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Title of Submission: The 'three trillion dollar financial exposure to Stranded Fossil Fuel Assets' – Risks and Opportunities

I am a candidate for the degree:

MPhil in Environmental Policy

Bio-sketch (Approximately 150 words)

Moritz Baer is a candidate for the Master of Philosophy in Environmental Policy at the University of Cambridge. He is currently involved in the project FRANTIC 'Financial Risk and the Impact of Climate Change' in cooperation with CISL and C-EENRG in Cambridge.
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Number of words of submission: 3965 words

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The 'three trillion dollar financial exposure to Stranded Fossil Fuel Assets' – Risks and Opportunities

Moritz Ted Baer
MPhil Environmental Policy
University of Cambridge

The urgent need for mitigating climate change, as set out in the Paris Agreement and the IPCC report[1] is calling for a substantial reallocation of capital away from the fossil industry in order to achieve a transition towards a low-carbon economy. This transition is likely to entail significant risks for the financial system and the real economy. This essay aims at: i) investigating a specific type of such risk - the risk stemming from Stranded Fossil Fuel Assets (SFFA) – and ii) deriving relevant risk-mitigating implications for the private sector and regulators.

*[**Key findings**. The direct SFFA exposure for Financial Institutions is significant, resulting in 3.74 trillion US$ value-at-risk, representing more than 4% of global GDP. Given the interconnectedness of the financial system, the financial loss from SFFA is likely to be amplified by a factor of two, due to indirect exposure, posing a systemic risk to the stability of the financial system. From a private market perspective, individual organisations should incorporate the 'combinatorial sequence' framework proposed in this essay to assess and manage the risk stemming from SFFA. Among fostering transparency and climate-related disclosure, individual financial institutions should see the SFFA exposure equally as risk and opportunity. From a regulator perspective, the composition of the SFFA exposure and the specific Risk-Levels proposed in this essay should be taken into consideration when designing financial policies and climate-related regulation for the respective jurisdiction.]*

In a comprehensive conceptual and empirical financial analysis, I address the following issues: What are Stranded Fossil Fuel Assets? How high is the global financial exposure to SFFA? To what extent are individual financial institutions and country jurisdictions affected by such climate-related risks? How can we use this analytical understanding to manage these risks and build a climate-resilient financial system?

Answering these questions by supporting it with concrete empirical findings from my own exposure analysis serves as the structure for this essay. On a more abstract level, I aim to illustrate and put forward an analytical framework that can be used by: i) private market actors (financial institutions and consulting firms) to assess individual climate-related risk exposures and manage the risks that arise from SFFA; and ii) regulators (central banks and financial regulators) to manage and mitigate risks on a systemic level across jurisdictions.

What are Stranded Fossil Fuel Assets? As illustrated in Figure 1, the financial system is directly exposed to a shock from climate-related transition risk to the fossil fuel industry, leaving a significant share of the fossil fuel reserves 'stranded'.[2] In other words, stringent climate policies such as a carbon tax have the potential to e.g. reduce global oil demand, such that fossil fuel reserves and the associated extraction infrastructure, would prior to the end of their economic life, no longer be able to earn an economic return. If this transition risk is not accurately priced in in the financial agents' risk model or if there is a systematic misalignment of expectations about the underlying nature of the socio-economic transition, this results in an overvaluation of the fossil fuel firms on the financial markets. These misaligned expectations pose a threat to the macroeconomic performance of the real economy[3] and the stability of the

