

# A macro-network of the financial interdependencies in the Euro Area: power relations and exposure to climate policy risks

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## 1 Abstract

Nowadays there is a growing concern about the impact of climate change on macroeconomic and financial stability as well as a role of financial institutions in facilitating decarbonisation pathway of the global economy. As a result of climate policies supporting green technologies and discouraging brown technologies, large portions of assets of financial institutions are potentially subject to positive or negative re-evaluation. Despite this fact, currently, there are no monetary estimates of the potential gains and losses of the economy due to decarbonization. Here, we develop a methodology to map a macro-network of financial exposures among the institutional sectors (e.g. non-financial corporations, investment funds, banks, insurance and pension funds, other financial institutions, governments and households) and estimate direct and indirect exposures to climate policy risks. The macro-network of financial interdependencies can be regarded as a multiplex weighted network in which multiple types of links correspond to different financial instruments: equity holdings (ownership shares), corporate and sovereign bonds (tradable debt obligations) and loans (non-tradable debt obligations). Using this network and taking into account assets and liability risks, we estimate the exposures of the institutional sectors to climate-policy risks, building on previously developed climate-stress approach<sup>1</sup> and identify institutional sectors that are the most (other financial institutions, government and investment funds, insurance and pension funds) and the least (banks) exposed to climate policy risks. We also uncover institutional sectors with most bargaining

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<sup>1</sup>Battiston, S., Mandel, A., Monasterolo, I., Schuetze, F., Visentin, G., A Climate Stress-Test of the Financial System, *Nature Climate Change*, 7, 283-288, 2017, doi:10.1038/nclimate3255

power on the climate policies and provide for them a data-based evidence for supporting the decarbonization the economy.

## 2 Introduction

Nowadays, there is a growing concern about the impact of the climate change of macro-economic and financial stability (Carney, 2015). Climate change financial risks can be decomposed into two major categories: physical risks (e.g. caused by extreme wether events resulting in damages of the infrastructure) and policy risks (risks resulting from the climate policy regulations, e.g. imposing carbon tax or Emission Trading System (ETS), which leads to re-evaluation of the financial assets of the market players). While physical risks of climate change are hardly avoidable, climate policy risks can be evaluated and diminished if recognised early enough.

On the necessary and unavoidable way to decarbonization of the economy, more and more financial institutions become concerned with potentially relevant risks of this transition. In particular, many development banks started to introduce climate risk assessment of their projects' portfolio. The reason to this is the size of the climate finance - financial resources allocated to support green-growth technologies. Such, in 2014, 292 USD bn was invested in low-carbon and climate-resilient growth, and these numbers are growing. For the comparison, the size of climate finance is comparable with GDP of the United Arab Emirates in 2014. However, it is important to highlight, that shocks imposed on the financial system due to climate policy risks are not necessarily negative, they can also be positive and could boost the economy. Therefore, financial institutions are interested in finding their best portfolio of the assets allocation in the transition to a low-carbon economy. However, despite the growing interest in the affect of the climate change on the financial system and economy, there is a lack of methodological framework which would allow to estimate the costs of transition to a low-carbon economy (Bloomberg's FSB task force, 2degrees investing, G20 enquire). Existing literature is mostly focused on stranded assets (financial assets that can not me used in the future if satisfying the climate regulations) from fossil fuels and unburnable carbon (IADB, Carbon Tracker Initiative, Oxford's stranded assets initiative). In addition, applying financial risk evaluation methods is misleading (e.g. Value at Risk for global financial assets, Dietz et al 2016) and there is a lack of proper statistical information and coverage. However, recently, a novel methodology of the climate stress-test has been proposed by (Battiston et al., 2016a) which allows to estimate the climate policy risks on several levels starting from individual firm, household or bank and finishing with the whole economy. In this manuscript, building on this novel methodology, we address three following main questions. How much would decarbonization cost to the Euro Area economy? Who is against climate policy? And how to convince them to change their minds?

This manuscript is organised as follows. First, we perform a review of the available

data sets and conduct a data sets consolidation from a number of sources including the Bureau Van Dijk Orbis database and ECB Data Warehouse. Second, we describe the methodology of the macro-network reconstruction from the recently available and consolidated in the first step data sources. Third, we provide a monetary estimates for the mutual interdependencies between the financial sector of the Euro Area and the real economy through the main financial instruments: equity holdings, bonds (tradable debt obligations) and loans (non-tradable debt obligations). Finally, we discuss the obtained results.

