Being Stranded the Carbon Bubble?
Climate Policy Risk and the Pricing of Bank Loans

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Abstract

Does neglecting the possibility that fossil fuel reserves become “stranded” result in a «carbon bubble», i.e., an overvaluation of fossil fuel firms? To address this question, we study whether banks price the climate policy risk. We hand collect global data on corporate fossil fuel reserves, match it with syndicated loans, and subsequently compare the loan rate charged to fossil fuel firms — along their climate policy exposure — to non-fossil fuel firms. We find that before 2015 banks did not price climate policy exposure. After 2015, however, the risk is priced, especially for firms holding more fossil fuel reserves. We also provide some evidence that “green banks” charge marginally higher loan rates to fossil fuel firms.

Keywords: Environmental policy; Climate policy risk; Loan pricing; Loan maturity; Carbon bubble; Fossil fuel firms; Stranded assets
JEL classification: G2; Q3; Q5

1. Introduction

The «carbon bubble» is a hypothesized bubble in the valuation of firms that heavily depend on fossil fuels as factors of production. The term first appeared in a media article published by Le Page (2011) and in a report by the Carbon Tracker Initiative (2011).[1] Subsequently, there has been an ongoing public discussion on the possibility that this hypothesized bubble affects financial stability (e.g., Bank of England 2015; ESRB 2016). Theoretically, higher than intrinsic values of fossil fuel firms might occur owing to ongoing policy initiatives to move to cleaner technology in the near future, so that fossil fuel reserves will lose their economic value and become unburnable or "stranded". This would imply considerable losses for fossil fuel firms, especially *vis-à-vis* other firms. Investors increasingly consider climate change risks as already relevant with a high potential to materialize in the near future (Krueger, Sautner, and Starks 2018, Ilhan, Sautner, and Vilkov 2018). Thus, adequately pricing climate change risks becomes more and more important in all parts of the financial system.

In this paper we examine the extent to which a so-called «carbon bubble» exist using data from the corporate loan market. In particular, we estimate whether banks price-in the risk that fossil fuel reserves will become stranded, i.e., whether banks actually price-in the climate policy risk or exposure of fossil fuel firms. Our hypothesis is that the risk is priced if banks place considerable weight on climate policy exposure when formulating the terms of lending to fossil fuel firms. Despite the potential importance for financial and economic stability of such loan pricing decisions of banks, there are no studies aiming at identifying a «carbon bubble» in the credit market.

[1] The notion of a «carbon bubble» is not necessarily meant to be taken as a "bubble" in the fundamental economic sense. In this context it simply refers to market participants not taking the risk of the stranding of fossil fuel reserves fully into account.

The syndicated loan market provides an ideal setting to test our hypothesis for at least three interrelated reasons. First, banks are well-informed economic agents and, in principle, should price in the possibility that fossil fuel reserves will be stranded and the involved firms will incur losses. If they do not, then they clearly disregard an important source of risk for the sake of offering more competitive loan rates. In addition, syndicated loans are large loan contracts, potentially implying large or even crippling losses for the involved lenders if they are mispriced. This holds especially for the lead arrangers, who usually hold large shares of the loans and are the ones responsible for pricing decisions.

Second, in the formation of the loan syndicate, lead banks are liable to participant banks for the pricing of all relevant risks, and the effective screening and monitoring of borrowing firms. Thus, despite any moral hazard issues in the formation of the syndicate (Sufi 2007; Ivashina 2009), lead arrangers have additional reputational incentives to price loans accurately and face associated reputational costs if they do not.

And finally, syndicated loans typically come with a medium-term maturity, which makes it not only possible for lenders to effectively assess complex climate policy or exposure risks but also allows us to study how this risk assessment evolved within our sample period (that runs from 2007 to 2016). Indeed, while the risk of stranded fossil fuel reserves was initially considered to be mostly a long term risk (Caldecott, Tilbury, and Carey 2014), the (relatively unexpected) 2015 Paris climate agreement was a departure that brought policy action much more forward in time. Hence the transition to a low-carbon economy became a medium (and even a short) term concern for all parts of the financial sector. Thus, we can expect to observe that the risk of stranded fossil fuel reserves becomes increasingly relevant during our sample period even in the pricing of the medium term syndicated lending.