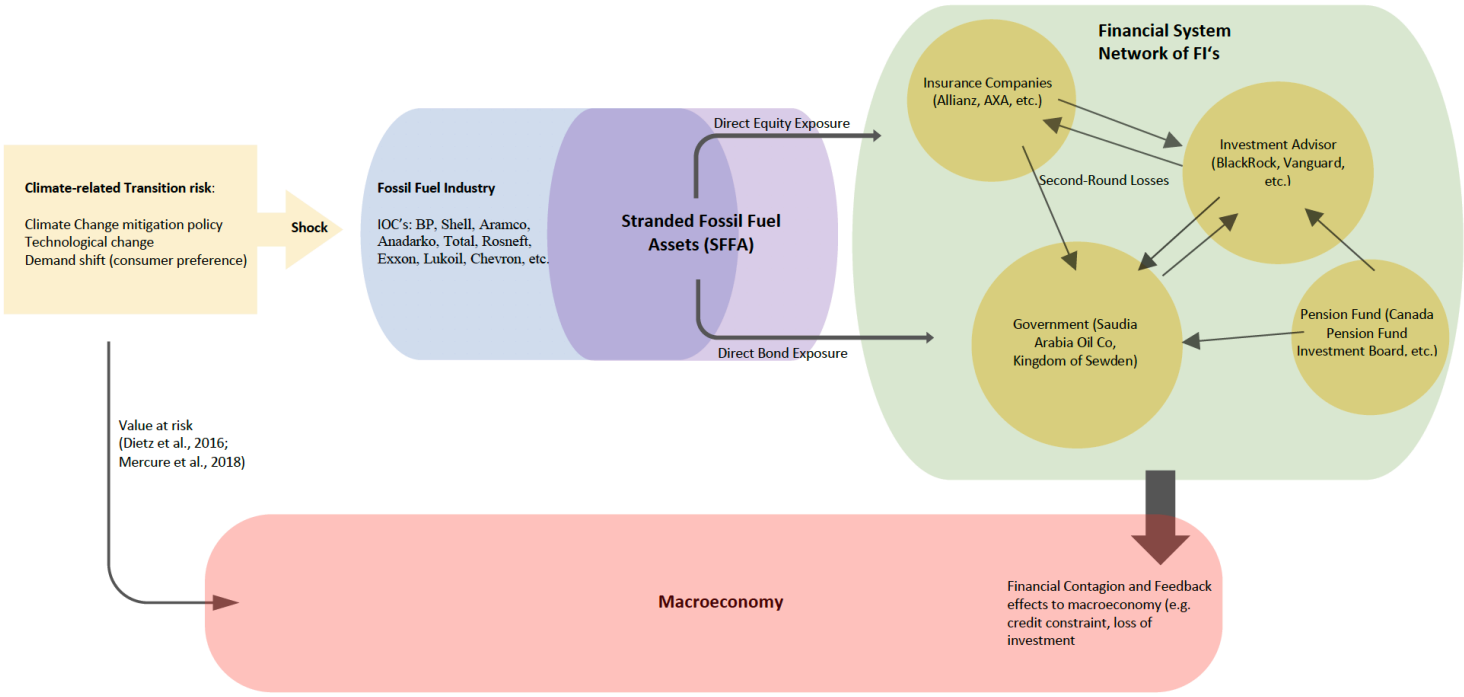
[1] IPCC, "Global Warming of 1.5°C" (Intergovernmental Panel on Climate Change, 2018).

[2] Christophe McGlade and Paul Ekins, "The Geographical Distribution of Fossil Fuels Unused When Limiting Global Warming to 2 °C," *Nature* 517, no. 7533 (January 2015): 187–90, https://doi.org/10.1038/nature14016.

[3] J.-F. Mercure et al., "Macroeconomic Impact of Stranded Fossil Fuel Assets," *Nature Climate Change* 8, no. 7 (July 2018): 588–93, https://doi.org/10.1038/s41558-018-0182-1.

financial system[4], which in turn highlights the relevance of a comprehensive understanding of such risks as evident in this essay.

Figure 1.



How high is the global financial exposure to SFFA? Employing a newly created dataset on the bond and equity exposure of 6.510 international financial institutions to the largest 25 fossil fuel firms[5] allows me to quantitatively analyse the i) aggregated financial exposure to SFFA, ii) the firm-, sector- and country-level exposure and iii) the resulting financial losses based on the value-at-risk. My analysis suggests a direct exposure of 3.74 trillion US$ from Financial Institutions (FI's) to Stranded Fossil Fuel Assets, representing more than 4% of global GDP.[6] Globally, the aggregated bond exposure amounts to 162.6 Billion US$ with an SFFA exposure of 61 Billion US$ for the global insurance sector alone. Within the insurance sector, the bond exposure accounts for a significant share of 43.79% of the overall SFFA exposure, highlighting the need to incorporate the indispensable bond-channel in systemic climate-stress testing efforts by financial regulators such as the European Insurance and Occupational Pensions Authority (EIOPA).[7] Further, the insurance sector is also increasingly

[4] Mark Carney, "Breaking the Tragedy of the Horizon – Climate Change and Financial Stability," Speech given at Lloyd's of London by the Governor of the Bank of England (London: Bank of England, September 29, 2015); ESRB, "Too Late, Too Sudden - Transition to a Low-Carbon Economy and Systemic Risk" (Frankfurt: European Systemic Risk Board, 2016); Finansinspektionen, "Climate Change and Financial Stability" (Stockholm: Finansinspektionen, 2016).

