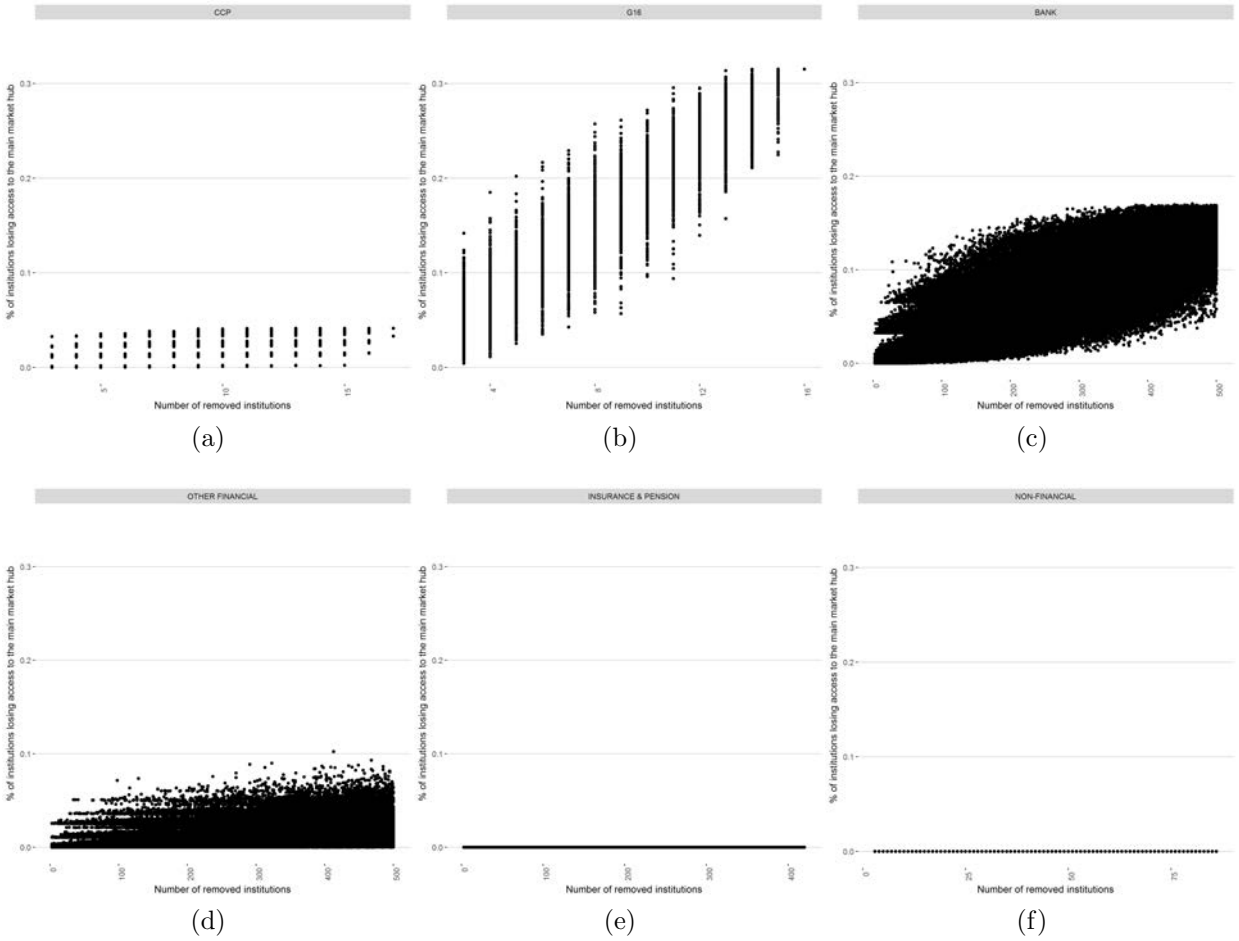



Figure 25: Percentage of institutions (in the number of all institutions in the network) that would be disconnected with the main trading network of both house and client clearing (CCP-CM-Client), as a result of a random removal (based on 1,000 realisations, for confidentiality reasons each dot represents an average of 3 realisations) from the