Mapping exposures of EU banks to the global shadow banking system

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Abstract

This paper provides a unique snapshot of the asset exposures of EU banks to shadow banking entities within the global financial system. Drawing on a rich and novel dataset, we show that 60 per cent of the EU banks' exposures are towards non-EU entities, particularly US-domiciled shadow banking entities. We assess the degree of concentration across different types of shadow banking counterparties. We show that while banks' exposures are diversified at the individual level, this diversification leads to high overlap across different types of shadow banking entities, with consequent systemic risk. We also examine how bank- and country-level characteristics relate to the exposures of EU banks to shadow banking entities. Our results emphasise the importance of monitoring these cross-border and cross-sector exposures and closing remaining data gaps.

JEL classification: F65, G21, G23.
Keywords: bank complexity, shadow banking, interconnectedness, financial stability, macroprudential policy.

"Policymakers and researchers need better models and data to understand the interconnections between the banking system and nonbank financial institutions."
- Stanley Fischer, December 2015

1 Introduction

The 2008 global financial crisis highlighted the importance of assessing cross-sector and cross-border linkages in the financial system. It illustrated, in particular, the high degree of complexity and interconnectedness between banks and a range of non-bank financial institutions ('shadow banking entities') across a number of financial markets. Such interconnectedness across the financial system can lead to the amplification and transmission of risks and spillovers across national borders.

Shadow banking entities often form part of complex financial intermediation chains which can also include banks (Pozsar et al. 2013, Cetorelli 2014). Owing to their heterogeneous activities, shadow banking entities can be direct counterparties to banks in a number of markets including derivative and funding markets. In addition, banks may be exposed to shadow banking entities through their common membership of a corporate group, through the provision of explicit or implicit backstops or indirectly through their common exposures to assets. In particular, liquidity support provided by banks to off-balance sheet entities can reinforce the link and potential contagion paths between the international banking system and the shadow banking system (BCBS, 2015).[1]

As a result of these linkages, significant shocks in the shadow banking system can have potential spillover effects on other parts of the financial system. The substantial size and growth of the shadow banking system in recent years, as well as the important linkages mentioned above, have led to increased monitoring of this part of the

[1]See Claessens and Ratnovski (2014) and BCBS (2015) for a discussion on explicit and implicit backstops. The results of Gornicka (2016) lend support to the view that guarantees provided by sponsoring institutions are an important element of shadow banking. Clerc et al. (2016) examine the channels through which indirect contagion can spread across the financial system, including funding and asset markets, and highlight the role of the market price channel and information spillovers in propagating shocks. Segura (2018) examines the interaction between sponsor banks and their SIVs and presents a signaling model of rescues. Meanwhile, a number of studies including, for example, Acharya, Schnabl and Suarez (2013), Bengtsson (2013), Covitz, Liang and Suarez (2013) and Portes (2018) document risks related to some types of non-bank financial institutions.

financial sector.[2] As shadow banking entities are subject to varying degrees of supervision, there is a lack of granular data and comprehensive risk monitoring of their linkages and activities.[3] Aldasoro, Huang and Kemp (2020) find that the cross-border links between banks and non-bank financial institutions at a global level have continued to grow in recent years. The authors also highlight that the financial market turmoil prompted by the COVID-19 shock revealed several vulnerabilities associated with cross-border linkages between banks and non-bank financial institutions. While their analysis captures banks' exposures to non-bank financial institutions at an aggregate level, the granularity of their data does not allow for a mapping of exposures to different types of non-bank financial institutions. Understanding the nature of these linkages is important from a systemic risk perspective owing to the different types of non-bank financial institutions and their associated diverse business models.

This paper contributes to filling this important data gap by providing a unique insight into the asset-side exposures of EU banks to different types of shadow banking entities globally.[4] While some of the linkages between banks and shadow banking entities may simply capture standard financial intermediation flows, others may reflect the increased complexity of intermediation chains across the financial system. A growing body of academic evidence suggests that some of the linkages between banks and non-bank financial institutions may be associated with regulatory arbitrage opportunities (Kashyap, Stein, and Hanson, 2010, Adrian and Ashcraft, 2012, Acharya, Schnabl and

[2]At the global level, the Financial Stability Board (FSB) has coordinated efforts in improving data coverage for monitoring developments within the shadow banking system (see, for example, FSB, 2011, 2015 and 2020). At the European level, the European Systemic Risk Board (ESRB) has focused on monitoring potential financial stability risks, including those risks and negative externalities posed by entities and activities within the shadow banking system (see ESRB 2016, 2017, 2018, 2019, 2020a; and Grillet-Aubert et al. 2016).

[3]Many regulatory reforms following the 2008 global financial crisis are relevant to the shadow banking system. In Europe, the Alternative Investment Fund Managers Directive (AIFMD) introduced new regulatory requirements for hedge funds and real estate funds. Moreover, regulatory reforms covered activities related to derivative trading under the European Markets Infrastructure Regulation (EMIR) and securities financing transactions under the Securitisation Financing Transaction Regulation (SFTR). Therefore, depending on the business model and activities of the shadow banking entity, it may be subject to some level of regulatory oversight. These regulations include new data reporting requirements, but there are still major gaps. One striking example is the continuing importance of unspecified 'Other Financial Institutions' in the annual reports of the FSB and ESRB cited above.

[4]A detailed description of the exact meaning of 'exposures' in the context of our paper is provided in Section 2.

Suarez, 2013, Plantin, 2015). Indeed, Plantin (2015) suggests that the rise of the shadow banking system has been largely motivated by regulatory arbitrage. Adrian (2017) notes that regulatory arbitrage may occur where capital, liquidity, taxation or information requirements can potentially be circumvented to make activities more profitable that might otherwise not be. In a related paper, Acharya, Schnabl and Suarez (2013) show that regulatory arbitrage was the main motive behind the establishment of securitisation vehicles prior to the global financial crisis. In more recent studies, Cizel et al. (2019) and Claessens et al. (2021) show that the tightening of macroprudential policies for the banking sector led to a shift in activities to the non-bank financial sector. While assessing potential regulatory arbitrage is beyond the scope of this paper, our findings provide unique insights into the cross-border linkages of EU banks to shadow banking entities globally which confirm the opportunities for regulatory arbitrage.

Our paper therefore makes an important contribution to the literature by mapping, for the first time, these linkages using granular bank- and exposure-level information. While banking supervisors and policymakers have information about the exposures of the banks in their respective jurisdiction, the analysis presented in our paper captures a large sample of banks at the EU level. In addition, the data we use are unique because, as noted above, the exposures of EU banks are classified according to the type of shadow banking entity. Moreover, these data allow us to examine the cross-border nature of the linkages of EU banks, as we have data on their exposures to shadow banking entities at a global level. Using a range of analytical approaches, we document the exposures of EU banks to different types of shadow banking entities at a global level and consider which are the most relevant for systemic risk monitoring. In this way, our paper is related to a strand of literature focused on assessing the financial stability implications of shadow banking activities (see, for example, FSB 2011; Adrian and Ashcraft 2012; Adrian, Ashcraft and Cetorelli 2013; Adrian 2014; Claessens and Ratnovski 2014; Grillet-Aubert et al. 2016; Portes 2018; ESRB 2019, ESRB 2020a).

While the complexity of banks' exposures to shadow banking entities is often cited as a key financial stability concern, we are not aware of other studies which docu-

ment and describe the nature of these linkages using granular EU bank and asset exposure-level information. Buch and Goldberg (2021) document the growing evidence on banks' complexity over the past decade including studies detailing organisational, business and geographic complexity. Organisational complexity captures the number of entities within the full banking organisation while business complexity refers to the span and concentration of affiliates across different types of business whereas geographical complexity measures the span and concentration of the number of affiliates across country locations. The authors summarise some of the main findings from the bank complexity literature which suggests that the largest banks in countries tend to be the more complex while complexity patterns can be quite persistent. They also note that while the relationship between complexity and risks involves trade-offs, regulatory changes can affect both banking organisation complexity and the associated risk profiles. In a related paper, Correa and Goldberg (2021), using data on large US banking holding companies (BHC) over the period 1996-2018, find that while business, geographic and organisational complexity can provide benefits linked to diversification and reduced liquidity risk exposure, all forms of complexity are found to increase BHC systemic risks. Our paper confirms similar tradeoffs that are related to systemic risk when assessing the asset exposures of EU banks to shadow banking entities.

Our paper complements this growing literature on banks' complexity (e.g., Cetorelli and Goldberg 2014, 2016; Krause, Sondershaus and Tonzer 2017; Aldasoro, Hardy and Jager 2020; Flood et al. 2020; Buch and Goldberg, 2021; Correa and Goldberg, 2021) by detailing the asset exposures of EU banks to the global shadow banking system using a unique dataset collected by the EBA in 2015. While some of these aforementioned studies on bank complexity capture the structure of banking organisations, including affiliate composition, our paper focuses instead on the asset exposures of EU banks to the global shadow banking system drawing on this novel dataset.

We employ several complementary analytical approaches to exploit the richness of the asset-exposure data. First, we analyse the direct exposures by providing a de-

tailed overview of the network of asset exposures of the EU banking system towards global shadow banking entities, which exhibits the geographic complexity of the exposures. Second, we focus on indirect interconnectedness, by quantifying the degree of exposure to common sources of risk stemming from shadow banking entities. Third, we build on these elements to analyse the vulnerability of the EU banking system to shocks to the global shadow banking system. Leveraging our novel dataset and guided by theoretical studies which describe the rationale for banks to correlate exposures allows us to analyse the interconnectedness stemming from common exposures and their sensitivity to shocks. We thereby provide a systemic risk perspective on the role the exposures to shadow banking entities play for the EU banking system. Fourth, we examine the bank- and country-level characteristics that are associated with these cross-border asset exposures.

Fischer (2015) points to the importance of mapping the linkages of banks and shadow banking entities. He notes "an important area in need of development is economic modelling on interconnectedness, particularly on the interaction of shadow banking, banks and the broader financial system... such research could guide regulatory efforts to collect data and set policies to limit possible instabilities associated with interconnectedness." Similarly, Beck, Carletti and Goldstein (2016) note that it is important to monitor the financial system in a holistic way including to consider the potential fragility of banks alongside shadow banking entities rather than banks in isolation. Accordingly, our detailed analysis on EU banks' asset-side exposures to shadow banking entities contributes to assessing the potential impact of spillovers between these different components of the financial system.

Our results show that EU banks have significant exposures to shadow banking entities globally and, in particular, to entities domiciled in the US, which represent approximately 27 per cent of the total exposures. Moreover, we find that approximately 65 per cent of EU banks' exposures are to securitisations, non-money market fund (MMF) investment funds and finance companies. Motivated by theory showing the rationale behind correlated exposures across banks, we use a network analysis to exhibit the de-

gree of concentration of EU banks' exposures across different types of shadow banking counterparties. We show that, even though banks' exposures are diversified at the individual level, this diversification leads to high overlap across different types of shadow banking entities. Finally, with a gravity model regression analysis, we examine the bank-level and country-level characteristics that are related to the exposures to shadow banking entities.

The rest of the paper is structured as follows. Section 2 describes the data used in our analysis and provides a brief overview of our data cleaning procedure. We then take two empirical approaches to the data. Section 3 examines first the cross-sector and cross-border linkages of EU banks' exposures to shadow banking entities. We then exhibit characteristics of the network of exposures including the levels of concentration and overlap. The results allow us to assess the vulnerability of the EU banking system to shocks from the global shadow banking system. Section 4 presents our econometric analysis of the bank-level and country-level characteristics associated with these exposures. Section 5 concludes.

2 Data

This section describes the data used in our analysis.