[5] The 25 fossil fuel firms are selected based on their market capitalization and are assumed to be representative of the oil and gas industry.

[6] Based on IMF data: https://www.imf.org/external/datamapper/datasets/WEO/1 (Accessed 15.02.2020). Estimates based on GDP for 2019 in current prices – 90.19 trillion international dollars, adjusted for purchasing power parity

[7] Scholars are increasingly aware of the relevance of incorporating the bond channel in climate-related risk assessments. See e.g. for sovereign bonds; Stefano Battiston et al., "Climate Risk Assesment of Sovereign Bond Portfolio of European Insurers," EIOPA - Financial Stability report, 2019, 21. or Veronika Stolbova, Irene Monasterolo, and Stefano Battiston, "A Financial Macro-Network Approach to Climate Policy Evaluation," *Ecological Economics* 149 (July 2018): 239–53, https://doi.org/10.1016/j.ecolecon.2018.03.013.

vulnerable to climate-related physical risk leading to increased financial damage from droughts and storms.
These results add to the previous work of leading scholars in the field, which extensively focused either solely on the equity exposure of FI's[8] or with a limited geographical scope.[9]

Private market perspective

To what extent are individual financial institutions affected by such climate-related risks? Focusing on individual FI's, the results show a significant exposure of the 'Vanguard Group' with 240 Billion US$, 'Black Rock' with 230 Billion US$ and 'Norges Bank' with 115 Billion US$. However, this absolute exposure does not necessarily indicate a high risk, as their relative exposure to the overall portfolio value is moderately low, 1.52% for Vanguard Group, 1.98% for Black Rock and 2.19% for Norges Bank, respectively. So, what determines the actual degree of risk that individual FI's are exposed to?
To conceptually determine the risk of actual materialized financial loss, I propose three relevant and interconnected factors. It should be noted, that this categorization serves as a simplified illustration and is by no means exhaustive, but rather serves as a starting point for specifically targeted empirical analysis.

First, reserve structures and extraction methods of the fossil fuel firm determine how effected these firms are to exogenous transition-related shocks from stringent climate policy, technological change or a demand change for fossil fuels *(Determinant A)*. In other words, this determines which fraction of the firm's assets are becoming stranded. To meet the targets set out in the Paris Agreement, 82% of global coal reserves, 49% of global gas reserves and 33% of global oil reserves cannot be extracted and burnt[10]. Put differently, out of the 2.910 gigatonnes (GT) of CO_2 locked away in fossil fuel assets, only 464GT are allowed to be released to stay within the global carbon budget. Moreover, stringent climate policies in the form of carbon taxes significantly decrease the demand for fossil fuels in the near future. This would result in the 'stranding' of the global fossil fuel reserves and the associated extraction infrastructure that would prior to the end of their economic life, no longer be able to earn an economic return.[11] In my data, the fossil fuel firm 'Anadarko Petroleum' is highly sensitive to a policy induced demand reduce (e.g. through a carbon tax), as the firm operates mostly with relatively expensive shale oil, leading to relatively high costs due to unprofitable extraction methods compared to conventional oil extraction.