### 3 Data

Data on financial exposures at the sectoral level have been obtained from the ECB Data Warehouse <sup>2</sup>. Equity holdings exposures are presented as listed shares and investment fund-shares. Unfortunately, the data on unlisted equity shares exposures, which correspond up to 64% of the equity holdings in the Euro Area is not available, therefore, we assume similar allocation for the unlisted equity shares as for listed equity shares. Bond holdings data are presented as short-term bonds (with maturity less than a year) and long-term bonds (with maturity more than a year). For the loans exposures, we combine the data on short-term loans, long-term loans and deposits.

Despite the fact that ECB Data Warehouse provides the data on mutual exposures between the institutional sectors of the Euro Area, it only allows to identify the mutual exposures within the Euro Area and the amount of equity, bonds and loans connecting the Euro Area institutional sectors with the rest of the world. However, the information about institutional allocation of the exposures of the rest of the world is not identified. In order to fill this gap in the reconstruction of the financial exposure allocation outside of the Euro Area, in our work we used micro-level firm data.

While there is a lack of available bonds and loans data sets at the micro-firm level, we were able to obtain the data on equity holding through the Bureau Van Dijk Orbis database. We collected a sample covering all Euro Area shareholders with a global portfolio of listed companies for the last available year - 2014. As a result of a search we found all active companies worldwide with operating revenue more than 1000 thousand USD and with at least one shareholder in EA with shares from 0.01% to 100%, characterized by 4 digit NACE codes. Characteristics of companies in the search include: operating revenue, direct percentage of share, or total percentage share (when direct was not available, total was used<sup>3</sup>). The result of the search described above is 687 840 companies. For the mapping of the 4-digit NACE code into climate-relevant sectors we used classification pro-

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<sup>2</sup><http://sdw.ecb.europa.eu/>

<sup>3</sup>It is not always possible to determine the direct share of a shareholder. In order to overcome this obstacle we used information on the total share provided by the Bureau Van Dijk Orbis database.

posed in Battiston et al. (2016a)<sup>4</sup>. For allocation off bonds and loans to climate-relevant sectors we assumed similar breakdown as for equity shares for each institutional sector. In our study, we use classification of the institutional sectors of the Euro Area provided by the European Central Bank (see Appendix).

## 4 Methods

Similar to Battiston et al. (2016a), we estimate the direct and indirect exposures among the financial actors of the Euro Area. The direct exposures are estimated as

$$A_i = \left( \sum_{j \in \mathcal{S}} \alpha_{ij}^{\text{Equity}} + \alpha_{ij}^{\text{Bond}} + \alpha_{ij}^{\text{Loan}} \right) + R_i \quad (1)$$

where  $\alpha_{ij}$  denotes the monetary values of the exposures of  $i$  in the securities associated with economic actors  $j$  for the different types of instruments, and  $R_i$  – is a residual accounting for the exposure to other sectors and instruments not considered in our analysis.