2.1 The EBA (2015) data collection on EU banks' exposures to shadow banking entities

In December 2015, the European Banking Authority (EBA) issued guidelines on the approach that institutions (banks and investment firms) should adopt for the purposes of setting appropriate individual and aggregate limits on exposures to shadow banking entities which carry out banking activities outside a regulated framework.[5] In parallel to the development of the guidelines, the EBA conducted a data collection to understand better the volume and distributions of institutions' exposures to certain types of

[5]https://www.eba.europa.eu/regulation-and-policy/large-exposures/guidelines-on-limits-on-exposures- to-shadow-banking

non-bank financial institutions, and the potential impact of imposing limits to these exposures.[6]

As explained in detail in EBA (2015), a sample of banks and investment firms were asked to provide information regarding their exposures to counterparties considered as 'shadow banking entities'.[7] 'Exposures' mean any asset or off-balance sheet item used in the calculation of capital requirements for credit risk under the standardised approach, without applying risk weights or degrees of risk. It is important to note that no information was collected on banks' or investment firms' exposures on the liability side of exposures.

Institutions were asked to calculate their exposures in the same way as any other exposure reported under the large exposures regime set out in Part 4 of the Capital Requirements Regulation (CRR) and to report original exposures to individual counterparties, as well as the exposure before and after taking into account the effect of Credit Risk Mitigation (CRM) and large exposures exemptions, and also the percentage of the eligible capital.[8] The exposures used in the analysis were after CRM and large exposures exemptions. For the purposes of the data collection 'shadow banking entities' were defined as undertakings that met two conditions:

1. They carry out one or more credit intermediation activities. Here 'credit intermediation activities' means bank-like activities involving maturity transformation, liquidity transformation, leverage, credit risk transfer or similar activities.

2. They are not excluded undertakings (i.e., mainly credit institutions and investment firms subject to the capital requirements directive CRD / CRR, insurance or

[6]The definition of 'shadow banking entity' used for the purposes of the data collection was broader than the definition used in the final EBA guidelines, so as to capture as much information as possible and not to pre-empt future work by the EBA and/or the European Commission on this topic.

[7]While the data used in our analysis were collected in 2015, the main results are still relevant when examining the shadow banking system today. For instance, while the global and EU shadow banking systems have expanded over the 2015-2020 period (see, for example, FSB 2020 and ESRB 2020), many of the main types of shadow banking entity captured within our analysis such as investment funds and securitisation vehicles remain key components of the shadow banking system. Moreover, despite recent data advances, there is still a lack of granularity of exposures between banks and non-bank financial institutions which our paper documents.

[8]Article 4(1), point 71 of regulation (EU) No.575/2013 defines 'eligible capital' as the sum of Tier 1 capital as referred to in Article 25 (of the same Regulation) and Tier 2 capital as referred to in Article 71 (of the same Regulation) that is equal to or less than one third of Tier 1 capital.

reinsurance companies, institutions providing occupational pensions, central clearing counterparties, or institutions considered to be regulated in a similar way in third countries).[9]

Institutions were asked to identify their counterparties by indicating their identifier code,[10] name, and country of residence and to classify them in accordance with their underlying economic functions (i.e., activities rather than legal form): Undertakings for the Collective Investment in Transferable Securities (UCITS) money market funds (MMFs), non-UCITS MMFs, non-MMF investment funds, finance companies, broker-dealers, credit insurers / financial guarantors, securitisations, non-equivalent banks / insurers and a residual category labelled as 'other' for institutions that can not be classified according to the types presented above.[11]

These data were collected from the reporting entities at the highest level of consolidation in a Member State, or individual level if the consolidated level did not apply. For example, a bank A's exposures to a shadow banking entity B were calculated adding up all bank A's exposures including all its banking subsidiaries' exposures in a country. It is also worth noting that the shadow banking entity B could also be affiliated to bank A, but would still be reported as a shadow banking counterparty if it was not consolidated as part of the wider banking group for supervision purposes.

In addition, institutions were asked to indicate, to the best of their knowledge, whether a shadow banking entity was: (a) not supervised on a solo level, but supervised on a consolidated level in the Union; (b) not supervised on a solo level, but supervised on a consolidated level in a third country that has a regime at least equivalent to the one applied in the European Union, or (c) neither of the two.

The EBA data collection sample included 184 reporting institutions from 22 Mem-

[9] See EBA (2015) for further details on excluded undertakings.

[10] In some cases, the identifier codes provided were legal entity identifiers (LEIs) while others were internal codes.

[11] Furthermore, data were collected for the non-MMF investment fund category at the higher level of granularity and included the following categories: hedge funds, equity funds, real estate funds, fixed income funds, other investment funds, and not identified non-MMF investment funds. However, data at this level were not used in the analysis.

ber States; the reference date for the reported data was 31 March 2015.[12] The reporting included 56 Group 1 banks, 113 Group 2 banks, and 15 investment firms. Group 1 banks had Tier 1 capital in excess of EUR 3 billion and were internationally active. Other banks would be considered Group 2 banks. For confidentiality reasons, the analysis did not identify individual countries that had a sample composed of three or fewer reporting institutions.[13] EBA (2015) provides further details on the coverage of the sample in each Member State and further background information on the data collection process.

In total, there were 107,621 individual exposures reported, which amounted to a total exposure of €1,082 billion. The instructions for the EBA data collection gave institutions a choice regarding the way they would report individual exposures after exemptions and CRM below the materiality threshold of 0.25% of eligible capital. That is, institutions could just indicate the aggregated amount for these exposures instead of reporting them individually. This approach does not allow the identification of individual exposures that are smaller than the materiality threshold of 0.25% of eligible capital.

The subset of exposures that are equal to or above 0.25 per cent of institutions' eligible capital represent 3,272 exposures (3 percent of the total number of exposures) with a total exposure amount of €568 billion (52 per cent of the total exposure amount for the full sample of reported exposures) and were reported by 139 EU banks. Given the importance of uniquely identifying the individual shadow banking exposures of the reporting banks, we used this subset of exposures as a basis for preparing the dataset for our analysis. This is necessary in order to undertake our analysis of the cross-sector and cross border linkages as without detail on the shadow banking entity we would not be able to include them in our empirical analysis.

Several steps were taken in order to improve data quality both in the original data

[12]The participating Member States include Austria, Belgium, Cyprus, Czech Republic, Denmark, France, Germany, United Kingdom, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Spain and Sweden.

[13]In the network graphs presented in Section 3, banks from countries which have fewer than 3 reporting institutions are labelled 'XZ'.

collection but also in our subsequent analysis. As a first step, the national competent authorities (NCAs) made an initial assessment of the quality of the reported data prior to sending them to the EBA. Subsequently, the EBA performed several data quality checks in order to assess the completeness and consistency of the data and liaised with the NCAs where necessary.

In preparation of the data samples for the analysis, some essential further data cleaning and processing was performed. First, repeated shadow banking counterparties were identified based on duplicated counterparty IDs, duplicated counterparty names or on similar names (e.g. ABC Ltd as opposed to ABC Limited). Similarly, as shown in EBA (2015), 19 per cent of the shadow banking counterparties by value of exposures were not identified by country of residence. Therefore, we manually matched these data to reduce this data limitation to 1 per cent of exposures. Second, exposures greater than 25% of eligible capital were excluded in case of any inadvertent misreporting, which corresponds to the large exposure limit in Article 395 of the CRR.[14] Finally, the EBA's data with bank-level information on exposures was matched with data on bank characteristics taken from Bureau van Dijk's Orbis database. This leaves a final sample of 131 banks and 3,182 individual exposures with a total amount of approximately €560 billion. Overall, the characteristics of the data used in the analysis broadly match those of the subset of exposures that are equal to or above 0.25 per cent of institutions' eligible capital, i.e. the original data before data cleaning and processing.

The total exposures used in the analysis amount to approximately €560 billion, representing 4.3 per cent of EU GDP. Given the reporting institutions in our sample account for around 50% of EU banking sector assets, with more emphasis on the larger institutions' exposures, we are confident that the analysis is relevant from systemic risk analysis perspective. To gain an overview of the data, Table 1-3 show the total exposures in absolute amounts (Table 1), in relation to GDP (Table 2) and as a share of

[14]We do this to exclude any potential outliers in the data. Moreover, in line with the large exposure limit, the sum of all the exposure values of a bank to a single counterparty or to a group of connected counterparties must not be higher than 25 per cent of banks' eligible capital.

banks' eligible capital (Table 3), with significant heterogeneity across countries.

2.2 Other control data used in the empirical analysis

For the regression analysis presented in Section 4, we use a sub-sample of exposures data when examining how bank- and country-level factors relate to the exposures of EU banks to shadow banking entities. In particular, we merge the exposures data, which represent our dependent variable, with a host of bank-level characteristics such as bank size, liquidity (proxied by the interbank ratio, which measures if banks are net providers of liquidity in the interbank market), capitalization, return on average equity (ROAE) and the efficiency of banks captured by their cost-to-income ratios, which are taken from the Bureau van Dijk Orbis database.

Bank-level characteristics are often included in the literature focusing on international banking including, for example, Buch et al (2013) and Aldasoro, Hardy and Jager (2020). Owing to missing data for some bank-level characteristics, we match 78 banks from our initial sample of 131 banks based on the bank's legal entity identifier (LEI) code. The sample used in our empirical analysis comprises 1,503 individual exposures amounting to €387 billion. Overall, the broad patterns of the exposures data described above are consistent with the subset of matched data used in our empirical analysis.

While our final dataset is a cross-section of exposures as of March 2015, our merged sample allows us to exploit a rich geographical structure of the exposures across countries. This allows us to also examine empirically country-level factors related to the variation of EU banks' exposures to shadow banking entities. In this way, we merge country-level data regarding the host country of the bank such as GDP to proxy for the size of the country. Likewise, we control for the size of the host country of the shadow banking entity by also including its GDP. This is similar to the approach of Fong, Sze and Ho (2021) who examine the cross-border interconnectedness between shadow banking systems. These GDP data are taken from the World Bank's World Development Indicators (WDI) database.

Moreover, we use a number of gravity-related controls to proxy for financial fric-

TABLE 1. **Distribution of EU banks' exposures to shadow banking entities by country of reporting institution and domicile of shadow banking entity (in € billion)**

B/SB	DE	FR	GB	IE	JE	KR	KY	LU	NL	RU	TR	US	O-EU	RW	Total
AT	0.2	0.0	0.3	0.2	0.0	0.1	0.2	0.2	0.3	0.8	0.1	0.6	3.1	0.7	6.8
DE	28.1	0.8	5.1	9.4	1.3	0.4	2.9	6.9	1.7	2.3	3.9	33.5	2.2	7.6	106.0
FR	0.5	16.2	3.7	1.9	0.2	2.9	4.9	1.4	2.0	0.5	0.5	30.1	2.7	10.9	78.3
GB	5.2	4.8	44.7	19.8	14.7	7.8	24.9	12.0	3.5	1.5	3.0	84.0	4.0	54.5	284.4
IT	0.0	1.3	2.8	2.6	0.4	1.3	0.0	2.5	0.1	2.1	7.5	0.5	2.9	2.9	26.8
LU	1.1	0.7	0.8	0.4	0.0	0.0	0.3	2.5	3.0	0.2	0.0	0.1	1.0	0.4	10.4
O-EU	0.5	1.4	1.5	1.1	0.5	2.3	3.2	3.3	3.2	2.9	4.5	2.8	12.8	6.7	46.8
Total	35.5	25.1	59.0	35.4	17.0	14.8	36.4	28.8	13.8	10.4	19.5	151.5	28.7	83.5	559.4

Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to 'shadow banking entities', December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of eligible capital. Country labels on the left hand side of the chart refer to the country of domicile of the reporting institution. Country labels along the top of the chart refer to country of domicile of shadow banking entity. *O-EU* refers to other EU countries while *RW* refers to the rest of the world. The chart excludes investment firms and exposures greater than 25 per cent of the institution's eligible capital (the large exposure limit).