To conduct our analysis, we match syndicated loans data from Dealscan with firm-year data from Compustat. We concentrate on the period from 2007 onward because the appropriate environmental policy initiatives are relatively recent and data on country-specific climate stringency indicators become readily available. Our main outcome variable is the all-in-spread-drawn (AISD), defined as the loan spread plus any facility fee, but in sensitivity tests we also use information on commitment fees. Subsequently, we hand-collect firm-year data on fossil fuel reserves from firms' annual reports. Some firms hold fossil fuel reserves in more than one country and thus we construct a relative measure of reserves for each firm, in each country, and in each year. Finally, we generate a firm-year measure of climate policy exposure (risk) from the product of relative reserves and either one of the Climate Change Cooperation Index (C3I) by Bernauer and Böhmelt (2013) or the Climate Change Policy Index (CCPI) by Germanwatch. These country-year indices, respectively available for the periods 1996-2014 and 2007-2017, reflect environmental policy stringency and thus risk.

To ensure empirical identification, we mainly use a framework, whereby we compare (i) the loan pricing of fossil fuel firms (treatment group) to non-fossil fuel firms (control group), and (ii) fossil fuel firms according to their different country-specific climate policy exposure. This is a robust empirical model, as long as our measure of climate policy exposure is independent from other idiosyncratic shocks that also affect loan spreads and fees. To this end, the validity of our identification method is significantly strengthened via the fielding of several loan and firm-year characteristics and fixed effects (e.g., loan type and purpose, country and year fixed effects, etc.). Important fixed effects are the bank*year ones, which saturate the model with time-varying supply-side characteristics that might affect loan spreads, and the firms' country effects, which imply identification before and after changes in the country-specific climate policy exposure.

These controls and fixed effects make it unlikely that our model suffers from a violation of its identifying assumptions.

Our results, drawn from the full sample, show that the AISD of fossil fuel firms that are more exposed to climate policy risk are not significantly higher compared to non-fossil fuel firms and fossil fuel firms with relatively low risk. This result holds irrespective of the mix of firm controls and fixed effects, and the measure of environmental policy stringency used (C3I or CCPI). We posit that this finding suggests the non-pricing of environmental policy exposure of fossil fuel firms, possibly because banks consider the possibility that environmental policy will lead to considerable losses from stranded assets as small or unlikely over the loan's maturity.

As the notion of a «carbon bubble» is relatively recent, originating in 2011 and gaining in prominence only after the Paris Agreement in December 2015, we subsequently focus on the most recent years of our sample. Specifically, we examine a model, where we compare the AISD (i) of fossil fuel firms according to their environmental policy exposure, (ii) of fossil fuel to non-fossil fuel firms, and (iii) before and after each year from 2011 onward. When using the CCPI-based measure of climate policy exposure, which is available for the most recent years of our sample, we find the first evidence for pricing of climate policy risk in the post-2015 period. However, the economic significance is rather small: a one standard deviation increase in our measure of climate policy exposure implies that risky fossil fuel firms from 2015 onward are on average given a 2-basis points higher AISD compared to less exposed fossil fuel firms, non-fossil fuel firms, and themselves before 2015.

To give a feeling about the magnitude of this effect, we first show that the 2-basis point increase implies an increase in the total cost of the loan with a mean amount and maturity (of USD 19 million and 4 years) by around USD 0.2 million. Then, we hand collect data on the

dollar value of fossil fuel reserves and find that the mean fossil fuel firm in our sample holds approximately USD 4,679 million of such reserves. Thus, it seems unlikely that the corresponding increase that we identify in the post-2015 period covers the potential losses from stranded assets.

We further investigate this finding by using the actual value of the holdings of proved fossil fuel reserves, instead of simply examining average differences between the fossil fuel and non-fossil fuel firms. Retaining the dichotomy between the pre-2015 and post-2015 periods, we find that a one standard deviation increase in our measure of climate policy exposure implies an AISD that is higher by approximately 16 basis points for the fossil firm with mean proved reserves scaled by total firm assets in the post-2015 period vs. the non-fossil fuel firm. This implies an increase in the total cost of borrowing for the mean loan by USD 1.5 million. This extra cost of borrowing represents salient evidence that banks are aware of the climate policy issue and started pricing the relevant risk post-2015. The results on the all-in-spread-undrawn (AISU) reveal similar (albeit not fully robust) evidence for higher facility and commitment fees to fossil fuel firms; however, the economic effect is again too small not to be concerned about a «carbon bubble».