Second, the capital structure of the fossil fuel firm determines the vulnerability to changes in: i) the valuation of assets, and ii) the refinancing conditions on capital markets, as a worsened creditworthiness will raise the cost of capital for fossil fuel firms. This could cause further pressure on these firms from the financial markets *(Determinant B)*. In other words, this determines how likely these firms get into financial distress. This is especially problematic for highly debt financed fossil fuel firms that rely on refinancing on the capital markets such as for Anadarko with 44.8 % out of 13.67 Billion US$ of their debt held by FI's through bonds,

[8] Stefano Battiston et al., "A Climate Stress-Test of the Financial System," *Nature Climate Change* 7, no. 4 (April 2017): 283–88, https://doi.org/10.1038/nclimate3255.
[9] Robert Vermeulen et al., "The Heat Is on: A Framework for Measuring Financial Stress Under Disruptive Energy Transition Scenarios," *SSRN Electronic Journal*, 2019, https://doi.org/10.2139/ssrn.3346466.
[10] McGlade and Ekins, "The Geographical Distribution of Fossil Fuels Unused When Limiting Global Warming to 2 °C."
[11] IEA, "World Energy Outlook 2019," 2019.

Apache Corp with 59.12 % of 8.22 Billion US$ and ConocoPhillips with 52.42 % of 13.68 Billion US$ respectively.

Third, the exposure composition of the Financial Institution holding equity and bonds to the fossil fuel firm and to other financial institutions *(Determinant C).* This third factor explains how FI's such as Black Rock and the Norges Bank, even with a significant absolute exposure, are relatively less effected by the SFFA risk. As their SFFA exposure only accounts for around 2% of their overall equity portfolio, these FI's are highly diversified and are likely capable of absorbing transition shocks that lead to the devaluation of SFFA asset without sliding into financial distress.

So, which financial institutions are highly vulnerable to risks, stemming from SFFA? As conceptually showed above in the framework of three relevant determinants, the following specific ‚combinatorial sequence' of these factors leads to higher risk levels: The fossil fuel firm has a vulnerable reserve structure and extraction methods (A), combined with a high dependence on capital market debt refinancing (B), combined with a low portfolio diversification of the Financial Institution holding these assets (C). Empirically, I identify various FI's, for which Determinant C poses significant risks. Financial Institutions such as Caixa Bank SA with a relative SFFA equity exposure of 28.28% to their overall portfolio, Employees Retirement System of Alabama with 27.91%, Bank of Thailand with 12.79% and the United Nations Joint Staff Pension with 13.41% are at a high risk of substantive financial losses or sliding into financial distress. For illustration, consider the following case, where the risk stemming from climate-related Stranded Fossil Fuel Assets is particularly high. The Caixa Bank SA holds a significant share of their 28.28% SFFA exposure in equities and bonds of Anadarko Petroleum, Apache Corp and ConocoPhillips, which in turn are relatively more sensitive to transition risks due to a high dependence on refinancing on capital markets and relatively unprofitable extraction methods. Further, I identify this 'combinatorial sequence' as relevant in determining the weak links within a financial network.

Proposition 1: This framework of ‚combinatorial sequence' could be used by individual firms or consulting firms such as McKinsey to assess a FIs' direct exposure to SFFA. Further, such a financial analysis on the firm-level could be integrated into broader scenario analysis, that allow to model the impacts of transition risks in various climate-scenarios.

Proposition 2: To further advance the transparency around climate-related risks, financial institutions should, in line with recommendations from the Task Force on Climate-related Financial Disclosure and the European Sustainable Taxonomy, foster extensive disclosure of climate-related financial risk, to better assess the risk at hand. This should mitigate the market failure of short-termism of financial actors, which fail to incorporate the long-term effects of climate change, and hence are 'blind' to these climate-related risks.[12]

Proposition 3: If a significant exposure and risk for specific financial institutions is identified, this should be seen as a challenge and opportunity that demands an appropriate action to manage such climate-related risks through the incorporation into standard financial assessment methods. On the one hand, the lack of incorporating the risk of stranded assets in financial risk models or abrupt divesting from fossil fuel firms may result in a sharp fall in the asset valuation on the capital markets, leading to an increased risk of financial loss and