TABLE 2. **Distribution of EU banks' exposures to shadow banking entities by country of reporting institution and domicile of shadow banking entity (as a % of GDP of country of reporting bank)**

B / SB	DE	FR	GB	IE	JE	KR	KY	LU	NL	RU	TR	US	O-EU	RW	Total
AT	0.1	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.1	0.3	0.0	0.2	1.0	0.2	2.2
DE	1.0	0.0	0.2	0.3	0.0	0.0	0.1	0.3	0.1	0.1	0.1	1.2	0.1	0.3	3.9
FR	0.0	0.8	0.2	0.1	0.0	0.1	0.2	0.1	0.1	0.0	0.0	1.5	0.1	0.5	3.8
GB	0.3	0.3	2.4	1.0	0.8	0.4	1.3	0.6	0.2	0.1	0.2	4.4	0.2	2.9	15.0
IT	0.0	0.1	0.2	0.2	0.0	0.1	0.0	0.2	0.0	0.1	0.5	0.0	0.2	0.2	1.7
LU	2.4	1.5	1.8	1.0	0.0	0.0	0.6	5.5	6.5	0.5	0.0	0.1	2.1	0.8	22.9
O-EU	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.3	0.1	1.1
Total	0.3	0.2	0.5	0.3	0.1	0.1	0.3	0.2	0.1	0.1	0.1	1.2	0.2	0.6	4.3

Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to "shadow banking entities", December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of eligible capital. Country labels on the left hand side of the chart refer to the country of domicile of the reporting institution. Country labels along the top of the chart refer to country of domicile of shadow banking entity. *O-EU* refers to other EU countries while *RW* refers to the rest of the world. The chart excludes investment firms and exposures greater than 25 per cent of the institution's eligible capital (the large exposure limit).

tions and information asymmetries which are also found to be important factors in determining bilateral relationships in international banking and finance (see, for example, Portes and Rey 2005; Claessens and van Horen 2014; Davies and Killeen 2018). For instance, we control for whether the host country of the bank and host country of the shadow banking entity share a common border, currency, legal system, language or past colonial links. Moreover, we include the log of geographic distance between these countries as a proxy for information costs, as has been used in a number of studies in the international banking and finance literatures (e.g., Buch 2005; Portes and Rey 2005; Lane and Milesi-Ferretti 2008; Houston et al. 2012; Claessens and van Horen 2014; and Brei and von Peter 2018). These data are taken from Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). We also include a dummy variable equal to one if the country of the domicile of the shadow banking entity is classified as an offshore financial centre. Shadow banking entities such as securitisation vehicles are often found to be located in offshore financial centres. We employ the classifications used in Davies and Killeen (2018), who in turn combine the respective categorisations of Lane and Milesi-Ferretti (2011) for small international financial centres and Claessens and van Horen (2015).[15] The source and definition of each of these variables are presented in Table 9 in the Appendix.

3 Mapping EU banks' exposures to shadow banking entities

This section provides a unique analysis of EU banks' exposures to shadow banking entities. First, it examines the characteristics of the EU banks which have exposures to shadow banking entities. It then analyses the types of shadow banking entities to which EU banks are exposed before proceeding to an analysis of the cross-border nature of these linkages. This section concludes with an analysis of the concentration

[15] We therefore consider the following locations as offshore financial centres: Andorra, Antigua and Barbuda, Bahamas, Bahrain, Barbados, Bermuda, British Virgin Islands, Cayman Islands, Cyprus, Guernsey, Isle of Man, Jersey, Liechtenstein, Mauritius, Netherlands Antilles, Panama, Seychelles, and Singapore.

and overlap of EU banks' exposures to shadow banking entities.

3.1 EU banks' exposures to shadow banking entities

Our analysis of EU banks' exposures to shadow banking entities first examines the characteristics of the banks involved. As described in Section 2, we complement the EBA data using information taken from Bureau van Dijk's Orbis database.This allows us to match balance sheet data on total assets for 123 out of the 131 banks in our sample. Total assets of banks in our sample amount to €27 trillion. The data show that 23 per cent of the banks in the EBA sample are from Germany, 13 per cent are from the UK and 3 per cent are banks from France. Weighting by their balance sheet size, however, shows that UK banks account for 39 per cent of the total assets of the banks in our sample, while German and French banks account for 11 per cent and 21 per cent, respectively. As noted in EBA (2015), the banks in our sample cover 56 per cent of total assets of the EU financial sector, although the coverage is heterogeneous across countries. For example, French and UK banks account for 75 per cent and 85 per cent of their respective financial sectors (see EBA 2015), while Irish banks in our sample account for only 6 per cent of the Irish financial sector.[16] Nevertheless, our data captures the largest exposures to shadow banking entities which are most relevant for systemic risk identification and assessment.

In terms of exposures to shadow banking entities, UK banks in our sample have a total of 779 exposures (24 per cent of the total in our sample), accounting for €284 billion (slightly more than half of the total amount and 15 per cent of UK's GDP). German and French banks have a total of 939 and 194 exposures (29 per cent and 6 per cent of the total), accounting for €106 billion and €78 billion (roughly 4 per cent of their countries' GDP), respectively. The exposures of UK banks represent 76 per cent of their aggregate eligible capital, 108 per cent for German banks and 62 per cent for French banks (Table 3). A comprehensive breakdown of the exposures by sector and country of the shadow banking institutions is presented in the Sections 3.2 and 3.3.

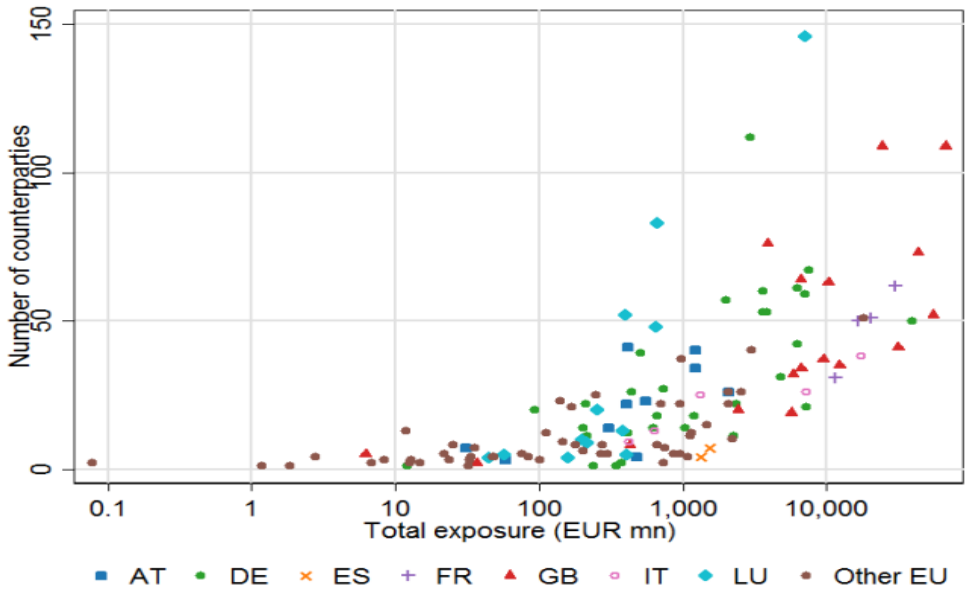
[16]However, in this case, it is important to note that approximately 80 per cent of the Irish financial sector consists of entities outside of the regular banking system, as described in FSB (2015).

TABLE 3. **EU banks' exposures to shadow banking entities as a % of banks' (by country) eligible capital**

B / SB	DE	FR	GB	IE	JE	KR	KY	LU	NL	RU	TR	US	O-EU	RW	Total
AT	2.2	0.0	4.4	2.0	0.0	1.2	2.4	2.8	3.5	10.3	1.5	7.0	39.1	8.9	85.1
DE	28.6	0.8	5.2	9.5	1.3	0.4	3.0	7.0	1.7	2.3	4.0	34.1	2.3	7.7	107.7
FR	0.4	12.7	2.9	1.5	0.1	2.3	3.9	1.1	1.6	0.4	0.4	23.7	2.1	8.6	61.7
GB	1.4	1.3	11.9	5.3	3.9	2.1	6.7	3.2	0.9	0.4	0.8	22.4	1.1	14.5	75.9
IT	0.0	3.4	7.5	6.9	1.0	3.5	0.0	6.6	0.4	5.6	20.1	1.3	7.7	7.7	71.6
LU	24.7	15.0	18.2	10.1	0.0	0.4	5.9	56.1	66.6	5.2	0.0	1.4	21.9	8.6	234.2
O-EU	0.9	2.7	2.9	2.1	1.0	4.4	6.1	6.3	6.1	5.5	8.4	5.3	24.2	12.6	88.5
Total	5.1	3.6	8.4	5.0	2.4	2.1	5.2	4.1	2.0	1.5	2.8	21.6	4.1	11.9	79.6

Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to 'shadow banking entities', December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of eligible capital. Country labels on the left hand side of the chart refer to the country of domicile of the reporting institution. Country labels along the top of the chart refer to country of domicile of shadow banking entity. *O-EU* refers to other EU countries while *RW* refers to the rest of the world. The chart excludes investment firms and exposures greater than 25 per cent of the institution's eligible capital (the large exposure limit).

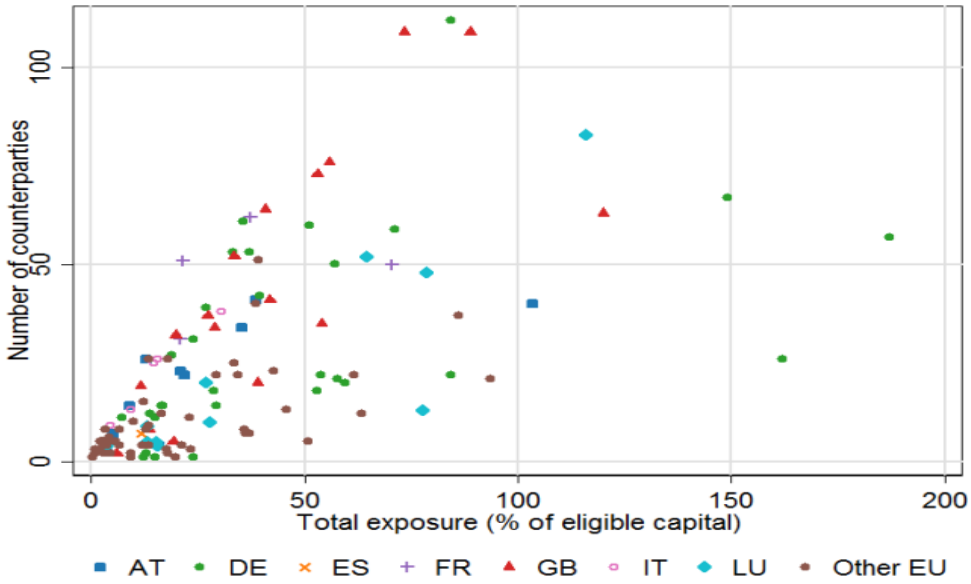
FIGURE 1. **Number of counterparties and total exposures by bank (EUR million)**



Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to "shadow banking entities", December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of eligible capital of the reporting bank. The chart excludes investment firms and exposures greater than 25% of the institution's eligible capital (the large exposure limit).