Subsequently we check our findings in a battery of robustness checks. For example, in various specifications we control for the crude oil price to ensure that our post-2015 results are not simply picking up the large drop in crude oil price in 2015. This analysis reveals that our finding is not driven by the developments of the underlying commodity price. We also conduct several other robustness tests related to the location of reserves (in one versus multiple countries), our measure of fossil fuel reserves, the mix of control variables and fixed effects used, etc., but once more our findings are not affected by these changes. Moreover, we look into

the role of loan maturity, given the potential higher importance of environmental policy risk for long-term loans. We find that the role of loan maturity either in the loan-pricing equations or as dependent variable (i.e., examining the direct effect of climate policy exposure on loan maturity) is very small.

Finally, we document two interesting findings that further complete the picture. First, we show a tendency of fossil fuel firms to obtain slightly larger loans compared to non-fossil fuel firms when environmental policy becomes more stringent. Even though the respective increase in loan amounts is economically rather small, our finding is in line with a substitution effect due to higher environmental policy risk from "lost" access to equity finance towards bank credit. Second, we document a slightly higher loan pricing to fossil fuel firms by "green banks" (i.e., those participating in the United Nations Environment Programme Finance Initiative) when climate policy risk increases.

The rest of the paper is structured as follows. In section 2, we further motivate our paper based on the existing qualitative literature and show that the relevant academic literature is quite distant from identifying the pricing of stranded fossil fuel reserves in the credit market. In section 3, we discuss our data set and the empirical model, with an emphasis on our identification method. In section 4, we analyze our empirical results and section 5 concludes.

2. Context, motivation and existing literature

2.1. A carbon bubble?

Researchers and most policy makers identify climate change as anthropogenic (IPCC 2014). Economic and population growth in the industrial era has caused extreme increases in greenhouse gas (GHG) emissions, which are identified as the main source of the observed global

warming (IPCC 2014). Since 1750, the major fraction of anthropogenic GHG emissions is carbon dioxide (CO2) emissions to the atmosphere and half of those have been emitted during the last 40 years.

The IPCC (2014) evaluates future impacts of emission scenarios with different temperature rises until 2100. Changes in global mean surface temperature up to the mid-21st century are similar for all considered scenarios in the absence of any major extreme weather events. However, from the mid-21st century onward, the global temperature, extreme weather events, and the sea level depend substantially on the choice of the emission path. The panel further identifies an almost linear dependency of global warming in 2100 on cumulative CO2 emissions.

In December 2015, the United Nations Framework Convention on Climate Change (UNFCCC) established the Paris Climate Agreement to limit the rise in global warming to 2°C compared to pre-industrial levels by the end of the century and further put forward an even more ambitious limit of 1.5°C. Limiting global warming to 2°C above pre-industrial temperature requires massive reductions in CO2 emissions in the next decades and near zero overall GHG emissions from the next century onward. To meet the 2°C limit in 2100 with a probability larger than 66%, the total cumulative emissions must not exceed 2900 gigatonnes CO2 (GtCO2). By 2011 already about 1900 GtCO2 have been emitted, leaving a budget of about 1000 GtCO2 for the remaining 89 years (IPCC 2014). For comparison, combusting all of the remaining (ultimately recoverable) fossil fuel resources would lead to emissions of nearly 11,000 GtCO2, while the combustion of current reserves (recoverable under current economic conditions) would lead to nearly 2900 GtCO2 (McGlade and Ekins 2015).

The limiting of total carbon emissions will leave the majority of fossil fuel reserves as “stranded assets”. That is, companies owing fossil fuel will not be able to use most of their reserves. The Carbon Tracker Initiative (2011; 2013) is the first effort to estimate the amount of stranded assets of listed companies based on the global carbon budget from 2000-2050, resulting from limiting global warming to 2°C above the pre-industrial level. The findings show that 60% to 80% of current carbon reserves of listed firms will become stranded assets. Similarly, McGlade and Ekins (2015) estimate that 33% to 35% of current global oil reserves, 49% to 52% of current global gas reserves, and 82% to 88% of global coal reserves will be unusable. The large fraction of potentially unburnable fossil fuels poses risks of substantial financial losses to fossil fuel companies.