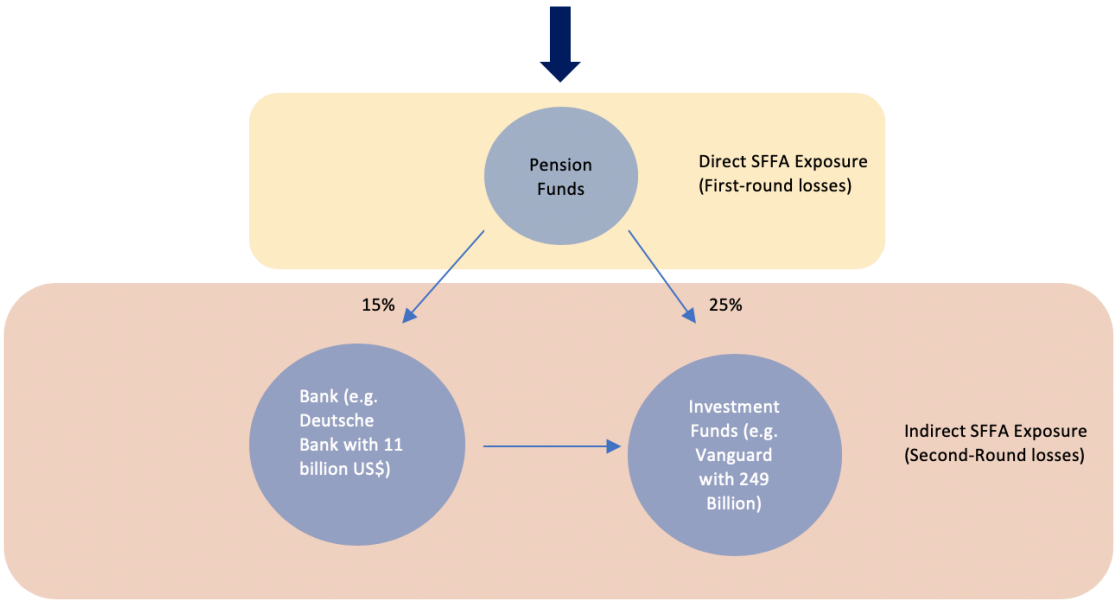
[12] Nicholas Silver, "Blindness to Risk: Why Institutional Investors Ignore the Risk of Stranded Assets," *Journal of Sustainable Finance & Investment* 7, no. 1 (January 2, 2017): 99–113.

contagion. On the other hand, holding a significant exposure to SFFA also translates into a substantial influence in the form of potential active shareholder engagement. This influence should be considered to actively encourage fossil fuel firms to incorporate transition risk in their operational business and scale up sustainable investment. This way, the fossil fuel industry can be realigned to the 1.5-degree transition scenario, resulting in a smooth adjustment of valuation of fossil fuel assets and a decreased risk of stranded assets.

Regulatory perspective

Moving to a systemic perspective, the question arises **to what extent country jurisdictions are exposed to climate-related risks?** To answer this question, a systemic approach has to be considered. As identified in the literature, in addition to the exorbitant direct exposure of Financial Institutions, the interconnectedness of the financial system results in a further indirect exposure to SFFA.[13] The financial actors' exposure to the financial sector itself via equity shares range from 13-25.8%.[14] Moreover, many FI's hold an additional exposure through

Figure 2.



bonds and loans to international banks and other FI's.[15] Combining these insights with my empirical data, the following exemplary illustration should be considered (Figure 2) - Pension funds hold a significant direct exposure to SFFA. Second, pension funds hold 25% of total assets in equity shares of investment funds, which in turn, in the UK, account for more than 65 billion US$ of the SFFA exposure. Third, pension funds also hold another 15% of total assets in bonds and loans to banks, which are in turn, in France, significantly exposed themselves to SFFA (about 50 Billion US$). These indirect exposures and the interconnectedness of the

[13] Vermeulen et al., "The Heat Is On"; Alan Roncoroni et al., "Interconnected Banks and Systemically Important Exposures," November 2019, 50; NGFS, "Macroeconomic and Financial Stability Implications of Climate Change - Technical Supplement to the First Comprehensive Report," July 2019.
[14] Battiston et al., "A Climate Stress-Test of the Financial System."
[15] About 40% of the bond market is comprised of outstanding obligations issued by financial institutions.

financial system have the potential to amplify the risk of SFFA by a factor of up to 'two'[16] – posing a systemic risk to the stability of the financial system. A potential contagion and amplification risk should therefore be considered by financial regulators, central banks and governments when managing the systemic risk stemming from SFFA.