Turning to the bank-level data, Figures 1 and 2 illustrate the positive relationship between the number of counterparties of each bank and their total exposure to shadow banking entities (both measured in € millions and as a percentage of their eligible cap-

FIGURE 2. **Number of counterparties and total exposures by bank (% of eligible capital)**



Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to 'shadow banking entities', December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of eligible capital of the reporitng bank. The chart excludes investment firms and exposures greater than 25 per cent of the institution's eligible capital (the large exposure limit).

ital). Employing the geographical complexity metrics developed and discussed in detail in the bank complexity literature provides another analytical approach to document the asset exposures of EU banks toward shadow banking entities (see, for example, Cetorelli and Goldberg, 2014, 2016; Kwan, Ho and Tan 2019; and Goldberg and Meehl 2020). For instance, following Cetorelli and Goldberg (2014), we construct a measure of banks' geographic complexity and check whether more geographically complex banks tend also to have a greater geographical diversification of their exposures to shadow banking entities.[17] As in their paper, this complexity measure is constructed using data on the location of the subsidiaries of the banks in our sample. Figure 3 shows that the relationship between the banks' geographic diversification of exposures to shadow banks and their geographic complexity is positive, and it is also

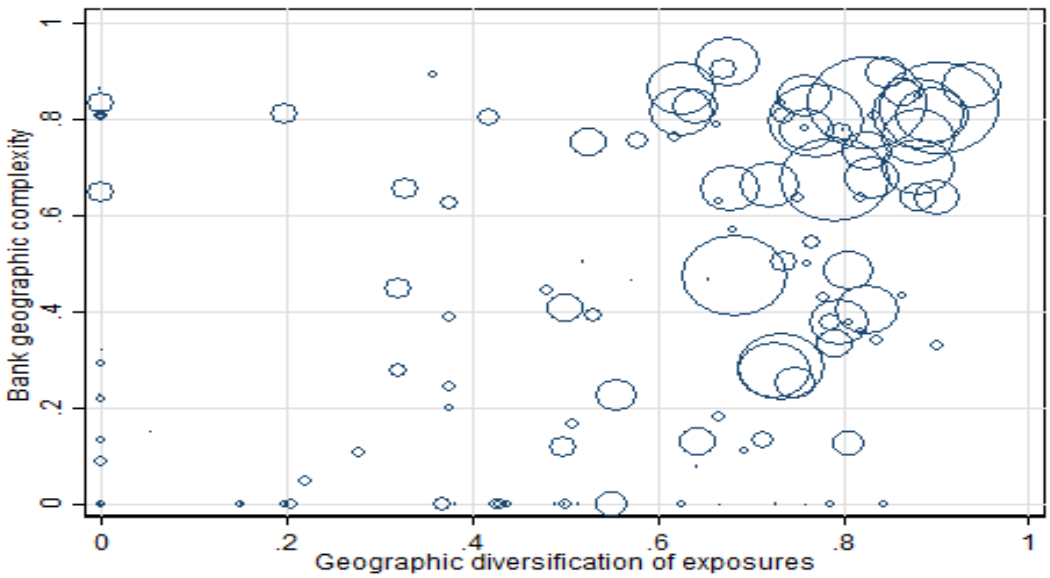
[17]The geographic complexity measure is constructed as a Herfindahl concentration index, as proposed in Cetorelli and Goldberg (2014). It is defined as:

$$\frac{N}{N-1}\left(1-\sum_{i=1}^{N}\left(\frac{count^i}{totalcount^i}\right)^2\right),$$

where N is the number of countries.

correlated with the banks' size (depicted as the size of each of the circles). Indeed, this finding is consistent with the wider bank complexity literature, as in Buch and Goldberg (2021): the expansion of geographic complexity is, in particular, a feature of the largest banking organisations. A more comprehensive analysis of the geography of the asset exposures is presented in Section 3.3.

FIGURE 3. **Geographic diversification of EU banks' exposures to shadow banking entities and banks' geographic complexity**



Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to 'shadow banking entities', December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of eligible capital. The chart excludes investment firms and exposures greater than 25 per cent of the institution's eligible capital (the large exposure limit).

3.2 The types of shadow banking counterparties

Table 4 shows that EU banks are exposed to many different types of shadow banking entities.[18] Importantly, there are significant differences in the business models and risk profiles across these shadow banking entities and therefore our dataset provides a unique insight into these linkages. Our final dataset shows that EU banks had around 65 per cent of their exposures to securitisations (26 per cent), investment funds other than MMFs (22 per cent) and finance companies (18 per cent). Regarding the top five exposures by type and country of domicile of the shadow banking entities (in EUR billions), Table 4 highlights that EU banks are most heavily exposed to finance companies domiciled in the US, followed by US securitisation vehicles, 'other' US shadow banking entities, securitisation vehicles domiciled in Ireland and US non-MMF investment funds.

Our data also show that 13 per cent of EU banks' total exposures are to entities that could not be further identified and are labelled as 'other' shadow banking entities, highlighting the information limitations for some types of entities. Moreover, the data illustrate that the reporting banks possess limited information about the supervisory treatment of their shadow banking counterparties. Banks' responses to the EBA survey indicate that, by value of the exposures, almost 90 per cent of the shadow banking counterparties were reported as either not supervised or not further identified by the reporting institution.

3.3 The cross-border exposures of EU banks to shadow banking entities

Next, we explore the cross-border nature of the exposures of EU banks to shadow banking entities to understand better the internationalisation of the shadow banking system and the cross-border complexity of the linkages. Our data highlight the global and cross-border nature of EU banks' exposures to shadow banking entities, as ap-

[18] Regarding non-MMF investment funds, the data are even more granular and are split into hedge funds, equity funds, real-estate funds, fixed income funds, other investment funds and 'not identified' funds.

TABLE 4. **Distribution of EU banks' exposures to shadow banking entities by country of domicile and type of shadow banking entity (weighted by size of exposure)**

Country / type	1	2	3	4	5	6	7	8	9	Total
DE	0.0	0.0	3.7	1.0	0.0	0.0	1.2	0.0	0.4	6.3
ES	0.0	0.0	0.0	0.3	0.0	0.1	0.3	0.0	0.1	0.7
FR	0.7	0.0	0.5	0.6	0.0	0.0	2.2	0.0	0.4	4.5
GB	0.0	0.4	2.5	2.0	0.4	0.5	2.2	0.0	2.4	10.5
IE	0.0	0.0	0.8	0.7	0.0	0.0	4.5	0.0	0.3	6.3
LU	0.3	0.0	2.3	0.7	0.2	0.0	1.2	0.0	0.4	5.2
NL	0.0	0.0	0.2	0.6	0.0	0.0	1.5	0.0	0.1	2.5
O-EU	0.1	0.0	2.0	1.4	0.0	0.0	0.4	0.1	0.3	4.4
HK	0.1	0.0	0.5	0.0	0.6	0.0	0.0	0.0	0.1	1.3
JE	0.0	0.0	0.2	0.1	0.0	0.0	2.7	0.0	0.0	3.0
JP	0.0	0.0	0.2	0.1	0.6	0.0	0.0	0.4	0.2	1.5
KR	0.0	0.0	0.0	0.2	0.0	0.0	0.0	1.9	0.5	2.6
KY	0.0	0.0	3.4	0.7	0.0	0.0	1.8	0.1	0.5	6.5
RU	0.0	0.0	0.0	0.1	0.0	0.0	0.0	1.7	0.1	1.9
TR	0.0	0.0	0.0	0.4	0.0	0.0	0.0	3.0	0.0	3.5
US	0.7	0.2	4.0	8.2	0.3	0.3	7.1	1.6	4.7	27.1
RW	0.0	0.1	1.9	1.2	0.6	0.6	0.8	4.4	2.5	12.1
Total	2.0	0.9	22.3	18.2	2.8	1.4	26.2	13.3	13.0	100.0

Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to 'shadow banking entities', December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of eligible capital. Country labels on the left hand side of the chart refer to the country of domicile of the shadow banking entity. *O-EU* refers to other EU countries while *RW* refers to the rest of the world. The numbers along the top of the chart refer to the type of shadow banking entity as in EBA (2015). 1 = UCITS MMF; 2 = Non-UCITS MMF; 3 = Non-MMF investment fund; 4 = finance companies; 5 = broker-dealers; 6 = credit insurers/ financial guarantors; 7 = securitisation; 8 = non-equivalent banks / insurers; 9 = other. 3. Non-MMF investment funds can be further broken down to the following sub-categories: Hedge funds, Equity funds, Real estate funds, Fixed income funds, Other investment funds, and a residual category of not identified.

proximately 60 per cent of EU banks' total exposures to shadow banking entities are towards non-EU domiciled entities. In particular, these data show the strong links between EU banks and US-domiciled shadow banking entities, which account for approximately 27 per cent of the total exposures in our final dataset (see Table 1). A number of studies including, for example, IMF (2014) and Maes (2014), highlight the interaction of EU banks and US-domiciled shadow banking entities during the global financial crisis.

Figures 4 and 5 map the international exposures of EU banks to shadow banking entities using granular bank-level and individual exposure level information.[19] The green nodes represent the reporting banks, while their size is determined by the number of individual counterparties or shadow banking entities to which they are exposed to (degree centrality). Orange nodes represent non-EU-domiciled shadow banking entities while the purple nodes represent EU domiciled shadow banking entities. Moreover, the orange links in the network in Figure 4 show that EU banks have a large number of exposures to non-EU domiciled shadow banking entities. The purple links show that EU banks have exposures to a number of EU-domiciled shadow banking entities, while the blue links represent domestic exposures (EU bank exposure to a shadow banking entity domiciled in the same country as the bank).

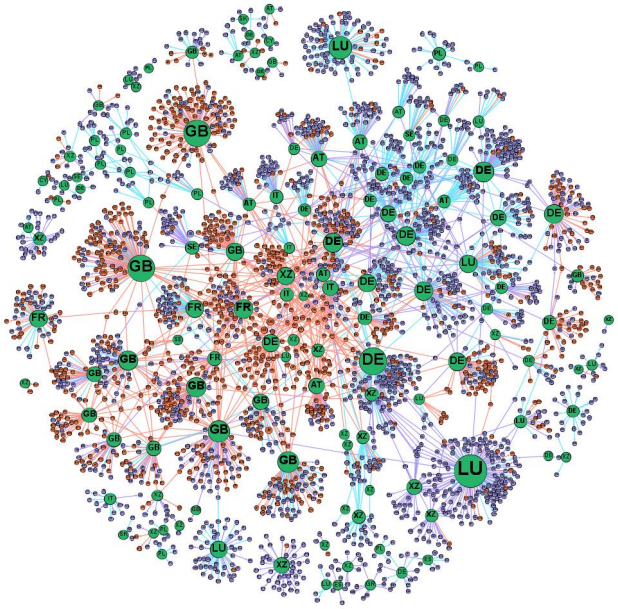
In Figure 6, we examine the geography of the exposures of the top twenty-five banks by their exposures to shadow banking entities. While there is some heterogeneity across banks, it is clear the EU banks are heavily exposed to shadow banking entities located outside of the EU. The monitoring of such linkages is particularly challenging if authorities lack a comprehensive view of banks' and shadow banks' international activities or if they lack information on some aspects of their activities. Moreover, Figure 7 presents a global map of the exposures based on the country of domicile of the shadow banking entity. As highlighted by Lane (2016), information sharing amongst regulators and policymakers can be an important component in the surveillance of

[19]These networks, based on our granular exposures data, are similar in structure to those showing portfolio overlaps in Europe in ESRB (2020b, Fig. 2) and globally in Miranda-Agrippino et al. (2020, Fig. 13), as well as to those showing the structure of the EU derivatives markets in Abad et al. (2016, Fig. 15, 30 and 38).

international shadow banking activities.

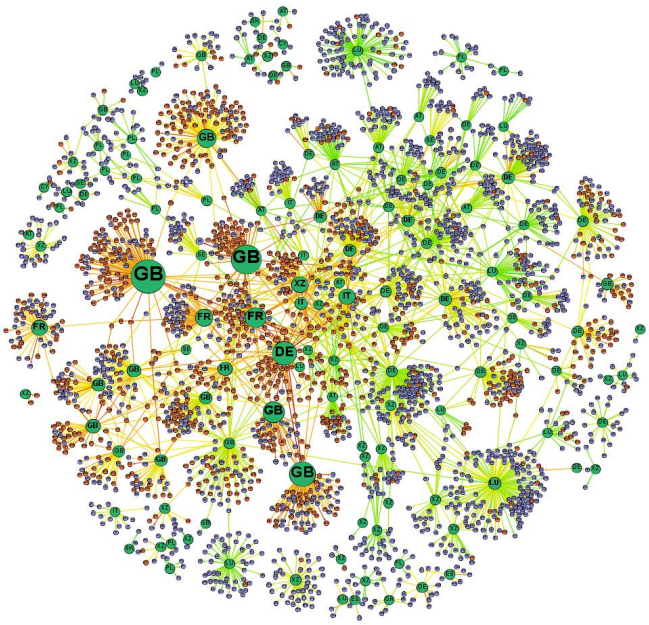
While our analysis provides a unique insight into the geography of the exposures of EU banks to shadow banking entities, it is subject to a number of limitations. The data underpinning our analysis show the domicile of the shadow banking entity. As noted by Grillet-Aubert et al. (2016), the "country of domicile is important in determining the geographic locus of potential supervisory measures". However, such geographic data are based on a first counterparty basis and may not reflect the ultimate risk bearers within the shadow banking entity. For example, while a shadow banking entity may be domiciled in country A owing to a favourable business or tax environment, the end investor may be located in country B, and therefore such flows of potential risk would not be captured in our analysis. In addition, we lack information on the regulatory treatment of the shadow banking counterparty which would be required to map the cross-border risks in more detail.