Despite the big fraction of potentially stranded assets, the Carbon Tracker Initiative (2013) further highlights that listed oil, gas, and coal companies still largely invest into locating and developing new fossil fuel reserves. This ongoing investment, together with the already large fraction of potentially stranded assets, suggests that the risks of stranded fossil fuels due to climate policies might be inaccurately priced by markets. Further, fossil fuel companies themselves find it "highly unlikely" that carbon emissions are cut to reach the 2°C target by 2050 (ExxonMobil 2014, 16). Therefore, financial markets might carry a carbon bubble, i.e., an overvaluation of fossil fuel reserves and related assets due to neglecting the possibility of those assets becoming unusable or “unburnable”, especially under the target of limiting global warming to 2°C above pre-industrial levels.

2.2. Existing empirical literature and the cost of loans

Empirical evidence on the existence of a «carbon bubble» is limited. In stark contrast, the potential effect of a «carbon bubble» on financial stability is vigorously discussed by researchers

(Weyzig, Kuepper, van Gelder, and van Tilburg 2014; Schoenmaker, van Tilburg, and Wijffels 2015; Batten, Sowerbutts, and Tanaka 2016) and increasingly enters the agenda of regulators and supervisors (Bank of England 2015; Carney 2015; ESRB 2016). Thus, while discussing potential implications of a carbon bubble, the clarification of the existence and the extent of a «carbon bubble» are essential.

As one of the first, HSBC (2013) estimate the value-at-risk (VaR) from stranded assets of six oil and gas companies (Shell, BP, Total, Statoil, Eni, and BG). They measure unburnable assets according to their costs using data from Wood Mackenzie and show that the fraction of stranded assets varies among those companies. The VaR of stranded assets is calculated by aggregating the values of all unburnable projects. They show that a moderate reduction in the oil and gas demand could reduce the firms' equity value by 40% to 60% due to stranded oil and by 6% to 9% due to stranded gas reserves.

The event study by Batten, Sowerbutts, and Tanaka (2016) analyzes the market reaction to climate change news that covers the period 2011-2016. They classify an event as a news story in a major newspaper or energy-specific investment press, which contains the words «carbon bubble», “unburnable carbon”, or “fossil fuel divestment”. They find a positive and significant effect on the abnormal return for renewable energy companies, and a negative but insignificant effect on the abnormal return of oil and gas companies. They suggest that the insignificant effect could result from investors’ difficulties to assess credible future climate policies and their impact on the carbon-intense sectors.

Similarly, Byrd and Cooperman (2016) use as events announcements (between 2011 and 2015) concerning developments in the Carbon Capture and Storage (CCS) technologies. They find a positive and significant effect on the stock price from breakthroughs in CCS

developments. However, setbacks in CCS technologies have a negative but insignificant effect on abnormal returns of the coal companies. The authors conclude that, either investors already price in the potential risk of climate-related stranded fossil fuels, or investors believe that governments would never limit the production of coal.

The risk of stranded fossil fuel reserves and climate change risks in general are no longer considered to affect only future generations. A survey of institutional investors attitude towards climate change reveals that a large fraction of investors consider climate change risks (especially transition risks) as already present and believe these risks will materialize within the next five years (Krueger, Sautner, and Starks 2018). Ilhan, Sautner, and Vilkov (2018) measure climate risks exposure with firms' carbon emissions and identify an effect of carbon emissions on the downside risk of put options with two-year maturities.

Carbon-intense sectors are largely debt financed, implying that the impact of stranded fossil fuels can easily spill over to the banking sector. This almost naturally generates a question on whether banks consider the risk that fossil fuel reserves will become stranded when originating or extending credit to fossil fuel firms. *Essentially, this implies that if banks thoroughly consider the risk of climate policy exposure in the pricing of corporate loans, then no «carbon bubble» (i.e., non-pricing of the risk of stranded fossil fuel reserves) exists in the credit market.* This is the hypothesis we test in this paper.