To further show the vulnerability of country jurisdictions on this systemic level and to justify possible interventions based on financial policies and regulation, I translate the sector-specific exposure risk into illustrative 'Risk and Action Levels', based on quantile distribution estimates of the aggregated sector exposure relative to the respective peer-group sector in other countries.[17]

The following results can be derived. Compared to the SFFA Exposure of the global Banking sector, Banks in France and the United States are higher exposed than their direct peers in other countries. Interestingly, Norway is highly exposed through both Pension Funds and Sovereign Wealth funds, representing public money, with the direct exposure to SFFA amounting to more than 128.5% of Norway's GDP. Norway's SFFA exposure is mainly driven by the Kingdom of Norway Ministry of Petroleum & Energy with a 373 billion US$ exposure, Norges Bank with 112 billion and Folketrygdfondet (Pension Fund) with 18.5 billion US$.

Table 1.

	Bank	***Corporation***	***Government***	***Insurance Company***	***Investment Advisor***	***Pension Fund***	***Sovereign Wealth Fund***	***Exposure/GDP in % (2019, ppp)***
Brazil	**Low**	-	**Medium**	-	**Medium**	-	-	*1.5*
Canada	**High**	**Very Low**	**Very Low**	**High**	**Very High**	**Medium**	**Low**	*4.1*
China	-	**Medium**	**Medium**	**Very Low**	**Low**	-	-	*1.3*
France	**Very High**	**Medium**	-	**Medium**	**Lo**	-	-	*2.1*
Germany	**High**	-	-	**High**	**Very Low**	-	-	*0.8*
India	-	**High**	**High**	**Low**	**High**	**Low**	-	*7.7*
Japan	**Medium**	**Very Low**	-	**Low**	**Very Low**	-	**High**	*0.7*
Luxembourg	**Very Low**	-	-	-	**Medium**	-	-	*33.1*
Netherlands	**Low**	**Low**	-	**Medium**	**High**	**Very Low**	-	*4.8*
Norway	**Low**	**High**	**High**	**Medium**	**Low**	**Very High**	**Very High**	*128.5*
Russia	**Very Low**	**Very Low**	**Very High**	-	**High**	-	-	-
Saudi Arabia	**Very Low**	-	**Very High**	-	**Very Low**	-	-	-
Switzerland	**High**	**Low**	**Low**	**Very Low**	**Medium**	-	-	*10.1*
UK	**Medium**	**Very High**	**Very Low**	**Very High**	**Very High**	**Very Low**	-	*3.7*
United States	**Very High**	**Medium**	**Low**	**Very High**	**Very High**	**High**	**Medium**	*5.1*