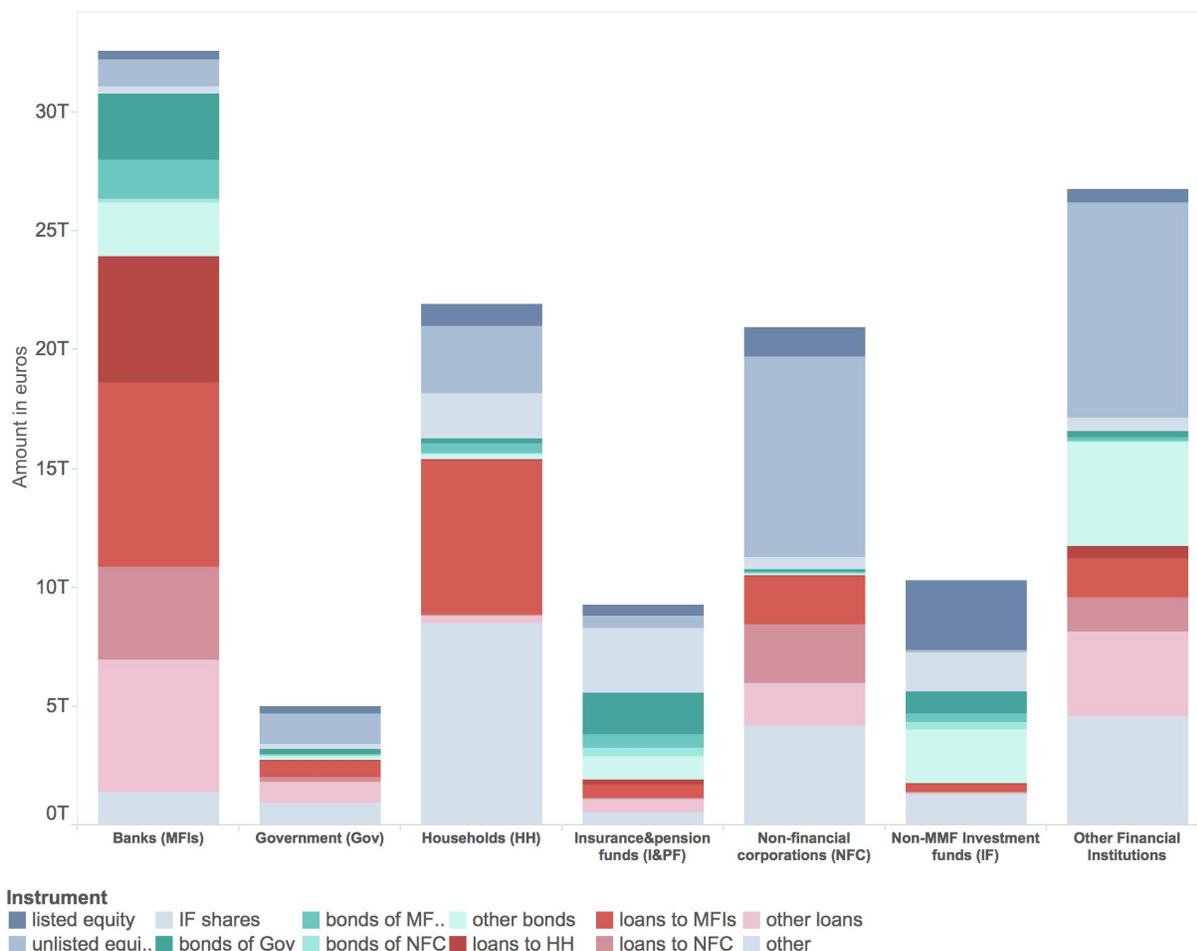
Due to the fact, that financial institutions has a lot of financial contracts with other financial institutions, in order to compute the full exposure of a portfolio of a financial institution to climate-relevant sectors, one needs to take into account the financial interdependencies among the institutional sectors. This indirect exposures also play an important role in case of propagation of the financial distress as a result of positive or negative shocks. Following Battiston et al. (2016a), the indirect exposure of a chosen institutional actor to the real economy sector, financial or any other sector, along chains of financial actors is calculates as a product of the face value of the exposures along the chain,  $\alpha_{ij}^0 \alpha_{jk}^0$ . This result can be generalized to longer chains, however here we focus only on chains of length two.

## 5 Results

In order to analyse the exposure of the institutional sectors of the Euro Area to climate-relevant sectors and, as a result, to climate policy risks, we first look at the asset side of institutional sectors and distinguish their assets by instruments. The exposures of each financial actor can be decomposed along the main types of financial instruments: equity holdings (e.g. ownership shares including both those tradable on the stock market and those non-tradable), bond holdings (e.g. tradable debt securities) and loans (e.g. non-tradable debt securities). Figure 1 shows the breakdown of asset side of financial actors of the Euro Area<sup>5</sup>.

<sup>4</sup>See in particular the supplementary information section in Battiston et al. (2017)