FIGURE 4. **Network of EU banks' exposures to shadow banking entities**



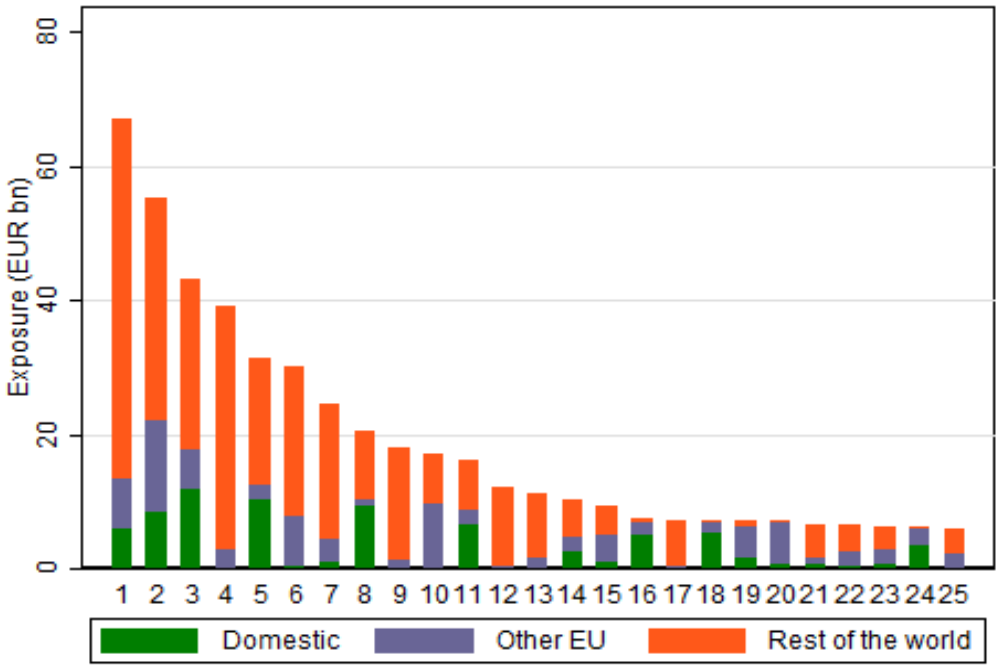
Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to "shadow banking entities", December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of institutions' eligible capital. Green nodes: reporting institutions (banks) labelled by country of residence. Purple and orange nodes: EU and non-EU domiciled shadow banking entities, respectively. The chart excludes investment firms and exposures greater than 25% of the institution's eligible capital (the large exposure limit). Node size is proportional to degree centrality (the number of counterparties). Blue links represent domestic exposures (EU institution to a domestic shadow banking entity); purple links represent EU exposures (EU institution to EU-domiciled shadow banking entity) and orange links represent non-EU exposures (EU institution to non-EU domiciled shadow banking entity).

FIGURE 5. **Network of EU banks' exposures to shadow banking entities**



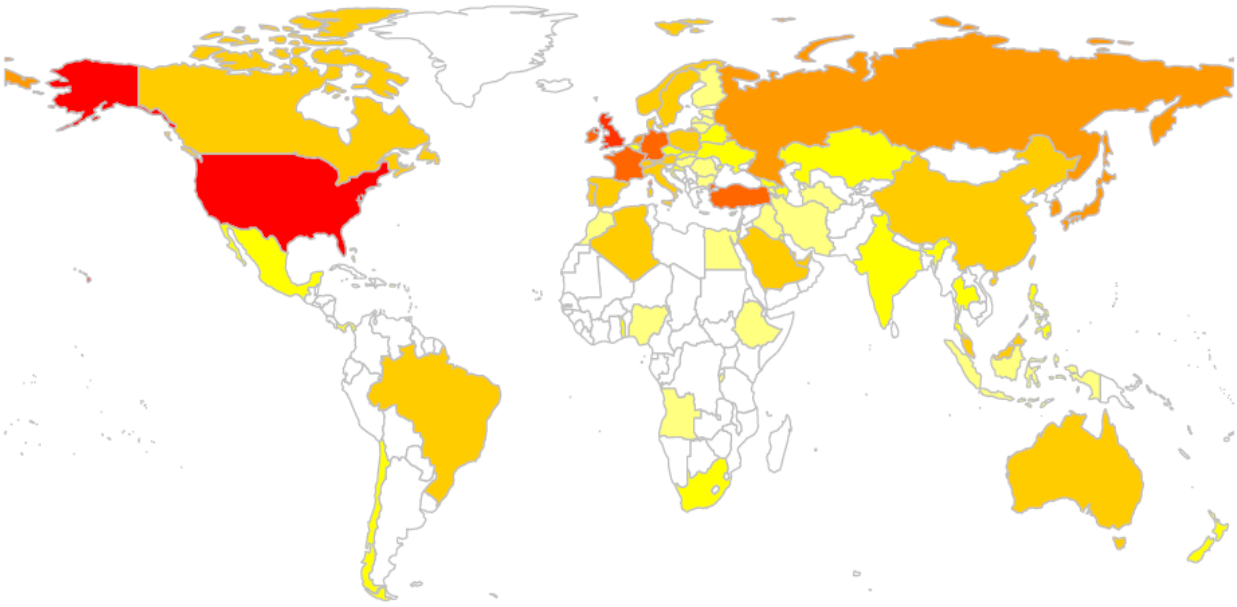
Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to "shadow banking entities", December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of institutions' eligible capital. Green nodes: reporting institutions (banks) labelled by country of residence. Purple and orange nodes: EU and non-EU domiciled shadow banking entities, respectively. The chart excludes investment firms and exposures greater than 25% of the institution's eligible capital (the large exposure limit). Node size is proportional to total exposures (sum of all individual exposures). Colour of link ranges from green to orange depending on the size of the individual exposure (green links: smaller exposures, orange links: larger individual exposures).

FIGURE 6. **Top 25 EU banks by their exposures to shadow banking entities**



Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to 'shadow banking entities', December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of eligible capital.

FIGURE 7. **Geography of risk: distribution of exposures by domicile of shadow banking entities**



Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to 'shadow banking entities', December 2015. Note: Data refer to individual exposures equal to or above 0.25 per cent of eligible capital.

3.4 Concentration and Overlap Analysis

Having described the broad patterns in our dataset, we next explore the concentration of banks' exposures to shadow banking entities. In particular, we measure the fraction of each bank's total exposure to shadow banking entities that is in common with other banks. This analysis is guided by a series of studies which provide a theoretical understanding on the motivation for banks to correlate exposures. For example, Acharya and Yorulmazer (2007) analyse the incentives banks have in increasing the risk that many banks fail together by herding and correlating their exposures. Similarly, Farhi and Tirole (2012) show that strategic complementarities in individual banks' choices may lead banks to optimally decide to correlate exposures.

Moreover, when banks are exposed to common sources of risks, shocks originating in one part of the shadow banking system could lead to vulnerabilities across several banks at once, potentially exacerbating contagion in the banking system. In order to quantify this channel of contagion, we express the exposures to shadow banking entities as a fraction of a bank's capital. Such a measure reflects the sensitivity of a bank to a relative shock in the exposure to the shadow banking entity and allows us to quantify the amount of additional capital that is necessary to absorb the shock at the individual bank level. By computing sensitivities at different levels of aggregation, this measure enables us to quantify the contribution of subsets of shadow banking entities towards the banks' capital shortfall. This measure is similar to the concept of systemic risk shortfall (SES) introduced in Acharya, Pedersen, Philippon, and Richardson (2017) as the "propensity to be undercapitalized when the system as a whole is undercapitalized".

Guided by these theoretical underpinnings and given the richness of our dataset, we can analyse the extent to which EU banks' are concentrated and overlapped in their exposures to shadow banking entities. By "overlap", we measure the degree of common exposures (i.e., the exposures of different banks to the same source of risk) of EU banks towards shadow banking entities, and we introduce a specific measure in our analysis below. Our analytical approach is therefore similar to Roncoroni et al.

(2019) who examine the interconnectedness of euro area banks to assess the degree of overlap in their systemically important exposures.

There is a natural relationship between concentration and overlap, which we illustrate in the following example. In this example we analyse three different financial systems composed of 2 banks and 3 shadow banking entities. For illustrative purposes, for each bank, we consider its portfolio structure as the normalised total exposures summing to one.

Consider the three financial systems represented by the following portfolio matrices:

$$\pi^1 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \qquad \pi^2 = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 1 \end{bmatrix} \qquad \pi^3 = \begin{bmatrix} 1/3 & 1/3 & 1/3 \\ 1/3 & 1/3 & 1/3 \end{bmatrix}$$

where the element π^s_{ik} refers to the exposure from bank i to shadow banking entity k in the s-th system.

The first system (matrix π^1) presents zero overlap because of the high concentration of the two banks. Each of the banks has no diversification and concentrates its exposures to one entity. A shock to any of the shadow banking entities will not impact the two banks at the same time. The second system (matrix π^2) has maximal overlap because of the concentration of its banks. Banks have a concentrated portfolio of exposures (no diversification) but they are both exposed to the same shadow banking entity. A shock to the third shadow banking entity will affect both banks at the same time. The third system, captured by the matrix π^3, presents a completely different picture: the two banks achieve maximal diversification by being exposed to all shadow banking entities in the system. The third system has therefore maximal overlap because of low concentration (maximal diversification) of its banks. Any shock will impact equally both banks at the same time.

Overall, this example highlights that the increased diversification of exposures may increase overlap and therefore reduce the benefit of diversification owing to the commonalities of the sources of shocks. In this sense, banking systems may be potentially

fragile to certain types of shocks while being robust to others. A banking system with a high degree of common exposures due to diversification may be resilient to small common shocks, but vulnerable to shocks beyond a specific threshold (see, for example, Acemoglu et al., 2015). This *systemic* feature of the financial system has received increased attention in recent years. As financial systems increase their levels of complexity and interconnectedness, they face a trade-off between diversification and systemic risk (Battiston et al., 2012). This stream of research shows that more connections may increase *individual* diversification while, at the same time, making the *system* more susceptible to common shocks which may lead to wide-scale systemic failures.[20]

Some studies argue that a certain degree of individual concentration can be beneficial. Stomper (2006), for instance, links concentration to the expertise lenders have in certain sectors. On the other hand, a more locally concentrated system does not benefit from diversification, and individual institutions may become riskier. Concentration risk therefore still represents one of the main possible causes of major losses in a credit institution. The global financial crisis brought to light many examples of risk concentrations within financial institutions. Since it can directly affect the survival of an institution, concentration risk requires special attention by supervisors. This has led policymakers to focus specifically on concentration.[21] Understanding whether overlap is ascribable to either concentration or diversification or both is therefore important from a financial stability perspective.

Next, we seek to understand the type and geography of the shadow banking entities for which overlap occurs. To this end, consider the set of n banks (indexed by $i = 1, 2, \ldots, n$) and the set of the m shadow banking entities (indexed by $k = 1, 2, \ldots, m$). Given an exposure x_{ik} of bank i to shadow bank k, the total exposure to shadow banking entities of each bank i is therefore $\sum_k x_{ik}$. Further, define the following two ratios:

$$\pi_{ik} = \frac{\text{exposure of } i \text{ to } k}{\text{total shadow bank exposures of } i} = \frac{x_{ik}}{\sum_k x_{ik}},$$

[20]There is an analogy here with the argument (arising from analysis of the March 2020 market disruptions) that regulatory requirements for minimum liquidity for individual entities may contribute to systemic liquidity risk.