network of a certain number of: (a) CCPs; (b) G16 dealers; (c) banks; (d) other financial institutions; (e) insurance & pension firms; (f) non-financial institutions. We observe that CCPs have a limited effect on the stability of the counterparty network. Removal of all CCPs would leave over 95% of the counterparties in the market connected. This may be particularly relevant to the question of the potential suspension of the clearing obligation. The network is the least stable with regards to the removal of G16 dealers, then banks and other financial institutions. Removal of insurance & pension or non-financial firms does not affect the network structure.

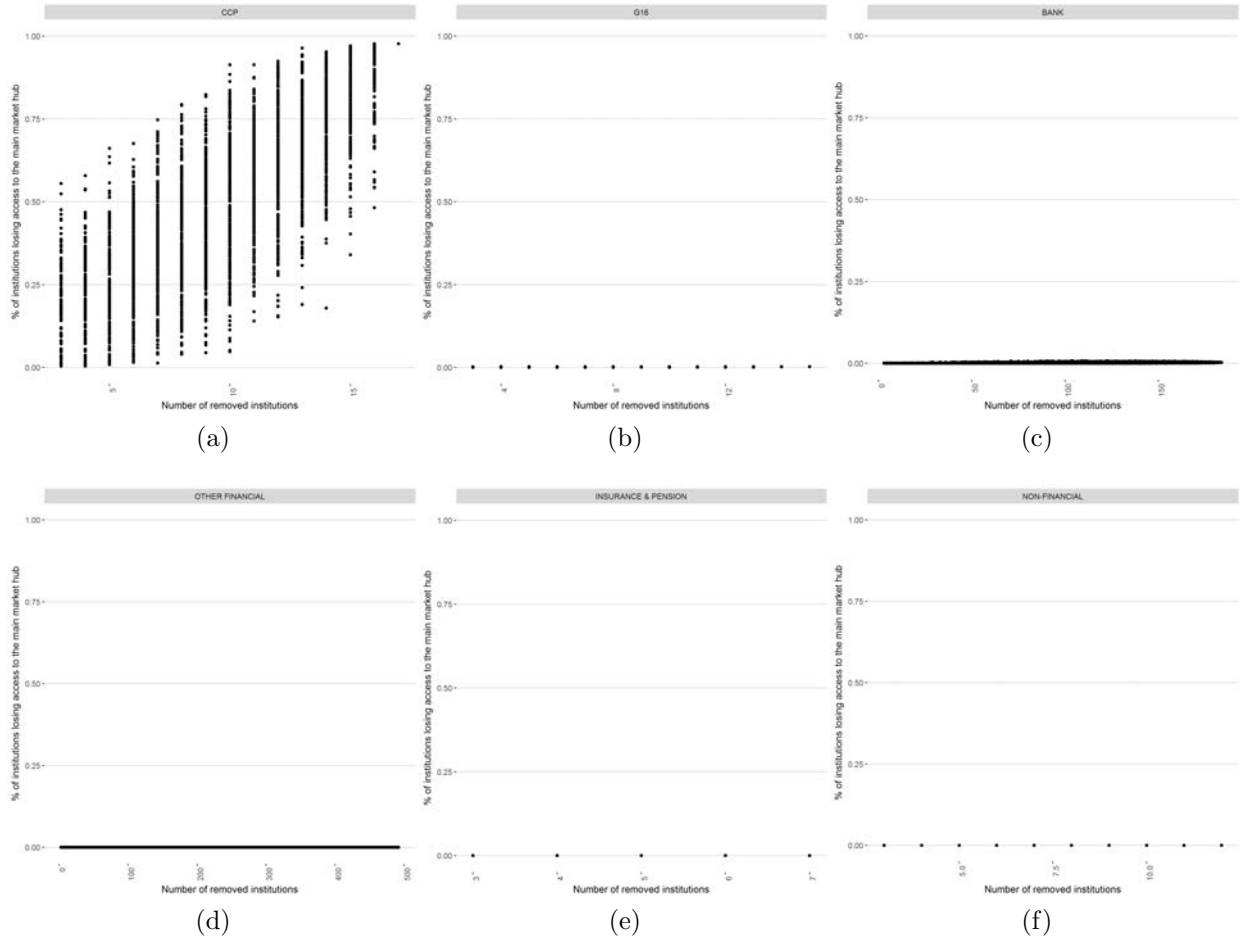
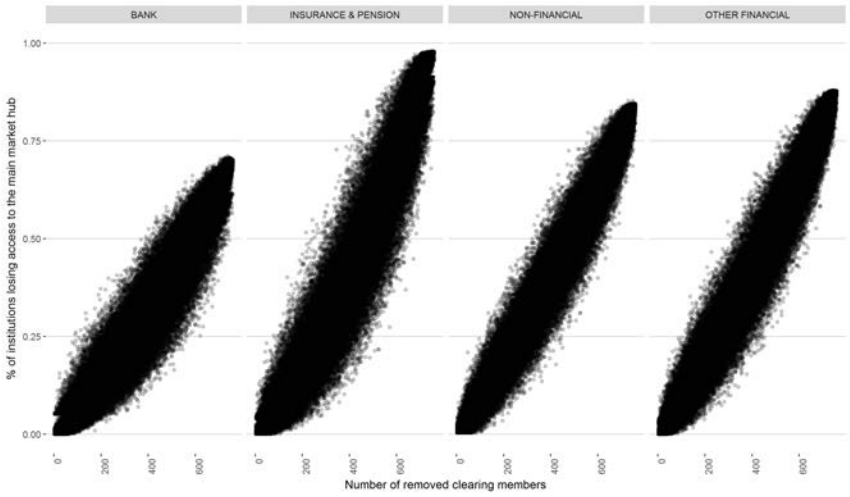
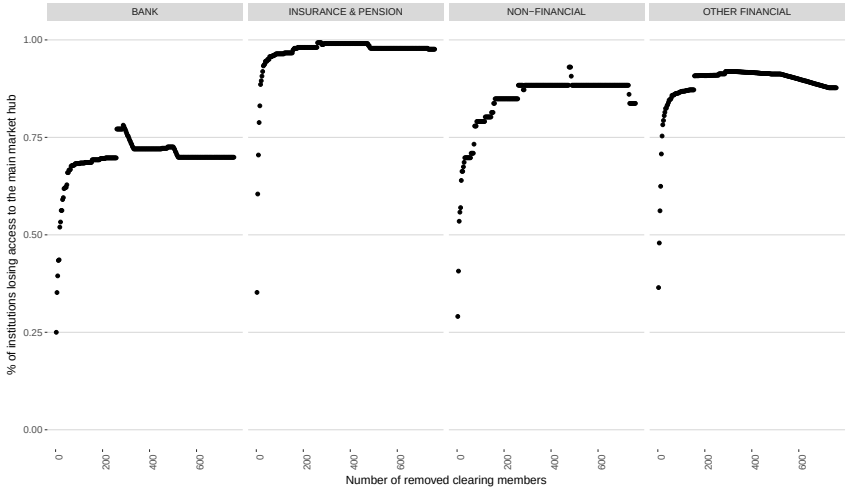