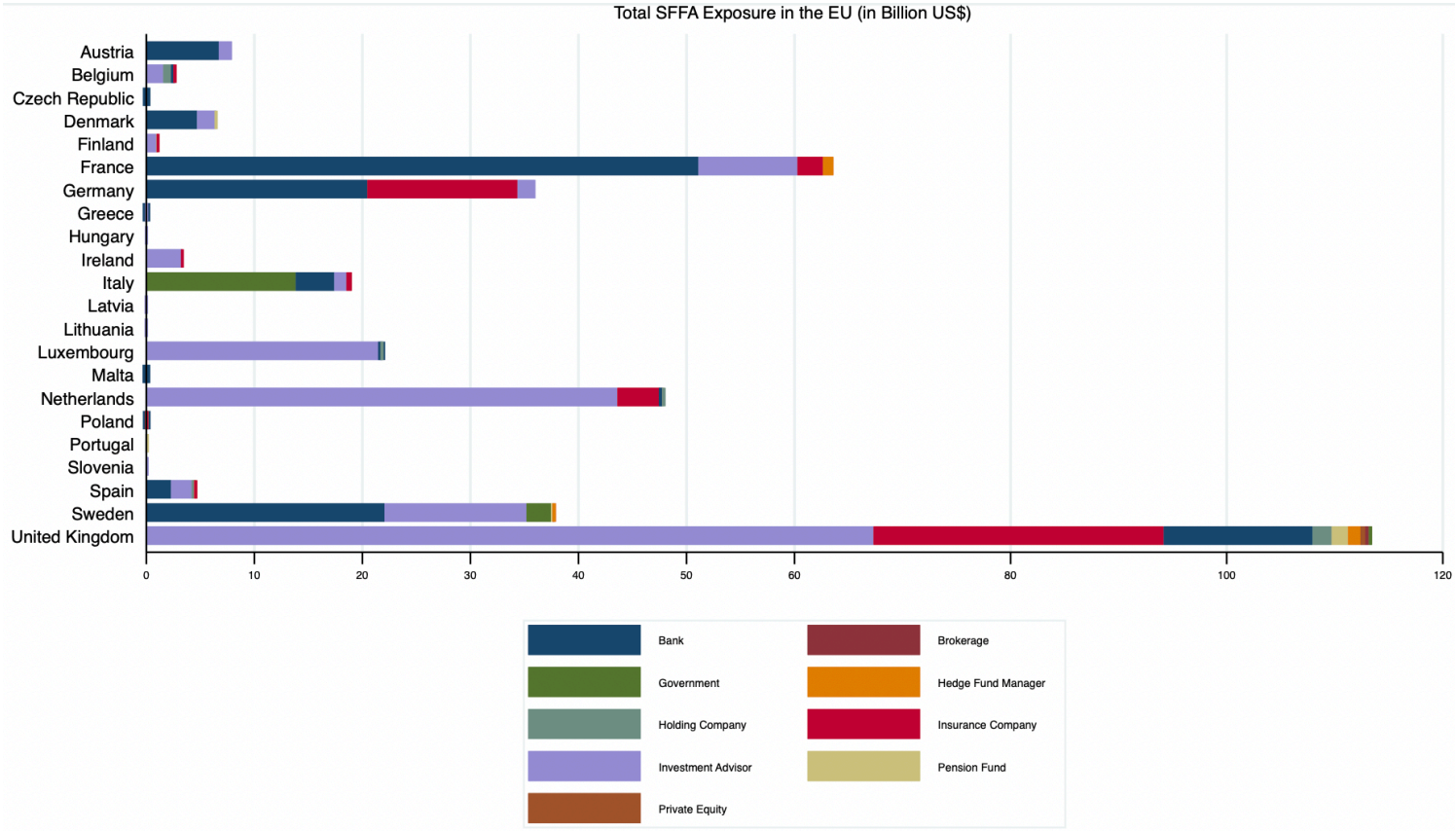
[16] Roncoroni et al., "Interconnected Banks and Systemically Important Exposures."

[17] The five risk levels are computed based on the quantile distribution of each national sector relative to the aggregated exposure of the respective global sector. Note: Additional weights should be applied to account for the fact that some countries have a relatively higher financial activity relative to the global peer sector, irrespective of the exposure level to the fossil fuel industry. This might, in some instances, bias the Risk Level. This bias can however be positive and negative, and it is assumed that the distribution of this error is on average uncorrelated to the SFFA exposure, hence will not affect the accuracy of the risk level.

Relative to their GDP, Canada with 4.1%, Luxembourg with 33.1%, the Netherlands with 4.8%, Switzerland with 10.1%, the UK with 3.7% and United States with 5.1% are relatively higher exposed than their peer countries. This exposure should give rise to concern for affected governments such as Norway. Further, the extent to which a country is at risk of financial loss from SFFA is depended on the degree of diversification among heterogenous actors. For example, the exposure of the UK is spread around 195 FI's, mainly driven by Schroders Plc with an overall exposure of 36.4 billion, HSBC with 11.9 billion and the Legal & General Group PLC with 9.81 Billion. The overall exposure of US FI's is most diversified spreading across 4184 institutions and hence diversifying the risk among many entities.

Focusing on the European Union, Figure 3 further shows the composition of the respective countries' SFFA exposure. In the EU, the SFFA exposure is mainly driven by highly exposed Banks, Insurance Companies and Investment Advisors. The highest exposure in Germany is found for Allianz SE with 13.8 Billion and Deutsche Bank with 11 billion US$. In Switzerland the exposure is mainly driven by UBS with 20.9 Billion, Pictet Funds SA with 13.9 Billion and Credit Suisse Group AG with 10.2 Billion. Given the systemic relevance of some of these banks in the international financial system by the Financial Stability Board, these exposure levels have the potential to be propagated through an indirect exposure and might pose a systemic risk, depending, among other factors, on the adequacy of current capital requirements.