[21]See, for example, the BCBS (2006) and CEBS (2010).

and

$$l_{ik} = \frac{\text{exposure of } i \text{ towards } k}{\text{capital of } i} = \frac{x_{ik}}{c_i},$$

where π_{ik} can be thought of as the elements of the portfolio matrix of the system (with $\sum_k \pi_{ik} = 1, \forall i$), and l_{ik} are individual exposures as a fraction of bank i's capital. Moreover the total exposure of i as a fraction of its capital is simply given by $l_i = \sum_k l_{ik}$ and, therefore, it holds that $l_{ik} = l_i \times \pi_{ik}$. A simple, yet useful interpretation of the term l_{ik} is the percentage of equity lost by i given a shock on k.[22] In this sense, if $l_{ik} > 1$, i may itself default from the default of k.

We next consider the degree of concentration in the exposures. A well-known measure of concentration is the Herfindahl index (HHI) of concentration, computed in our case as follows:

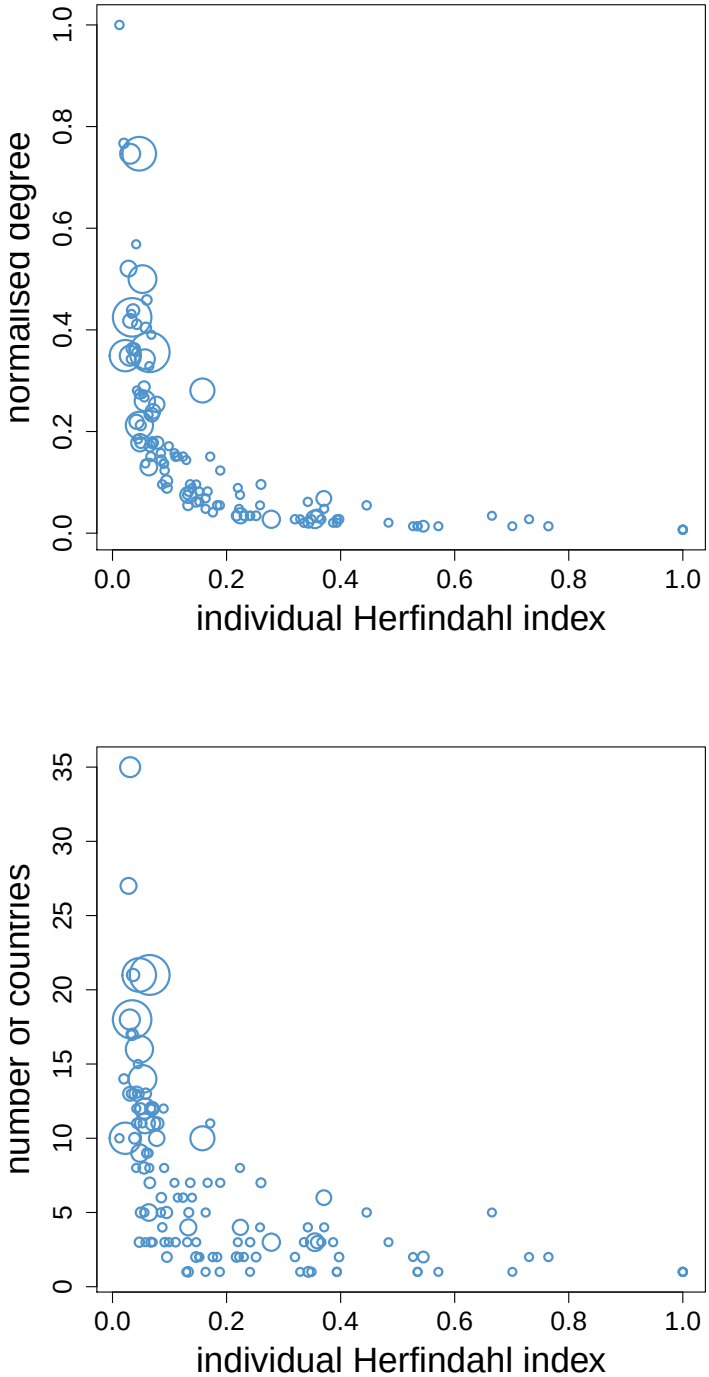
$$H_i = \sum_k \pi_{ik}^2,$$

which measures the concentration of the portfolio of exposures to shadow banking entities of bank i. The top panel of Figure 8 reports the values of H_i for each bank versus their normalised degree (i.e. the number of shadow banking entities to which bank i is exposed). It shows that concentration is inversely related to the number of shadow banking counterparties. Therefore, banks with less concentration in their exposures to shadow banking entities also have a larger set of counterparties. The bottom panel of Figure 8 reports the values of H_i versus the number of different countries to which each bank is exposed. It suggests that banks with low levels of concentration have their exposures split across many different countries. This has an important implication for our cross-border analysis if diversification is achieved by having exposures to jurisdictions or sectors where prudential regulation may not apply.

Turning to the degree of overlap in the exposures in our dataset, we next rely on a

[22]The notion of equity used in this analysis is conceptual and can refer to various measures of a bank's equity. It can be proxied, for instance, as a bank's Tier 1 capital.

FIGURE 8. **Concentration.**



Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to "shadow banking entities", December 2015. Note: the horizontal axes represent concentration indices for each bank as measured by Equation (1). The vertical axes represent normalised degree (top panel) and number of countries to which each bank is exposed (bottom panel).

simple measure for portfolio overlap between two banks:

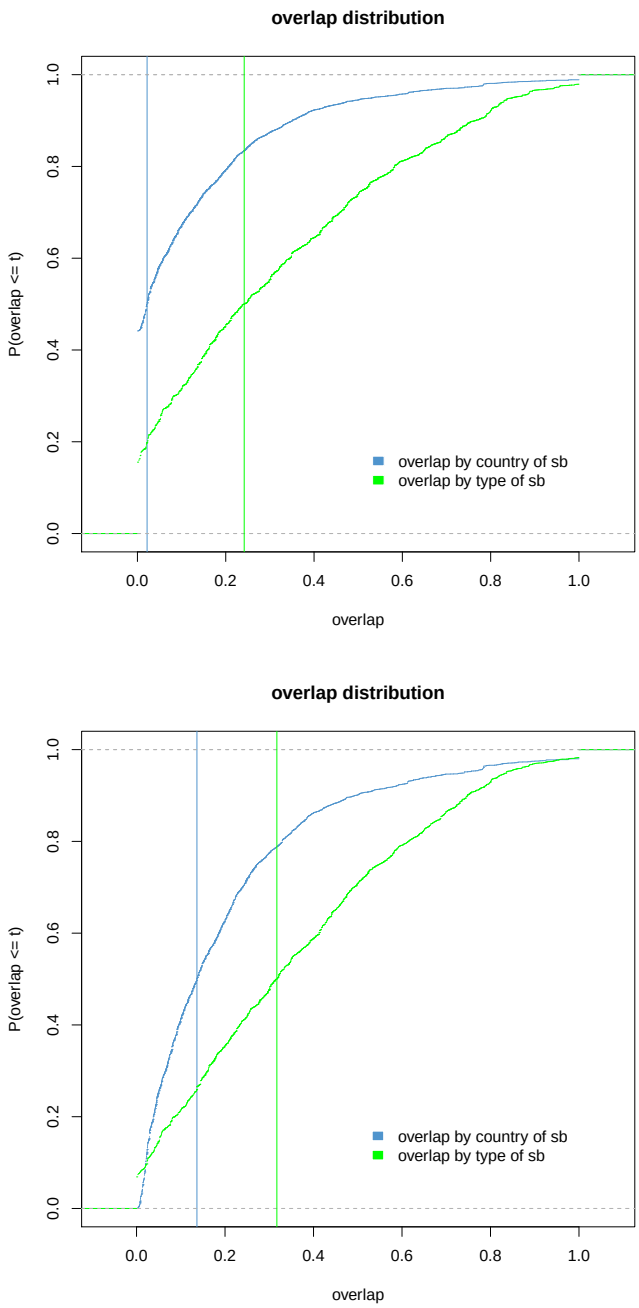
$$s_{ij}^{\pi} = \sum_{m} \min\{\pi_{im}, \pi_{jm}\} \tag{1}$$

where the index m refers to each of the nine shadow banking categories in our sample (as described in Section 3.2), aggregated by their country of domicile. The quantity s_{ij}^{π} can be interpreted as the intersection of the two portfolios. Therefore, the common amount of exposures to the same combinations of country/type of shadow banking entities. We compute this *pairwise* quantity for all the banks in our sample. Naturally, given the large number of shadow banking entities in our sample, many banks will have zero overlap, in that they will have no shadow bank exposure in common. It is therefore useful to compute the overlap both conditional on the existence of common exposures and unconditionally. Also, given the granularity of our dataset, we can analyse the levels of overlap at two levels of aggregation: by country of shadow banking entity and by type of shadow banking entity. The results are reported in Figure 9, where we plot the empirical cumulative density functions (ECDF) of the overlaps for these two levels of aggregation. In both cases, the aggregation by type of shadow banking entity provides higher levels of overlap. The conditional overlap ECDF on the top panel shows that, once non-zero overlaps are computed, these overlaps can be high for a relatively large amount of bank pairs. For example, the overlap by country is at least 0.6 for ten percent of the bank pairs. An important fraction of banks may therefore be exposed to common shocks originating from the same set of countries.

Vulnerability Shocks from the shadow banking system may potentially engender distress in the banking sector and can lead to significant losses. To explore this, we build on the framework of Battiston et al. (2016) to understand potential capital losses owing to shadow banking activities. First, define the following quantity:

$$h_i = \min\left\{1, \sum_{k} h_{ik}\right\}, \text{ where } h_{ik} = l_{ik} r_k$$

FIGURE 9. **Overlap.**



Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to "shadow banking entities", December 2015. Note: empirical cumulative density functions (ECDF) of the overlap measure is computed by Equation (1). Vertical lines represent the median overlap. Blue lines represent the overlap in terms of countries to which banks are exposed. Green lines represent the overlap in terms of the types of shadow banking entities (as defined in Section 3.2). Top panel: distribution of overlap conditional on the existence of commonalities. Bottom panel: unconditional distribution.

which measures the potential relative equity loss due to a shock $r_k \in [0, 1]$ on a shadow banking entity k. The total relative equity loss for the banking system of a country C is:

$$H_C = \min \left\{ 1, \sum_{i \in C} \left(w_i \sum_k l_{ik} r_k \right) \right\}$$

where $w_i = \frac{c_i}{\sum_j c_j}$ is the relative capital of i with respect to the total aggregate capital in the system.

Within this framework, it is possible to understand what are the types of shadow banking entities, aggregated by their country of domicile, that could lead to the largest losses for the EU banking system, by computing the following quantity:

$$H_m = \min \left\{ 1, \sum_i w_i l_{im} r_m \right\}, \tag{2}$$

where m represents one of the nine shadow banking categories in our sample (as described in Section 3.2), aggregated by their country of domicile. By assuming a common shock to all sectors ($r_m = r, \forall k$), we can rank them in terms of the potential equity loss they would cause in the EU banking system. Table 5 presents the ranking for the top ten results. We observe that finance companies (Type 4) domiciled in the US represent the top source of vulnerability for the EU banking sector, followed by US-domiciled securitisation vehicles (Type 7) and US-domiciled shadow banking entities that could not be further defined or classified as 'other' (Type 9). This shows that the top three largest exposures for the EU banking system are indeed US-domiciled shadow banking entities.