Furthermore, the paper adds to the literature on environmental, social, and governance issues in banking. Studying the impact of corporate social responsibility of firms on their cost of credit, Goss and Roberts (2011) find that banks charge significantly higher loan spreads to firms with below average corporate social responsibly. Similar, Hasan et al (2014) study the impact of tax avoidance by firms on their cost of credit. They conclude that tax avoidance increases the

firm's loan rate. Focusing on firms' exposure to climate change, Kleimeier and Viehs (2016) analyze the effect of extra non-financial information by firms on their cost of credit. They show that firms that voluntarily disclose their carbon emissions are charged lower loan spreads than non-disclosing firms. Moreover, firms disclosing larger carbon emissions face higher cost of credit than firms with low emissions. Battiston et al (2016) analyze the systemic impact of climate risks in the banking sector using an environmental stress-test. While they identify a small direct exposure of the banking sector to the fossil fuel sector, the exposure to all high-carbon sectors is much larger, especially due to the indirect exposure via financial counterparties. And finally, in related follow-up and policy inspired work, De Greiff, Ehlers, and Packer (2018) further investigate the impact of climate risks on the pricing in the syndicated loan market using firm-specific exposure data for a broad set of firms. Specifically they identify a premium for climate risk after the Paris Agreement, which seems mainly driven by increasing awareness of climate policy risks.

3. Data and empirical model

3.1. Data and main variables

To test if the risk of stranded fossil fuel reserves is priced in the corporate loan market, we use syndicated loans from Dealscan. These data are ideal because they provide information on new large loan facilities from large well-informed banks to large firms for which industry SIC codes are available. The loan pricing decisions in a loan syndicate are taken by lead banks (lead arrangers), who are liable to other participant banks for their decisions and thus bear reputational costs if they misprice loans. If anything, and despite moral hazard issues in the formation of the

syndicate (Sufi 2007; Ivashina 2009), non-pricing the risk of stranded fossil fuel in the syndicated loans market, would also imply non-pricing in other smaller corporate loans.

We consider only loan facilities with information on loan spreads. In total, we have a cross-section of 72,742 loans in the period 2007-2016, but this number will be lower in our empirical analysis given data availability mainly on variables reflecting fossil fuel reserves. During our sample period, no specific banking regulations targeting fossil fuel assets have been introduced.[2] We match loans to firm-year accounting data from Compustat to identify general risk and performance indicators of firms. We provide detailed definitions of all variables in Table 1.

[Insert Table 1 about here]

Our main outcome variable is the so called all-in-spread-drawn, *AISD*, which equals the spread of the loan facility over LIBOR plus any facility fee. Berg, Saunders, and Steffen (2016) show the importance of fees in the overall pricing of loans. Thus, in robustness checks, we use the all-in-spread-undrawn (*AISU*) as dependent variable to assess the impact of climate policy exposure on fees. The *AISU* is the sum of the facility fee and the commitment fee.[3]

Ideally, our main explanatory variable illustrating climate policy exposure would be the amount of stranded assets of a fossil fuel firm f in year t.[4] However, such estimates are only given as snap shots in time (Carbon Tracker Initiative 2011, 2013, McGlade and Ekins 2015). In principle, a devaluation of fossil fuel reserves can be caused due to changes in regulation

[2] The only regulatory changes that may indirectly affect climate change mitigation are the new Basel III liquidity measures, which tend to punish long-term assets. Thus, banks might favor short-term investments and not investments in typically long-term low-carbon projects (Alexander 2014). While some countries (i.c., Brazil, China, Peru, Indonesia, and the EU) are discussing the inclusion of explicitly requiring higher capital for fossil fuel loans (Alexander and Fisher 2018), no such regulation is in place anywhere yet during our sample period.

[3] Due to lack of information for several countries, we cannot utilize other types of fees, such as the utilization fee (paid on the drawn amount once a threshold has been exceeded), or cancellation and upfront fees.

[4] Parts of a firm's climate policy exposure might also be affected by climate policy in their customers' countries. However, such foreign country policy is unlikely to reflect a firms' climate policy exposure because fossil fuel firms are unlikely to decline profitable business opportunities (and thus lower fossil fuel production) based on these risks.

(policies), technologies or carbon prices. Climate policies involve direct environmental regulations, e.g., pollution outputs and inputs, as well as stimulating the development of alternative technologies, by, e.g., subsidizing instruments. The probability of stranded fossil fuel reserves is thus higher in countries with higher climate policy stringency. Therefore, we can proxy the risk of stranded fossil fuel reserves by the risk of climate policies stringency, i.e., whether a country places considerable effort in climate change policies. That is, a fossil fuel firm owing exploration rights for reserves in a country with strict climate policy faces a higher probability of reserves being stranded than a firm with fossil fuel reserves in a country with loose climate policy.