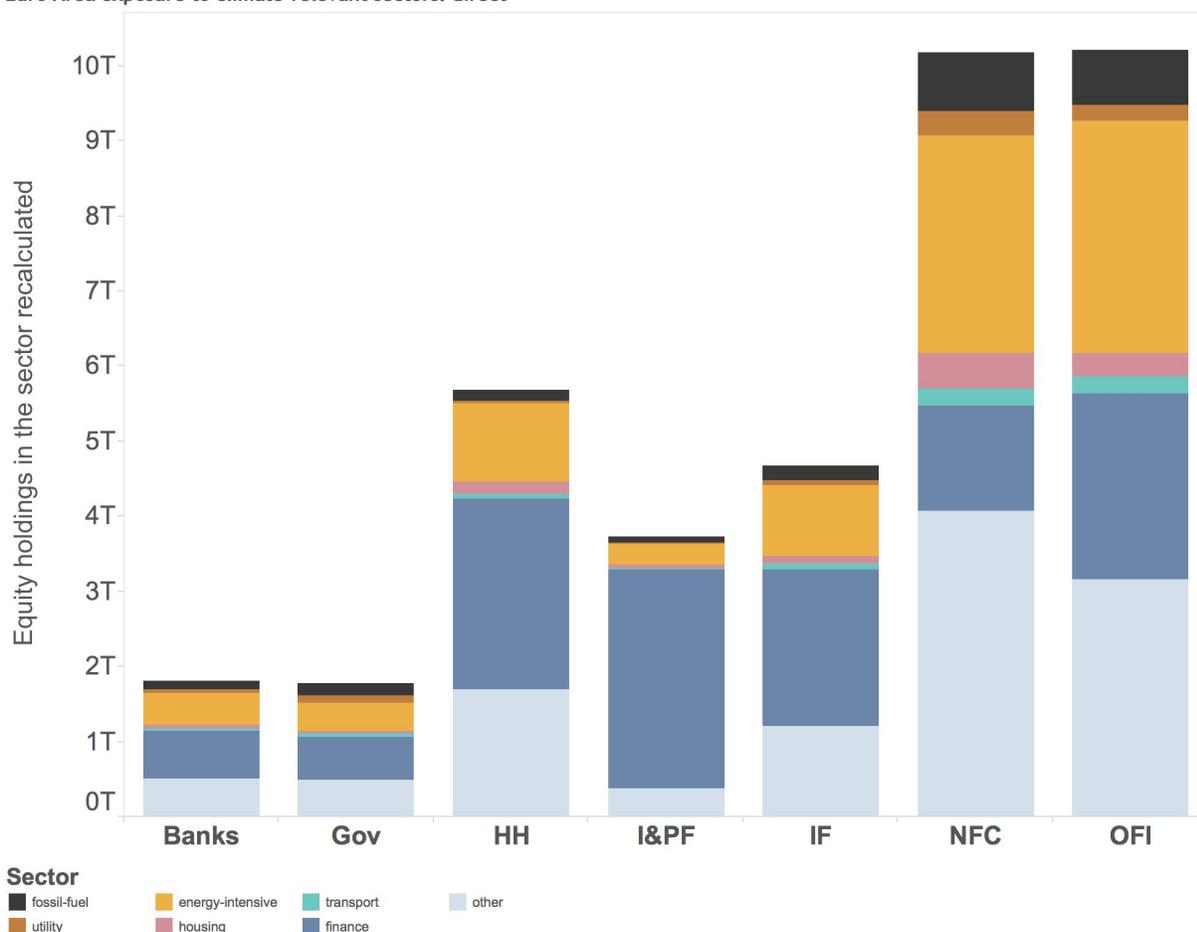
<sup>5</sup>Data are taken from ECB data Warehouse: <http://sdw.ecb.europa.eu/reports.do?node=100002344>



**Figure 1:** Breakdown of assets of the balance sheet of Euro Area institutional sectors (Non-financial Corporations, Monetary Financial Institutions, Governments, Households, Non-MMF Investment funds, Insurance and pension funds, Other financial Institutions) by market type (equity shares (black), short-term and long-term bonds (green), loans and deposits (red) and all remaining assets (significant part of which is derivatives)). Important to note a) the big portion of the loans and deposits of the MFIs in the Euro Area, most of which in interbank lending, b) small amount of loans of the non-MMF Investment funds.

It is important to note that banks represent the biggest institutional sector with the total assets of \$31T. Together with insurance and pension funds (\$9.3), non-MMF investment funds (\$10.3T) and other financial institutions (\$26.8T) they comprise the financial sector of the Euro Area with \$46.4T of total assets, while the real economy sector includes non-financial corporations (\$21T), government (\$5T) and households (\$22T) with total assets of \$48T euros.

**Euro Area exposure to climate-relevant sectors: direct**



**Figure 2:** Equity shares of Euro Area institutional sectors (Non-financial Corporations, Monetary Financial Institutions, Governments, Households, Non-MMF Investment funds, Insurance and pension funds, Other financial Institutions) worldwide.

From an analysis of figure 1, the following findings emerge:

1. The major direct exposures of financial actors to the real economy are concentrated on loans and bonds for banks, while they are concentrated on equity holdings for investment funds, pension funds, and other financial institutions (figure 1).
2. A large portion of assets held by financial institutions are in fact securities issued by other financial institutions (figures 1). For instance, about 40% of banks' balance sheet in the Euro Area and about 25% of the market capitalization is invested in equity issued by companies in the financial sectors; about 40% of the bonds market is represented by outstanding obligations issued by financial institutions.
3. The banking sector is by far the largest in terms of total assets (31 trillions) sector,