Figure 3.



These estimates suggest, that sector-specific financial policy and regulations should be considered by governments, financial regulators and central banks to manage and reduce the risk of a disruptive adjustment propagating through the financial system and potentially

evaporating billions of US$ off the balance sheet of major FI's, causing financial distress and economic downturns to the already afflicted economy in the aftermath the COVID-19 crisis. More specifically, based on the above shown empirical evidence on the country- and sector-specific exposure, I propose the following interventions:

Proposition 1: The Risk-Levels put forward in this essay should serve as a starting point for further assessment of the sectorial composition of SFFA and national/supranational financial regulation. More specifically, I highlight the need for extensive climate-stress tests that account for the interconnectedness of the financial system and economic sectors across jurisdictions and incorporate the uncertainty and fat-tailed distributed risk of catastrophes into standard financial risk models

Proposition 2: Beyond technical functions to mitigate risk with 'neutral' market impact, central banks should consider applying differentiated reserve and capital requirements for commercial banks to induce credit allocation toward sustainable investments and sectors.[18] This could incentivise e.g. highly SFFA exposed European Banks to shift their assets and allocate credit towards more sustainable activities. This could prevent a potential credit-tightening as a result of financial distress when the exposure to Stranded Fossil Fuel Assets materialises.

Conclusion

This essay assessed the risks associated with the exposure of international financial institutions to Stranded Fossil Fuel Assets in a comprehensive conceptual and empirical analysis.

I presented two analytical frameworks that are helpful in understanding the impact of SFFA from i) a private market perspective, and ii) from a regulatory perspective.

The **'combinatorial sequence'** framework assess the extent to which private financial institutions are at risk of SFFA by weighting and linking i) reserve structure and extraction methods of the fossil fuel firm (determinant A), ii) dependency on capital market refinancing (Determinant B) and iii) degree of portfolio diversification of FI's (Determinant C).
From a regulator perspective, the composition of the SFFA exposure and the framework for the specific **Risk-Levels** proposed in this essay should be taken into consideration when designing financial policies and climate-related regulation for the respective jurisdiction on a systemic level.

I further identify various specific propositions derived from each relevant framework. Among others, I identify that climate-related financial disclosure is the first best way to mitigate climate-related risk. A sufficient way to manage such risk is the incorporation into financial decisions and assessment frameworks of FI's. Whereas, the lack of incorporating the risk of stranded assets in financial risk models or the risk of a sharp fall in the asset valuation on the capital markets can be seen as a challenge, significant exposure to SFFA also translates into a potential influence in the form of active shareholder engagement. This influence should

[18] Paola D'orazio and Lilit Popoyan, "Fostering Green Investments and Tackling Climate-Related Financial Risks: Which Role for Macroprudential Policies?," *Ecological Economics* 160 (2019): 37, https://doi.org/10.1016/j.ecolecon.2019.01.029; Emanuele Campiglio, "Beyond Carbon Pricing: The Role of Banking and Monetary Policy in Financing the Transition to a Low-Carbon Economy," *Ecological Economics* 121 (2016): 220–230.

be considered to actively encourage fossil fuel firms to incorporate transition risk in their operational business and scale up sustainable investment.

On a systemic level, I identify various degrees of exposure among countries and sectors, with Norway being by far the most exposed country relative to GDP. A high degree of exposure based on the **Risk-Levels**, therefore demands a sufficient response by financial regulators and central banks, such as the proposed measure of differentiated capital requirements.

In general, my empirical findings suggest a significant direct SFFA exposure for Financial Institutions amounting to **3.74 trillion US$ value-at-risk**, representing more than **4% of global GDP**. Given the interconnectedness of the financial system, the financial loss from SFFA is likely to be amplified by a factor of two, due to indirect exposure, **posing a systemic risk to the stability of the financial system.**

Appendix

Graphs. All graphs and tables are based on the authors' own calculations and were created for the purpose of this essay.

Data availability. The data that support the findings of this study are publicly available from Bloomberg database and comprises 24.374 observations. Data and detailed methodology of the analysis are available from the author on request.