This also implies that we require information on the total amount of fossil fuel reserves of firms across countries. As these data are not readily available in conventional databases, we hand-collect them from firms' annual reports.[5] To get the most comprehensive data, we only consider the amount of proved oil and gas reserves and proven and probable coal reserves.[6] Proved oil and gas reserves are "the estimated quantities of oil and gas, which, by analysis of geoscience and engineering data, can be estimated with "reasonable certainty" to be economically producible from a given date forward, from known reservoirs, and under existing economic conditions, operating methods, and government regulations" (US Security and Exchange Commission-SEC).[7] We convert the amount of coal, gas, and oil reserves into barrels of oil-equivalent according to common approximate conversion factors.[8]

[5] Due to data availability, we can only distinguish between oil, gas, and coal reserves; we cannot classify these three groups in more detail.

[6] SEC uses the term "proved reserves" for oil and gas reserves and "proven" reserves for coal reserves. In the remainder of the paper, we use the term "proved reserves" for all kinds of reserves (oil, gas, and coal).

[7] Similarly, proven coal reserves are "reserves for which (a) quantity is computed from dimensions revealed in outcrops, trenches, workings or drill holes; grade and/or quality are computed from the results of detailed sampling and (b) the sites for inspection, sampling and measurement are spaced so closely and the geologic character is so well defined that size, shape, depth and mineral content of reserves are well-established." Probable coal reserves are "reserves for which quantity and grade and/or quality are computed form information similar to that used for proven

A further problem is that large firms could hold fossil fuel reserves in more than one country or even exploit loose policies of countries to move their exploration activities there. To capture the differences in the firms' allocation of fossil fuel reserves by country, we first hand-collect data (from firms' annual reports) on the location of these assets. Then, we define the climate policy exposure of a firm *f* in year *t* as:

$$Climate\ policy\ exposure_{ft} = \sum_c Relative\ reserves_{fct} \times Climate\ policy\ index_{ct}\ , \qquad (1)$$

In equation (1) *Relative reserves* is the relative amount of fossil fuel reserves of firm *f* in country *c* in year *t*.

In turn, *Climate policy index* is the climate policy index of country *c* in year *t*. A thorough measure of a country's climate policy stringency should include both its climate policy ambition and its climate policy effort. The former is measured by the efficiency in climate policy implementation while the latter is measured by climate policy outcomes such as CO2 emissions. There are two such indices available for our analysis.[9] The first is the Climate Change Cooperation Index (C3I) by Bernauer and Böhmelt (2013). The C3I evaluates countries' overall climate policy performance, as well as performance in terms of political behavior (output) and emissions (outcome). Currently, the index covers the period 1996-2014 for up to 172 countries, and takes values between 0 and 100 (inclusive) with higher values indicating stricter climate

(measure) reserves, but the sites for inspection, sampling, and measurement are farther apart or are otherwise less adequately spaced. The degree of assurance, although lower than that for proven (measured) reserves, is high enough to assume continuity between points of observation" (US Security and Exchange Commission-SEC).

[8] See additional material to BP Statistical Review of World Energy June 2017, http://www.bp.com/content/dam/bp/en/corporate/pdf/energy-economics/statistical-review-2017/bp-statistical-review-of%20world%20energy-2017-approximate-conversion-factors.pdf, accessed June 29, 2017.

[9] An alternative measure is the OECD's Environmental Policy Stringency (EPS) index (Botta and Kozluk 2014). However, the EPS index primarily considers policies in the energy sector, especially policies applying to electricity generation. Stricter policies for the electricity sector of a country do not necessarily affect fossil fuel reserves in that country. Therefore, the EPS index is not a good proxy for the risk of stranded fossil fuel reserves.

policy (more climate-friendly countries). An alternative is the Climate Change Performance Index (CCPI) by Germanwatch (Burck, Hermwille, and Bals 2016).[10] This index, available for the period 2007-2017 and covering 58 countries, takes values on the interval [0,100], with higher values reflecting higher climate policy effort by countries. The countries covered produce the majority of global energy-related CO2 emissions. As analyzed by Bernauer and Böhmelt (2013) the two climate policy indices are positively correlated and useful empirical measures.

Based on the above, a higher *Climate policy exposure* indicates a higher average level of fossil fuel reserves in countries with stricter climate policy.