Last, we analyse how these different sources of vulnerability may affect the same banks by computing a *leverage-based* overlap measure:

$$S^l_{ij} = \sum_k \min\{l_{ik}, l_{jk}\} \tag{3}$$

This measures the common relative equity loss to the banking systems of any pair of

TABLE 5. **Vulnerability**

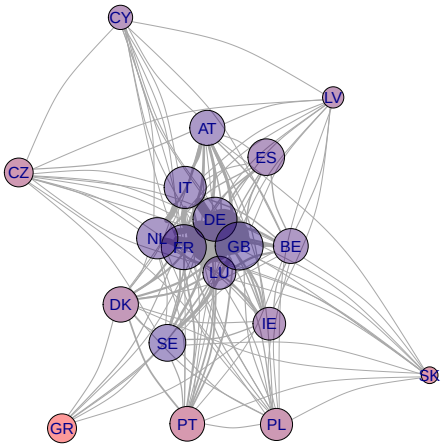
Rank	Source	Rank	Source
1	US Finance companies	6	DE Non-MMF investment funds
2	US Securitisation	7	KY Non-MMF investment funds
3	US 'Other'	8	TR Non-equivalent banks/insurers
4	IE Securitisation	9	JE Securitisation
5	US Non-MMF investment funds	10	GB 'Other'

Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to "shadow banking entities", December 2015. Note: Rank of the top ten sources of vulnerability (from highest to lowest) for the EU banking system (in terms of potential equity loss). The sources of vulnerability are shadow banking categories as classified in Section 3.2, aggregated by their country of domicile.

countries following a given shock.[23] We plot the network associated to S^l_{ij} in Figure 10. The colour of the nodes reflects the level of concentration computed as the Herfindahl index, ranging from blue (smaller concentration) to red (larger concentration). It shows that less concentrated banking systems tend to have more overlap: more diversification leads to more overlap between banking systems of different EU countries. Given that a common source of vulnerability is represented by US-domiciled entities, this highlights the potential transmission channels stemming from the US shadow banking system which were exposed during the global financial crisis (Maes, 2014).

[23]By *banking system* of a country, we refer to the aggregation of all banks in a given country, weighted by the size of their equity.

FIGURE 10. **Common vulnerability overlap: less concentrated systems tend to be more overlapped**



Source: Authors' calculations based on EBA (2015), Report on institutions' exposures to "shadow banking entities", December 2015. Note: each node in the network represents a banking system, defined as the aggregation of the banks by country. The size of the nodes is proportional to the system's total exposures to shadow banking entities. The size of the weights reflects the level of leverage-based overlap as computed in Equation 3. The colour of the nodes reflects the level of concentration computed as the Herfindahl index, ranging from blue (smaller concentration) to red (larger concentration).

4 EU banks' characteristics and their exposures to shadow banking entities

The analytical approaches employed so far have documented the nature of the linkages between EU banks and shadow banking entities with a specific emphasis on their cross-border and cross-sector characteristics and the degree of concentration and overlap in the exposures across banks.

Given the cross-country richness of our dataset and following an empirical methodology similar to Buch et al. (2013), we next employ an augmented OLS gravity model to examine how EU banks' country- and entity-level characteristics relate to their exposures to shadow banking entities. Our empirical methodology is informed by the international banking literature and can thus be written as follows:

$$\ln(EXP_{bij}) = W_{ij}\beta_1 + X_b\beta_2 + V_i\beta_3 + Z_j\beta_4 + \lambda_b + \alpha_j + \gamma_s + \varepsilon_{ij}. \tag{4}$$

In this specification $\ln(EXP_{bij})$ is the natural logarithm of bank b in country i's exposures to shadow banking entities located in country j.[24] Therefore, we exploit the cross-sectional variation of the exposures as of March 2015 across countries by estimating an augmented gravity regression for exposures against a host of bank-level and country-level covariates. W_{ij} is a vector of bilateral gravity related covariates such as sharing a common border, currency, legal system, language or past colonial links; X_b are bank-group level covariates such as size, capitalization, liquidity and cost-to-income ratio; V_i represents country-level controls related to the location of the bank such as GDP; while Z_j represents country-level explanatory variables for the location of the shadow banking entity. λ_b, α_j and γ_s relate to bank-group level, shadow banking *country* and shadow banking entity *type* fixed effects while ε_{ij} is an error term. Standard errors are robust to heteroskedasticity and clustered at the bank group level in line with the empirical international banking literature. Bank-level and time-variant

[24] In our robustness tests shown in Table 8, we use an alternative dependent variable when proxying the internationalization of EU banks' exposures to shadow banking entities.

country regressors are lagged by one period with respect to the dependent variable to address potential endogeneity issues. Summary statistics for the variables used in our empirical analysis are presented in Table 6.

TABLE 6. Summary statistics

Variable	N	Mean	Std. Dev	Min.	Max.
Log(size)	1432	18.9	2.1	12.4	21.5
Equity/total assets	1432	6.9	7.3	2.3	90.6
Interbank ratio	1432	95.83	71.1	4.3	421.9
ROAE	1432	2.1	13.6	−90.4	29.6
Cost-income ratio	1432	71.9	16.3	33.9	136.5
Log(distance)	1432	6.9	1.5	4.0	9.8
Log(GDP˙bank˙host)	1432	28.1	1.1	23.9	28.9
Log (GDP˙shadow˙bank˙host)	1432	28.3	1.5	23.9	30.4

Notes: A description of each of the variables in this table and their units can be found in Table 9 in the Appendix.

4.1 Main regression results

The estimates from our baseline specification are reported in Table 7. In columns (1) to (3), we include a host of bank-and country-level covariates that are likely to be associated with the exposures of EU banks to shadow banking entities. As described in Section 2.2, bank characteristics such as bank size, liquidity, capitalisation, cost-to-income ratio and return on average equity are often included in the empirical literature when examining the internationalisation and complexity of banking. Bank size is included in our analysis, in line with Buch et al. (2013) and Aldasoro, Hardy and Jager (2020), to capture the scale and complexity of the operations of the bank. It is expected that larger banks, given their additional resources and specialisation, are more likely to have exposures to shadow banking entities globally. As shown in Table 7, bank size has a positive and statistically significant effect on EU banks' exposures to shadow banking entities. Our results from Table 7 suggest that bank capitalization and ROAE

are negatively associated with the exposures to shadow banking entities. Moreover, we find that more efficient banks, as proxied by their cost-to-income ratios, tend to be positively associated with shadow banking exposures.[25]

We also control for a host of country-level factors in Table 7 such as the GDP of the country of the bank and shadow banking entity, gravity related bilateral covariates and a dummy variable equal to one when the shadow banking entity is domiciled in an offshore financial centre. In line with a number of empirical papers in the international banking and finance literatures (see, for example, Buch 2005; Portes and Rey 2005; Lane and Milesi-Ferretti 2008; Houston et al. 2012; Claessens and van Horen 2014; Davies and Killeen 2018; and Brei and von Peter 2018), we include the log of geographic distance between the country of the bank and shadow banking entity. This control variable has been widely employed in the empirical trade, FDI and finance literatures as a proxy for information costs and financial frictions. As expected, we find a significant negative effect of distance on the size of banks' exposures to shadow banking entities across all our specifications.

Moreover, we control for a number of bilateral gravity-related variables such as whether the country of the bank and shadow banking entity share a common border, currency, language, legal system and past colonial links (see, for example, Claessens and van Horen 2014; Davies and Killeen 2018; and Brei and von Peter 2018). The positive and significant effect (at the 1 per cent level) of sharing a common currency suggests that economic ties between the country of the bank and country of the shadow banking entity is an important factor when examining the exposures of EU banks to shadow banking entities. In contrast, we find that a common border has a significant negative effect suggesting banks' and shadow banking entities which are geographically separated are more likely to have higher exposures. Controlling for the size of the country of the bank and shadow banking entity as proxied by their GDP, we find that both covariates enter negatively, although the size of the country of the shadow banking entity is insignificant across all specifications. In columns (2) and (3), the offshore

[25] As noted in Tables 7 and 8, we lag our control variables by one period, in line with the existing empirical literature, to overcome possible endogeneity issues.

international financial centre dummy is positive but insignificant in both specifications. Finally, given the heterogeneity of shadow banking entities and their associated business models, column (3) includes a set of shadow banking entity-type specific dummy variables. Overall, our earlier findings remain robust to their inclusion, and the specification in column (3) now represents our preferred baseline estimation.

4.2 Regressions based on sub-samples

We next run a number of additional regressions based on sub-samples of data. The results so far have not considered the possible effect of different characteristics across different types of shadow banking entities or categories of banks. Given the diversity of entities and business models which comprise the shadow banking system, it may be expected that different factors may be associated with the exposures to different types of shadow banking entity. As noted above, we are not aware of other studies in the international banking and finance literatures which include the same level of granularity in EU banks' asset exposures to different types of shadow banking entities. To investigate these issues, Table 8 repeats our baseline specification across different sub-samples of data.

In column (1), we use the shadow banking entity categorisations included in the EBA data collection (and described in Section 2) to examine the factors which influence EU banks' exposures to non-MMF investment funds only. Similarly, in column (2) we examine exposures to finance companies only, while column (3) focuses specifically on securitisation vehicles. We do this as these three categories of shadow banking entities account for approximately two-thirds of the exposures to shadow banking entities. Consistent with our baseline estimates where we group all types of shadow banking entities together, we find that bank size is positively and statistically significantly associated with banks' exposures to the three types of shadow banking entities. Of the other covariates included, we again find that the distance between the country of domicile of the bank and shadow banking entity and whether they share a common currency or border are important factors associated with the exposures although the

TABLE 7. Estimates from Baseline Regressions

	(1) Full sample	(2) Full sample	(3) Full sample
Log(size)$_{t-1}$	1.471***	1.471***	1.532***
	(0.065)	(0.065)	(0.080)
Equity/total assets$_{t-1}$	-0.317***	-0.317***	-0.424***
	(0.069)	(0.069)	(0.101)
Interbank ratio$_{t-1}$	0.0227***	0.0227***	0.0292***
	(0.008)	(0.008)	(0.009)
ROAE$_{t-1}$	-0.163***	-0.163***	-0.194***
	(0.029)	(0.029)	(0.033)
Cost-income ratio$_{t-1}$	-0.0162***	-0.0162***	-0.0268***
	(0.004)	(0.004)	(0.004)
log(distance)	-0.778***	-0.778***	-0.765***
	(0.202)	(0.202)	(0.199)
comcur	0.952***	0.952***	0.886***
	(0.323)	(0.323)	(0.303)
colony	0.571	0.571	0.466
	(0.506)	(0.506)	(0.487)
comleg	0.021	0.021	0.038
	(0.261)	(0.261)	(0.242)
comlang_off	0.290	0.290	0.305
	(0.408)	(0.408)	(0.380)
contig	-1.197***	-1.197***	-1.134***
	(0.333)	(0.333)	(0.320)
GDP^bank^host$_{t-1}$	-1.510***	-1.510***	-1.686***
	(0.189)	(0.189)	(0.214)
GDP^shadow^bank^host$_{t-1}$	-5.480	-5.480	-4.660
	(3.324)	(3.324)	(3.455)
Offshore^fin^centre		0.684	0.911
		(1.147)	(1.203)
N	1432	1432	1432
No. banks	78	78	78
Bank Group fixed effects	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes
SB entity fixed effects	No	No	Yes
R^2	0.875	0.875	0.881
adj. R^2	0.863	0.863	0.869

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table presents the baseline estimates from an OLS regression for the cross-section data (2015) with bank fixed effects and shadow banking entity *host country* fixed effects. The dependent variable is the log of banks' total exposures to shadow banking entities in different host countries. Column (3) includes dummy variables for the type of shadow banking entities. Standard errors are robust to heteroskedasticity and clustered at the bank group level (shown in parentheses). Bank-level and time-variant country regressors are lagged by one period with respect to the dependent variable.

significance levels differ compared to the baseline estimates for some types of shadow banking counterparty.