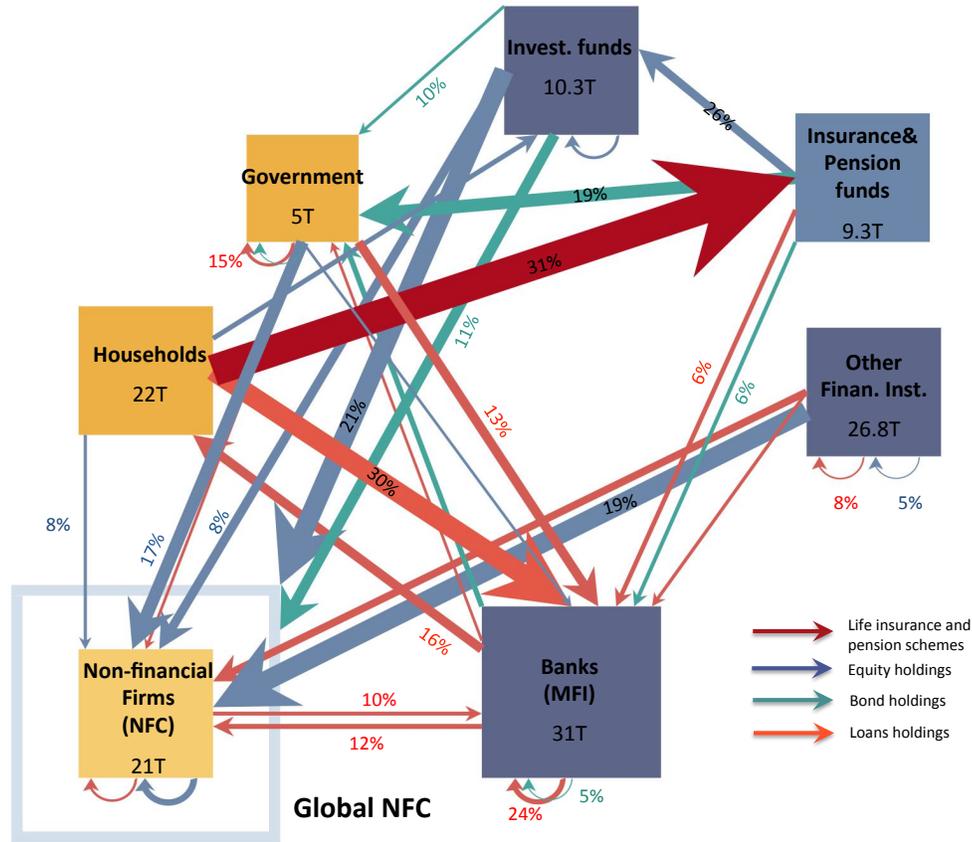
around 24% of its assets are interbank lending, meaning that a large fraction of financial resources is not channeled to the real sectors .

Using the micro-level firm data (see Methods), we first reconstructed the direct exposure of the Euro Area institutional sectors to climate-sensitive sectors of the economy through for one of the layers of exposure – equity shares. The results are presented on the figure 2. We find that for banks, government, households, insurance&pension funds, and investment funds, the exposure to the fossil-fuel sector through equity shares is very small (1%-3%), however, the overall exposure to climate-sensitive sectors (including finance sector) exceeds 60% of the total equity holdings of these institutional sectors. The largest exposure (around 10% of the total equity shares holdings) to fossil-fuel sector through equity shares is found for the non-financial corporations and other financial institutions. Important to note also a large portion of intra-financial exposure within the financial sector of the Euro Area, which should be taken into account while assessing climate policy risks and gains. We also carried out a similar analysis for the breakdown of exposure to climate-sensitive sectors for both bonds and loans. Combined, these exposures gives us a first estimate of a direct exposure of the Euro Area institutional sectors to climate-sensitive sectors of the economy, which could be affected either positively or negatively as a result of climate policies.

However, it is important to highlight that institutional sectors in the Euro Area are also connected through a network of financial contracts, e.g. equity shares, bond holdings, and loans holdings. Introduction of climate policies can be regarded as a positive or negative shock to the non-financial corporations. As a result, assets of institutional sectors exposed to non-financial corporations will have to be re-evaluated. This re-evaluation in turn, could lead to distress of certain institutional sectors, which will affect their ability to pay out their liabilities, and this fact would have to be reflected in the balance sheet of other institutional sectors holding their assets (so-called "second-round effects"). Therefore, to avoid underestimation of potential risks or gains coming from the introduction of climate policies, it is crucial to compute an indirect exposure to climate-sensitive sectors, taking into account the exposures of the institutional sectors to each other.