Figure 26: Percentage of institutions (in the number of all institutions in the network) that would be disconnected from the main trading network of house clearing (CCP-CM), as a result of a random removal (based on 1,000 realisations, for confidentiality reasons each dot represents an average of 3 realisations) from the network of a certain number of: (a) CCPs; (b) G16 dealers; (c) banks; (d) other financial institutions; (e) insurance & pension firms; (f) non-financial institutions. We observe that for the house clearing side CCPs are only counterparties that matter in terms of stability of the network with regards to the removal of institutions. This is an obvious consequence of the structure of house clearing. The network is stable with regards to the removal of any other types of institutions. This, together with the previous figure, highlights that the client clearing side has a very strong impact on the analysis of the stability of the structure of the derivatives market.

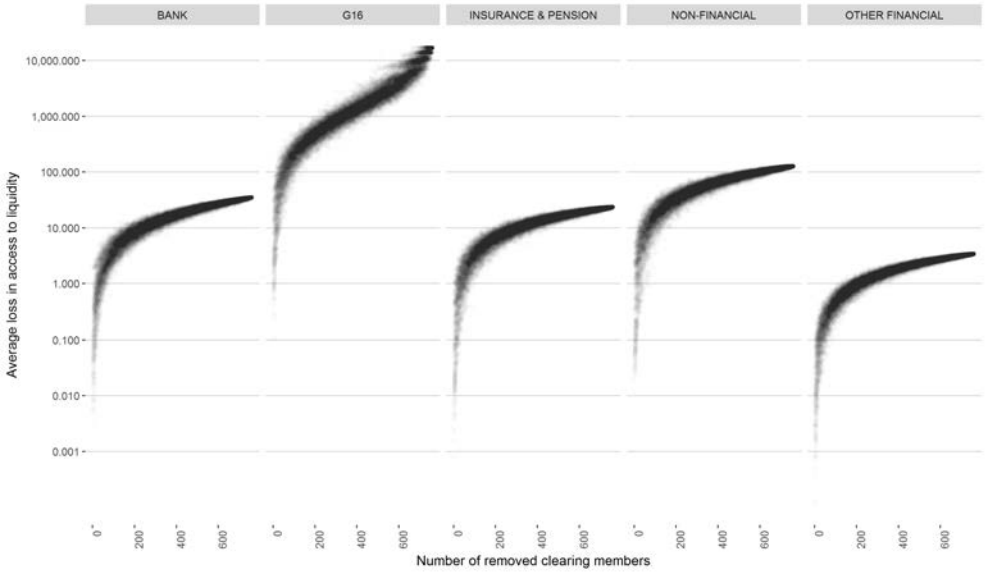



(a)

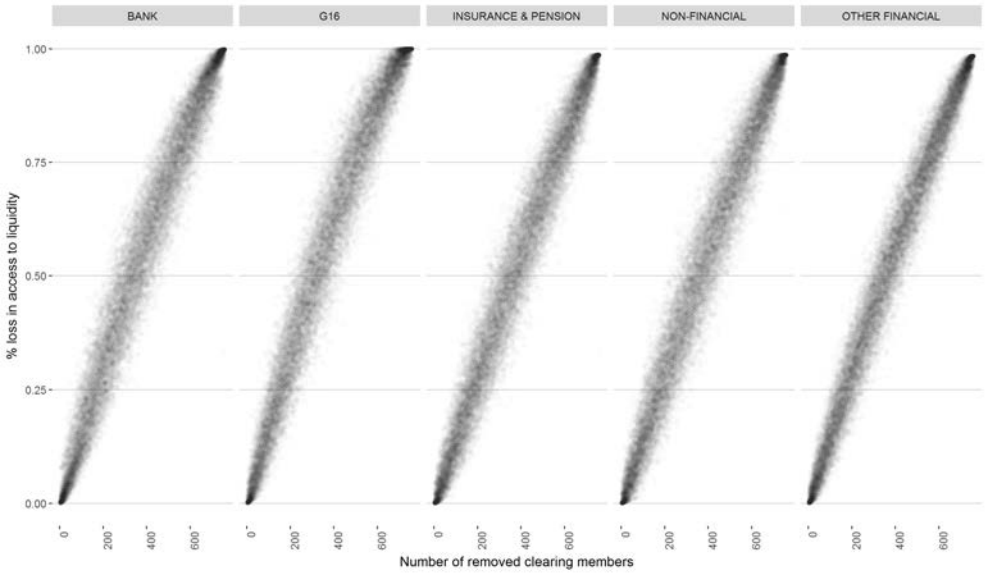



(b)