In columns (4) to (8) we examine differences across the classifications of banks by splitting our sample of exposures by type of bank. To do this, we use the categorisations of banks from the EBA data collection in columns (4) and (5), while we draw on a separate grouping of banks taken from the Orbis database for columns (6) to (8). In column (4), we focus specifically on the exposures of banks labelled as Group 1 banks, while the results from the sample of Group 2 banks are shown in column (5). Following EBA (2015), Group 1 banks have Tier 1 capital in excess of €3 billion and are internationally active while other banks would be considered Group 2 banks. We do find differences in the results according to these classifications. While larger banks are likely to have higher exposures to shadow banking entities for both categories, we do find differences in the direction of the estimates for the other bank-level controls. Similarly, regarding the country-level control variables, our results suggest that the distance between the host country of the bank and shadow banking entity has a significant negative effect for Group 1 banks (at the 5 per cent significance level), while although still negative, it is not statistically significant for Group 2 banks. Moreover, the other gravity-related covariates are largely insignificant for Group 2 banks. This suggests that internationally active banks are more responsive to these economic and geographical financial frictions.

Having exploited the bank classifications from the EBA (2015), we proceed next by cross-checking our findings using the bank categorisations provided by the Orbis data. Column (6) of Table 8 presents the estimates for banks that are classified as commercial banks, column (7) shows the results for bank holding companies while column (8) shows the estimates for banks classified as savings banks. Of the three types of banks considered, it is noteworthy that commercial banks, those which one would expect to be active in international financial markets, appear most responsive to distance, which enters negatively for these types of banks but is positive and significant for the other two categories of banks. We also find differential responses on the bank size coefficient,

with larger banks that are classified as bank holding companies or savings banks more likely to have higher exposures while the coefficient for commercial banks is negative and not statistically significant. Finally, we examine variations with respect to our dependent variable. In column (9), we replace our dependent variable with the per cent of bank b from country i's exposures to shadow bank country j as a percentage of each banks' shadow banking exposures. This alternative specification therefore proxies for the concentration of each banks' shadow banking exposures to entities located in specific host countries. While the sign for the main covariates of interest are broadly consistent with our preferred baseline, we observe a loss of statistical significance for some of the control variables including bank size.

TABLE 8. Results from Additional Regressions based on Sub-Samples

	(1) Non-MMF inv. funds	(2) Finance companies	(3) Securit-isations	(4) Group 1 banks	(5) Group 2 banks	(6) Commercial banks	(7) Bank holding companies	(8) Savings banks	(9) Dep. var: Concentration
Log(size)$_{t-1}$	1.602***	1.297***	1.803***	1.468***	37.94***	-1.130	10.40***	2.195***	0.040**
	(0.122)	(0.158)	(0.162)	(0.063)	(9.800)	(0.709)	(0.790)	(0.038)	(0.017)
Equity/total assets$_{t-1}$	0.431***	0.269	0.976***	-0.272***	1.838	-0.302	-5.194***	-1.055***	0.075***
	(0.05)	(0.169)	(0.210)	(0.082)	(0.753)	(0.246)	(1.176)	(0.06)	(0.023)
Interbank ratio$_{t-1}$	-0.011	-0.006	-0.037***	0.185	0.261***	-0.006	0.093***	-0.008***	-0.006***
	(0.007)	(0.005)	(0.010)	(0.009)	(0.028)	(0.006)	(0.012)	(0.000)	(0.002)
ROAE$_{t-1}$	0.021	0.044	0.061	-0.158***	0.486***	-0.196***	0.0	-3.460***	0.015**
	(0.041)	(0.031)	(0.036)	(0.036)	(0.038)	(0.043)	(0.0)	(0.099)	(0.007)
Cost-income ratio$_{t-1}$	0.022***	0.005	0.021	-0.021***	1.043	0.047	0.0	-0.205***	-0.003***
	(0.007)	(0.009)	(0.016)	(0.004)	(0.601)	(0.047)	(0.0)	(0.003)	(0.001)
log(distance)	-2.034***	-1.443***	-1.030***	-0.587**	-0.745	-0.588***	0.941**	0.611***	-0.127***
	(0.317)	(0.467)	(0.362)	(0.243)	(0.739)	(0.185)	(0.257)	(0.081)	(0.047)
comcur	1.334***	0.738**	0.812	1.368***	0.630	0.941**	3.297**	0.864**	0.085
	(0.428)	(0.360)	(0.656)	(0.370)	(0.676)	(0.397)	(0.588)	(0.352)	(0.063)
colony	0.173	0.922	-0.357	1.201***	0.0	1.425***	-3.267***	0.0	0.010
	(0.422)	(0.568)	(0.907)	(0.386)	(0.0)	(0.433)	(0.068)	(0.0)	(0.119)
comleg	-1.038**	-0.167	-0.0587	-0.400	-0.843	-0.313	-1.295***	3.149***	0.071
	(0.472)	(0.550)	(0.536)	(0.266)	(1.043)	(0.394)	(0.072)	(0.237)	(0.051)
comlang_off	1.206	0.644	1.132	0.809	-2.423**	0.970	10.78***	-5.026***	0.017
	(0.721)	(0.812)	(0.887)	(0.450)	(1.157)	(0.570)	(0.448)	(0.426)	(0.098)
contig	-1.867***	-0.984**	-1.507*	-1.305***	0.339	-1.078***	-7.081**	2.522***	-0.244***
	(0.424)	(0.458)	(0.684)	(0.328)	(1.205)	(0.304)	(1.067)	(0.174)	(0.067)
GDP˙bank˙host$_{t-1}$	1.908	1.096	-0.385	-1.539***	-10.51	1.135	0.0	-12.74***	-0.240***
	(1.148)	(0.627)	(0.304)	(0.318)	(11.91)	(0.598)	(0.0)	(0.369)	(0.037)
GDP˙shadow˙bank˙host$_{t-1}$	-4.296	0.775***	0.762***	-9.997***	0.591	-11.62**	-1.808***	-0.315***	-0.325
	(3.943)	(0.199)	(0.156)	(2.867)	(0.809)	(4.048)	(0.059)	(0.024)	(0.794)
Offshore˙fin˙centre	-12.41	0.0	1.246	-1.044	-4.917**	-35.00***	-3.413***	0.0	0.141
	(6.419)	(0.0)	(1.007)	(0.979)	(1.896)	(11.55)	(0.249)	(0.0)	(0.277)
N	440	324	253	947	485	585	133	175	1432
Bank Group fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
SB entity fixed effects	No	No	No	No	No	No	No	No	Yes
R^2	0.972	0.940	0.903	0.834	0.934	0.946	0.873	0.966	0.844
adj. R^2	0.966	0.919	0.882	0.818	0.24	0.936	0.848	0.961	0.828

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Notes: The table presents additional estimates from an OLS regression for the cross-section data with bank, shadow banking entity *type* and shadow banking entity *host country* fixed effects using sub-samples of data. In columns (1) to (8) the variable is the log of banks' total exposures to shadow banking entities in different host countries. As per EBA (2015), Group 1 banks have Tier 1 capital in excess of €3 billion and are internationally active while other banks would be considered Group 2 banks. In column(9) the dependent variable is the percentage of banks' total exposures to shadow banking entities in different host countries as a percentage of each banks' total exposures to shadow banking entities. Standard errors are robust to heteroskedasticity and clustered at the bank group level (shown in parentheses). Bank-level and time-variant country regressors are lagged by one period with respect to the dependent variable.

5 Conclusions

The increasing size of the shadow banking system underlines the need for a better understanding of the linkages of shadow banking entities with different parts of the financial system, including the banking system. Despite the increased focus on assessing the interconnectedness between banks and shadow banking entities since the global financial crisis, to the best of our knowledge no study documents these linkages using bank- and asset exposure-level information at the EU level. These data gaps inhibit systemic risk monitoring on the linkages between banks and different types of non-bank financial institutions. This paper therefore examines the asset exposures of EU banks to shadow banking entities drawing on a unique data collection exercise by the EBA in March 2015.

Our analysis confirms that the exposures of EU banks to shadow banking entities is global and spans regional and national borders. EU banks have significant exposures to shadow banking entities globally and, in particular, to entities domiciled in the US, which represent approximately 27 per cent of the total exposures. Moreover, we find that EU banks' exposures to shadow banking entities are concentrated by type of counterparty, with approximately 65 per cent of the exposures to securitisations, non-MMF investment funds and finance companies. The networks shown in Figures 4 and 5 highlight that the most interconnected EU banks have the largest individual shadow bank exposures, with implications for systemic risk. Moreover, the extensive cross-border interconnections shown in these networks highlight opportunities for regulatory arbitrage.

At the individual level, banks' exposures are diversified; larger and geographically more complex banks have geographically more diverse shadow banking exposures. But our analysis confirms the suggestion from theory that such diversification may lead to high overlap across different types of shadow banking entities, hence common vulnerability. The global financial crisis showed how such linkages can act as contagion paths and can lead to the amplification of shocks across borders and sectors. There is indeed a tradeoff between individual portfolio diversification and systemic risk. Our

analysis of contagion risk arising from shadow banking exposures is also related to the concept of systemic risk shortfall in Acharya et al. (2017). Therefore, for the purposes of systemic risk identification and monitoring, our findings highlight the cross-border exposures of EU banks to the global shadow banking system and the importance of detailed exposure level data in order to understand better the nature of these linkages.

Moreover, using our unique exposure and bank-level dataset, we study for the first time the relationship between EU banks' characteristics and their exposures to shadow banking entities. Our regression results confirm the relevance of the gravity model to banks' cross-border exposures to shadow banking entities. They suggest that larger banks in particular have higher exposures and hence larger and more internationally active banks are likely to be more exposed to any potential shocks or spillovers from the shadow banking system. The results also highlight the importance of economic and geographical characteristics of the host country of the bank and shadow banking entity as key factors associated with the volume of exposures between EU banks and shadow banking entities.

Our results also suggest a number of avenues for future research. The analysis in this paper presents EU banks' exposures to shadow banking entities and is therefore based on the asset side of banks' balance sheets. Building on this, future work can seek to investigate the liability side of banks' balance sheets and specifically the role of shadow banking entities as a source of funding for banks (see ESRB (2020a) for aggregate data on such funding)). Moreover, understanding the linkages of shadow banking entities to other non-bank financial institutions is also an important part of the financial system which needs to be monitored. A mapping of these linkages and potential contagion paths between sectors and jurisdictions will contribute to a more complete picture of the interconnectedness of the banking and shadow banking systems. Other potential areas for further work include an examination of the supervision and regulation of individual shadow banking entities, including their potential prudential consolidation.

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Appendix: Data Definitions

TABLE 9. Variable Definitions and Data Sources

Variable	Description	Data Source
Log (Value-banks-exp)	Natural logarithm of gross exposures from bank b in country i to shadow bank country j	EBA and authors' calculations
Concentration	Per cent of banks' exposures from country i to shadow bank country j as percentage of each banks shadow banking exposures	EBA and authors' calculations
Colony	Dummy variable equal to 1 if home and host country ever shared a colonial relationship and 0 otherwise	CEPII
Comcurr	Dummy variable equal to 1 if home and host country share a common currency and 0 otherwise	CEPII
Comleg	Dummy variable equal to 1 if home and host country share a common legal system and 0 otherwise	CEPII
comlang_off	Dummy variable equal to 1 if home and host share a common language	CEPII
Contiguity	Dummy variable equal to 1 if home and host share a common border and 0 otherwise	CEPII
Cost-income ratio	Cost to income ratio of bank, per cent	Bureau van Dijk Orbis
Log(size)	Natural logarithm of banks' total assets in '000 €	Bureau van Dijk Orbis
Equity/total assets	Equity of bank / banks' total assets	Bureau van Dijk Orbis
Log(distance)	Log of distance, measured by km between host and home country capital cities, weighted by population	CEPII
Interbank ratio	Interbank Lending to Interbank Borrowing	Bureau van Dijk Orbis
GDP˙bank˙host	Log of GDP, constant 2005 prices US Dollars	WDI
GDP˙shadow˙bank˙host	Log of GDP, constant 2005 prices US Dollars	WDI
Offshore˙fin˙centre	Dummy variable equal to 1 if shadow banking host country is offshore fin centre	Davies and Killeen (2018)
ROAE	Return on average equity of bank	Bureau van Dijk Orbis