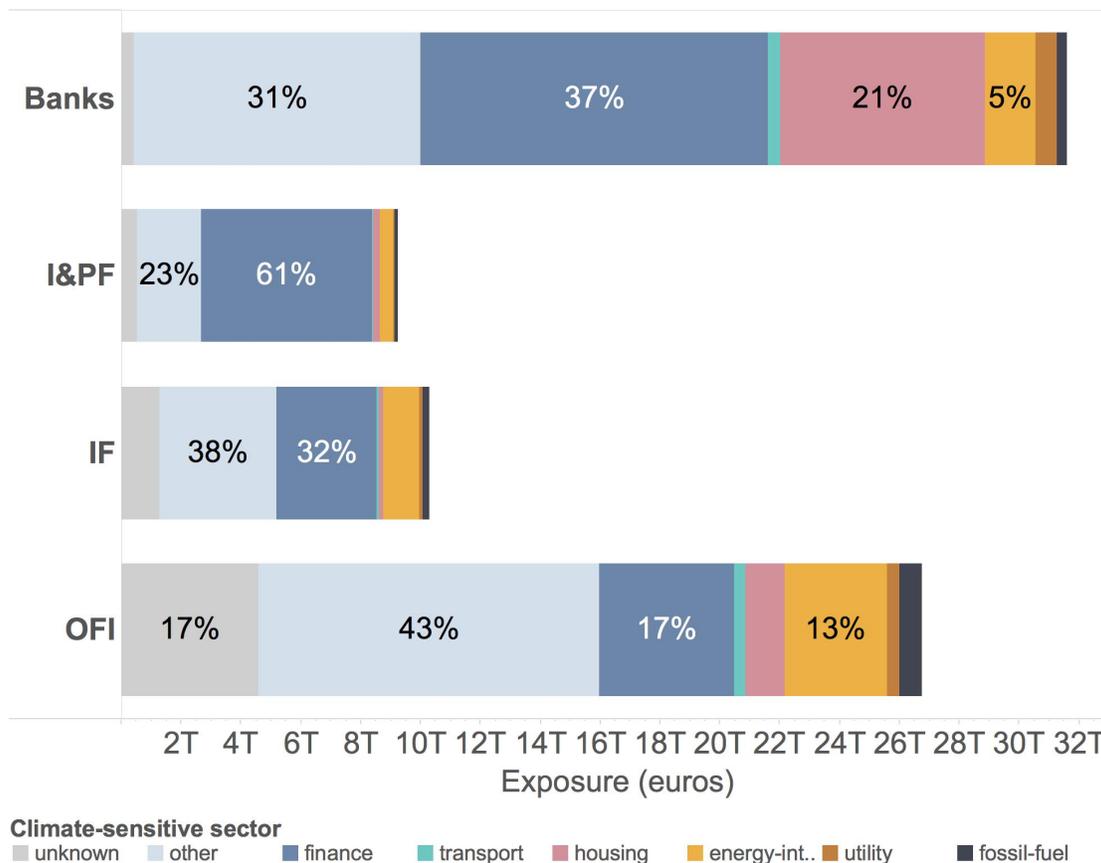
We perform this estimation of indirect exposure by first reconstructing the interdependencies among the institutional sectors of the Euro Area using data on mutual financial interdependencies provided by ECB. The results are shown on figure 3. The most important dependencies are exposure of the households to insurance&pension funds through the life insurance and pension schemes (33%), a large exposure of households to banks (30%), exposure of the insurance&pension funds to government of the Euro Area through bond holdings. There are also large indirect exposures of financial actors to the real economy. Remarkably, pension funds hold an exposure of about 30% of their total assets in equity shares of investment funds, which in turn hold an exposure of about another 27% in equity to non-financial corporation outside of the Euro Area.

Finally, taking into account both direct exposures of the institutional sectors to climate-sensitive sectors and their exposures to each other, we estimate the indirect exposure of