3.2. Empirical identification and control variables

We estimate the effect of a firm's *Climate policy exposure* on the cost of loans, using an empirical model of the following form:

$$CL_{lbft} = a + a_1 FossilFuel_{ft} + a_2 Climate\ policy\ exposure_{ft} + a_3 FossilFuel_{ft} \times Climate\ policy\ exposure_{ft} + a_4 L_{lt} + a_5 F_{ft} + u_{lbft} \quad (2)$$

In equation (2), *CL* is the cost (*AISD* or *AISU*) of a loan facility. The loan is given by lead bank(s) *b* of the syndicate to firm *f* in year *t*. *FossilFuel* is a dummy variable that equals 1 if firm *f* owns fossil fuel reserves in year *t* and 0 otherwise. As an alternative to *FossilFuel*, we can use the dollar value of proved reserves scaled for firm size (named *Proved Reserves over Total*

[10] The publicly available CCPI time series includes changes in weightings within the sample period; however, we have received a CCPI data set by Germanwatch that is based on a uniform weighting method introduced in 2013 and covers the period 2007-2017. The CCPI comprises of fifteen measures that are classified into the five categories, namely Emissions Level, Development of Emissions, Efficiency, Renewable Energies, and Climate Policy. 80% of the measures are based on objective indicators and 20% on national and international climate policy assessments from about 300 experts from the respective countries.

Assets) but we reserve this for sensitivity tests, as it is hard to calculate these reserves for coal firms. L and F are vectors of loan and firm-year characteristics that might affect the cost of loans. Further, a is a vector of fixed effects and u is the remainder disturbance.

At the loan-level, we control for the loan amount, the maturity of the loan facility, whether a loan has collateral, the number of lenders in the syndicate, whether a loan has performance pricing provisions, the number of general covenants, and a number of dummy variables that indicate the loan type and the purpose of the loan. Moreover, we control for the effect of unobserved loan-specific characteristics using loan type and loan purpose fixed effects. Typical control variables of borrowing firms that affect the cost of loans are firm size, market-to-book ratio, leverage, and tangibility. At the country-level, we control for borrower's country GDP per capita and the GDP growth rate. For definitions of these variables, see Table 1; for similar control variables in loan pricing equations, see e.g., Ivashina (2009) and Delis, Hasan, and Ongena (2019).

If the terms of lending are affected by the risk of fossil fuel reserves to become unburnable, then we should observe $a_3 > 0$. That is, firms with a larger average exposure to climate-policy stringency face a higher risk that their fossil fuel reserves become stranded. Consequently, if banks price in this risk, firms with larger average exposure should face higher cost of loans. Thus, our model compares the terms of lending of fossil fuel firms to other firms that bear no risk of stranded reserves and the risk of fossil fuel reserves to become stranded based on the exposure to country-specific climate-policy stringency.

A potential identification issue in equation (2) could be the presence of an omitted-variable bias emerging from other risk characteristics of banks and firms. First, it might be that the time-varying supply-side policies of banks drive the results. The fact that in our data every

lead bank gives multiple loans within a year, allows using bank*year fixed effects, which saturate the model from supply-side explanations of the findings. Specifically, bank*year fixed effects capture any year-specific price movements in the oil market and thus absorb the non-dispensable potential impact of oil price movements on the terms of credit of fossil fuel firms. Considering demand-side potential omitted variables, the usual time-varying firm-specific measures of risk and performance, along with the use of the interaction term, mitigate such concerns. Thus, along with the fielding of our model with firm-year indicators of risk and performance, it is unlikely that coefficient a_3 would capture anything other than a shift due to climate policy exposure of fossil fuel firms vis-à-vis other firms.

If we identify an effect, this should be more pronounced in the recent years in which environmental policy intensified and the notion of a «carbon bubble» appeared. Thus, in a more stringent identification method, we can distinguish the periods before and after 2011, which is the first year that the term «carbon bubble» appeared (Le Page, 2011; Carbon Tracker Initiative report, 2011). This implies a specification, where the triple interaction between *FossilFuel*, *Climate policy exposure*, and *Post2011* (along with relevant double interactions) enters our estimated model. *Post2011* takes the value 0 before 2012 and the value 1 from 2012 onward.