Figure 27: The percentage of institutions (in the number of all institutions of a given type in the network) that would be disconnected with the main trading network of central counterparties, clearing members, and clients, as a result of the removal from the network of: (a) a certain number of clearing members at random. A distribution of a 1,000 realisations for each number of removed institutions are presented (for confidentiality reasons each dot represents an average of 3 realisations); (b) a certain number of the most interconnected clearing members (for confidentiality reasons we present the cumulative effect lumped by 3 institutions). We see that there is a large disparity of results depending on which clearing member is removed, but on average insurance companies & pension funds are the most affected, followed by other financial institutions, non-financial institutions, and banks. The removal of the largest clearing member has similar effect on all types of presented institutions. The removal of the three largest clearing member has an effect of varying degrees, however. Banks are the least affected by it, followed by non-financial institutions. Insurance companies and pension funds as well as other financial institutions are the most affected by the additional removal of the second largest clearing member from the network.

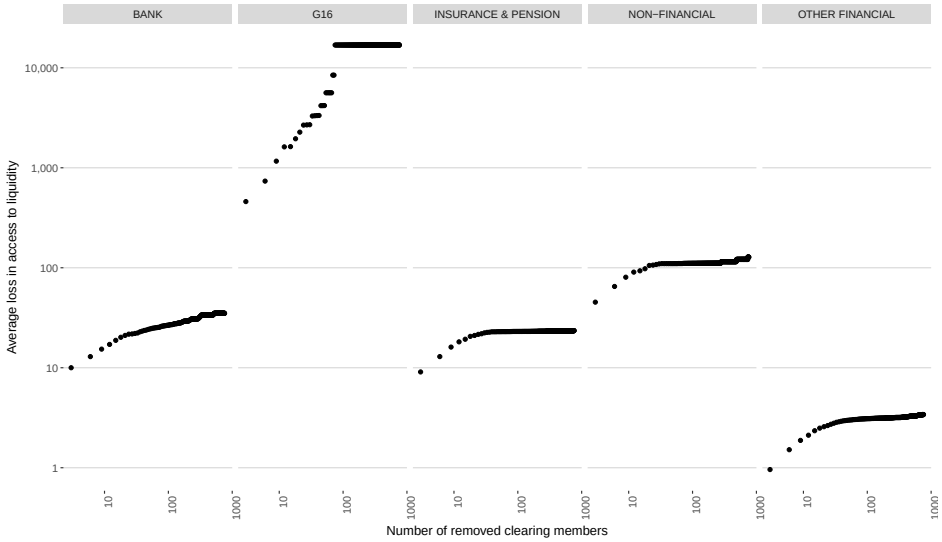



(a)

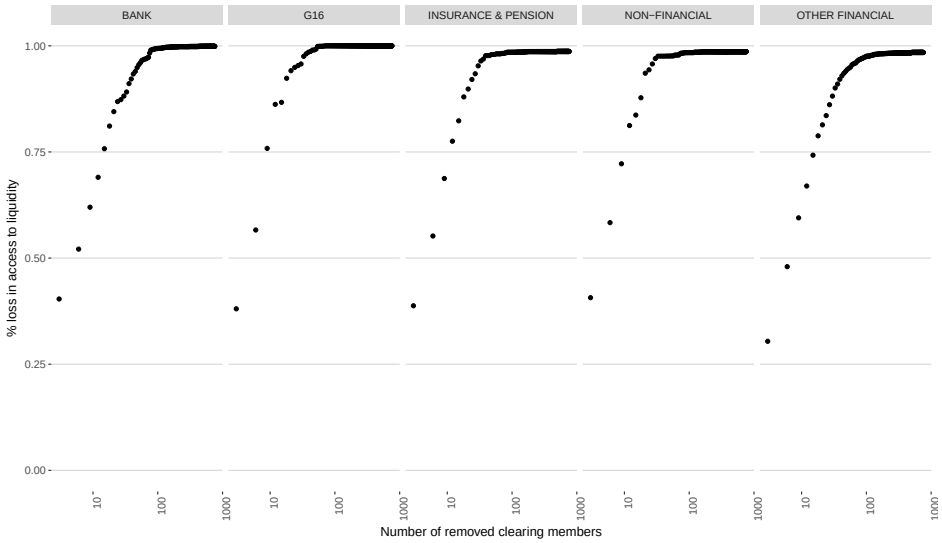



(b)