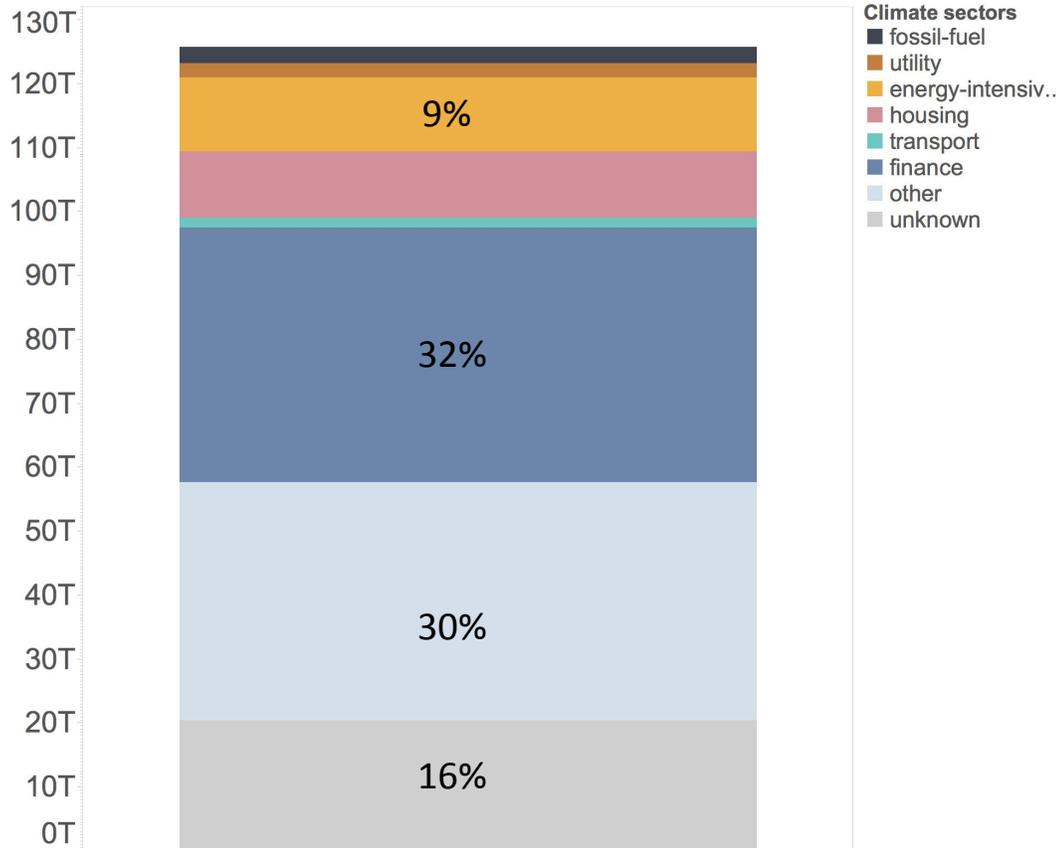
**Figure 3:** Macro-network of financial interdependencies among actors in the Euro Area (e.g. non-financial corporations, investment funds, banks, insurance and pension funds, governments and households) across instrument type (loans(light red), equity (blue), bonds (green), insurance guarantees (dark red) and other instruments (light blue)). This macro-network can be regarded as a multiplex weighted network in which multiple types of links correspond to different financial instruments: equity holdings (ownership shares), corporate and sovereign bonds (tradable debt obligations) and loans (non-tradable debt obligations). The weight of the link represents the amount of financial exposure of a "Source" institutional sector to a "Target" institutional sector in euros. The links are normalized by total assets of the source.

the Euro Area institutional sectors and the whole Euro Area economy to climate-sensitive sectors (see figures 4 and 5). We find that exposure of all institutional sectors to climate-sensitive sectors, excluding finance, is relatively small (between 10%-20% of their balance sheet), therefore, they should not oppose the transition to a low-carbon economy. However, all institutional sectors have a large exposure to finance (the largest single sector exposure for each institutional sector), which highlights the importance of intra-financial



**Figure 4:** Direct exposure of the Euro Area financial sector (banks, investment funds, insurance&pension funds, other financial Institutions) to climate-sensitive sectors worldwide.

dependencies for the estimation of costs and gains of the Euro Area on the way to decarbonization of the economy. Our analysis also shows that for banks the second largest exposure is mortgages, for insurance&pension funds - government bonds, for investment funds and other financial institutions - non-climate-sensitive sectors. Finally, the overall exposure of the Euro Area economy to climate sensitive sectors: 1% to the fossil fuel sector (negatively affected by climate policies), 9% to energy-intensive sector (more likely negatively affected by climate policies, unless it goes through the restructuring), 32% to finance sector (could be affected both positively and negatively, depending on the portfolio).



**Figure 5:** Total direct exposure of the Euro Area to climate-sensitive sectors worldwide.

## 6 Conclusions

Our findings contribute to addressing the problem of estimation of the financial interdependencies between the real economy and the financial sector in the Euro Area. By combining the balance sheet data, data on mutual exposures and mirco-data on the firm level, we provide estimates of the exposures of the institutional sectors among each other in relation to their total assets. We also estimate the monetary value of exposure of the Euro Area financial sector (banks, investment funds, insurance&pension funds) and real sector (households, government and non-financial firms) to climate-relevant sectors. From our analysis, the following findings emerge:

1. The major direct exposures of financial actors to the real economy are concentrated on equity holdings for investment funds, pension funds, and other financial institutions, while they are concentrated in loans and bonds for banks (holdings of government debt).

2. There are large indirect exposures of financial actors to the real economy. Remarkably, pension funds hold an exposure of about 30% of their total assets in equity shares of investment funds, which in turn hold an exposure of about another 27% in equity of non-financial corporation in the Euro Area and the US. Pension funds also hold another exposure of 12% of their total assets in bonds and loans to banks, which in turn hold an exposure of about 12% (of their total assets) to the real economy. In contrast, the direct exposure of pension funds to non-financial corporations of the Euro Area is only about 8% . These findings imply that adverse shocks on the real economy and increased volatility in asset values of the real economy could affect large portions of pension funds assets but this would occur more through indirect exposures than through direct exposures.
3. Banks are very lightly directly exposed to climate-sensitive sectors (<1% - on fossil-fuel sector, 8% of total assets – to all climate-sensitive sectors of the economy), and, as a result, to climate policy risks. Thus, they should not be against climate policies and should be in favour of the rapid transition to decarbonization. On the other hand, insurance&pension funds bear a large exposure to climate relevant sectors (more than 22% of their equity or 14% of their total assets) through direct and indirect exposures. Therefore, they should take measures to ensure the safe transition to a low carbon economy. Estimated direct exposure of the Euro Area economy to fossil-fuel is about 1.5%, and to all climate-sensitive sectors is about 50% of the total assets of the Euro Area. In addition, 16% of the total assets of the Euro Area can not be classified as "other" or "climate-sensitive" sectors, as this information is unknown. This fact highlights the need of public disclosure of information on the climate-sensitive economic activity, which would allow to better estimate risks and gains of the Euro Area on the way to decarbonization of the economy.

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# Appendix

## 7 Major actors

In our study, we use classification of the institutional sectors of the Euro Area provided by the ECB <sup>6</sup>. This classification results in seven institutional sectors <sup>7</sup> that can be defined as follows:

1. *Non-Financial Corporations (NFC)* – corporations or quasi-corporations that are not engaged in financial intermediation but are active primarily in the production of market goods and non-financial services.
2. *Banks or Monetary Financial Institutions (MFI)* – financial institutions which together form the money-issuing sector of the Euro Area. These include the Euro system, resident credit institutions (as defined in EU law) and all other resident financial institutions whose business is to receive deposits and/or close substitutes for deposits from entities other than MFIs and, for their own account (at least in economic terms), to grant credit and/or invest in securities. The latter group consists predominantly of money market funds (MMFs).
3. *Non-MMF Investment Funds (IF)*. An investment fund is a supply of capital belonging to numerous investors that is used to collectively purchase securities while each investor retains ownership and control of his or her own shares. An investment fund provides a broader selection of investment opportunities, greater management expertise and lower investment fees than investors might be able to obtain on their own. According to European Central Bank Data Warehouse, IFs can be classified into bond funds, equity funds, mixed funds, real estate funds, hedge funds, and other funds.
4. *Other Financial Institutions (OFI)*. An OFI is a corporation or quasi-corporation other than an insurance corporation and pension fund that is engaged mainly in financial intermediation by incurring liabilities in forms other than currency, deposits and/or close substitutes for deposits from institutional entities other than MFIs, in particular those engaged primarily in long-term financing, such as corporations engaged in financial leasing, financial vehicle corporations created to be holders of securitized assets, financial holding corporations, dealers in securities and derivatives (when dealing for their own account), venture capital corporations and development capital companies.

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<sup>6</sup><http://sdw.ecb.europa.eu/>

<sup>7</sup>ESA 2010

5. *Insurance Corporations and Pension Funds (I&PF)*. According to the ESA 2010, the insurance corporations subsector consists of all financial corporations and quasi-corporations which are principally engaged in financial intermediation as a consequence of the pooling of risks mainly in the form of direct insurance or reinsurance; the pension funds subsector consists of all financial corporations and quasi-corporations which are principally engaged in financial intermediation as a consequence of the pooling of social risks and needs of the insured persons (social insurance). Pension funds as social insurance schemes provide income in retirement, and often benefits for death and disability.
6. *General Governments (Gov)* – are defined as comprising resident entities that are engaged primarily in the production of non-market goods and services intended for individual and collective consumption and/or in the redistribution of national income and wealth. Included are central, regional and local government authorities as well as social security funds. Excluded are government-owned entities that conduct commercial operations, such as public enterprises. Central governments include all administrative departments of the (central) state and other central agencies whose competence extends over the entire economic territory, except for the administration of social security funds. State governments comprise separate institutional units exercising some of the functions of government (excluding the administration of social security funds) at a level below that of the central government and above that of local government.
7. *Households (HH)* consists of one or more people who live in the same dwelling and also share meals or living accommodation, and may consist of a single family or some other grouping of people. A single dwelling will be considered to contain multiple households if either meals or living space are not shared.