Figure 28: (a) the average loss of the market access by type of institution given a random removal of a given number of clearing members from the network (note log scale used); (b) the ratio of the market access lost as a result of a random removal of a given number of clearing members to the starting market access. For confidentiality reasons, each dot represents an average of 3 realisations. We can see that the loss of market access converges to the average market access for a given type of institution. There is a linear relationship between the number of clearing members removed from the network and loss of market access, and the nature of this relationship does not strongly depend on the type of institution in question. Thus, the underlying force in this case is the starting market access. CCPs are ignored in the analysis of market access as they operate in the post-trade realm.




(a)




(b)

Figure 29: (a) the loss of market access by type of institution given a removal of given number of the largest clearing members from the network (note log scale used); (b) the ratio of the market access lost as a result of the removal of given number of the largest clearing members to the starting market access (not log-log scale used). For confidentiality reasons we present the cumulative effect lumped by 3 institutions. We can see the differences in the effect of the removal of the three largest clearing members on the market access of the various groups of institutions. Other financial institutions and G16 dealers are the most resilient to the removal of largest clearing members (for the opposite reasons: while G16 dealers are strongly interconnected and do not depend so much on the other counterparties for their access to intermediation, the other financial institutions are so fragmented that they are not collectively affected in a strong way), while banks are the least resilient. CCPs are ignored in the analysis of market access as they operate in the post-trade realm.

# A List of the studied central counterparties

Table 6: The CCPs present in the analysis (authorised above the line, recognised below the line)

| CCP | Country | LEI |
|---|---|---|
| BME Clearing | Spain | 5299009QA8BBE2OOB349 |
| CCG | Italy | 8156006407E264D2C725 |
| CME Clearing Europe Ltd | United Kingdom | 6SI7IOVECKBHVYBTB459 |
| Eurex Clearing AG | Germany | 529900LN3S50JPU47S06 |
| ICE Clear Europe Limited | United Kingdom | 5R6J7JCQRIPQR1EEP713 |
| ICE Clear Netherlands B.V. | Netherlands | 7245003TLNC4R9XFDX32 |
| KDPW_CCP | Poland | 2594000K576D5CQXI987 |
| LCH Ltd | United Kingdom | F226TOH6YD6XJB17KS62 |
| LCH SA | France | R1IO4YJ0O79SMWVCHB58 |
| LME Clear Ltd | United Kingdom | 213800L8AQD59D3JRW81 |
| Nasdaq OMX Clearing AB | Sweden | 54930002A8LR1AAUCU78 |
| ASX Clear (Futures) Pty Limited | Australia | 549300ZD7BBOVZFVHK49 |
| ASX Clear Pty Limited | Australia | 549300JQL1BXTGCCGP11 |
| Chicago Mercantile Exchange, Inc. | USA | SNZ2OJLFK8MNNCLQOF39 |
| Japan Securities Clearing Corporation | Japan | 549300JHM7D8P3TS4S86 |
| OTC Clearing Hong Kong Limited | Hong Kong | 213800CKBBZUAHHARH83 |
| Singapore Exchange Derivatives Clearing | Singapore | 549300ZLWT3FK3F0FW61 |

# Imprint and acknowlegements

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**Paweł Fiedor**
European Systemic Risk Board, Frankfurt am Main, Germany; email: **pawel.fiedor@esrb.europa.eu**

**Sarah Lapschies**
European Systemic Risk Board, Frankfurt am Main, Germany; email: **sarah.lapschies@esrb.europa.eu**

**Lucia Országhová**
European Systemic Risk Board, Frankfurt am Main, Germany; Národná banka Slovenska and University of Economics in Bratislava, Slovakia



| | |
|---|---|
| Postal address | 60640 Frankfurt am Main, Germany |
| Telephone | +49 69 1344 0 |
| Website | **www.esrb.europa.eu** |





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