The model takes the form:

$$\begin{aligned} CL_{lbft} = {} & a'_{bt} + a'_1 L_{lt} + a'_2 F_{ft} + + a'_3 FossilFuel_{ft} + a'_4 Post2011_t + \\ & a'_5 Climate\ policy\ exposure_{ft} + a'_6\, FossilFuel_{ft} \times Post2011_t + \\ & a'_7 FossilFuel_{ft} \times Climate\ policy\ exposure_{ft} + a'_8 Post2011_t \times \\ & Climate\ policy\ exposure_{ft} + a'_9 FossilFuel_{ft} \times Post2011_t \times \\ & Climate\ policy\ exposure_{ft} + u'_{lbft} \end{aligned} \tag{3}$$

This approach compares, in the pre- and post-2011 periods, the terms of lending of fossil fuel to non-fossil fuel firms based on their climate policy exposure. Because the notion of a «carbon bubble» has publicly emerged, we should observe that financial intermediaries increasingly factor post-2011 the risk of fossil fuel reserves to become unburnable into the terms of lending of these firms (relative to non-fossil fuel firms). That is we should observe $a'_9 > 0$. In further tests, we include equivalent triple interactions with post-2012 and post-2013 dummies.

4. Empirical results

4.1. Summary statistics and anecdotal evidence

We provide basic summary statistics of our data set in Table 2 for the period 2007 to 2016. The characteristics of our fossil fuel subsample are in line with the overall sample characteristics. Given that the fossil fuel sector is largely debt financed and typically requires very large loans, it is natural to find all types (with respect to risk profile) of fossil fuel firms in the syndicated loan market. The mean C3I is 54.68 and the mean CCPI 43.90. Overall, we have fossil fuel reserves data for 217 fossil fuel firms, of which 25 operate in the coal-mining sector, and our reserves data covers 2/3 of the listed fossil fuel firms in the Dealscan data set. Moreover, in Table A.1 we provide summary statistics on the firms' relative amount of fossil fuel reserves by country. As highlighted in these statistics, in the period 2007-2016 firms in our sample own fossil fuel reserves in 59 different countries, with each firm owning fossil fuel reserves in 1.39 countries on average. Table A.2 reports fossil fuel firms' country of headquarter and Table A.3 lists all fossil fuel firms in our sample that own oil, gas, and coal reserves. Table A.4 reports summary statistics for the C3I for countries in which firms in our sample own fossil fuel reserves in the

period 2007-2014. Table A.5 provides the equivalent for the CCPI over the period 2007-2016. The evolution over time of the two climate policy indices is illustrated in Figure A.1 for eight representative countries.

[Insert Table 2 about here]

Figure 1 illustrates the relation of the firms' climate policy exposure and *AISD* and Figure 2 the respective between climate policy exposure and *AISU*. The results do not reflect a strong correlation between climate policy risk and each of the measures of the cost of credit. In what follows, we aim to examine causal effects.

[Insert Figures 1 & 2 about here]

4.2. Empirical results

We first use the C3I and the period 2007-2014 and report the results in Table 3. All specifications control for loan type and loan purpose fixed effects as well as for supply-side effects using bank*year fixed effects. To exclude a potential effect of bad controls, specification (1) includes only loan characteristics, specification (2) firm and macro controls, and specification (3) our full set of controls. All specifications yield very similar inferences. Based on the specification (3), being a fossil fuel firm does not imply a significantly higher cost of credit. Further, throughout specifications (1) to (3), the interaction term between *FossilFuel* and *Climate Policy Exposure* is statistically insignificant,[11] implying no differential effect of climate policy risk on the cost of credit between fossil fuel (treated) and non-fossil fuel (control) firms. The findings remain unchanged when we include bank's country and firm's country fixed effects in specification (4).

[Insert Table 3 about here]

[11] The main term of *Climate Policy Exposure* drops out due to multicollinearity.

In Table 4, we replicate the results of Table 3 using the CCPI to measure country policy risk. The results are somewhat different in that the main term of *Fossil Fuel* is positive and statistically significant across all specifications (i.e., irrespective of using different controls and/or fixed effects). This finding is intuitive because especially oil and gas projects are capital intensive and have long lead times. Further, the exploration of oil and gas is inherently risky, with an average exploration success of approximately 33% (Tordo, Johnston, and Johnston, 2010). However, we still do not find that this effect is due to climate policy risk, as the interaction term between *FossilFuel* and *Climate Policy Exposure* is statistically insignificant. In sum, our results so far are indicative of a carbon bubble, as banks in our full sample period did not price in the climate policy exposure of fossil fuel firms and the possibility that fossil fuel reserves will become stranded.[12] It might be that banks simply ignored any potential risk of stranded fossil fuel reserves because the possibility of any climate policy actions where considered to be very low.

[Insert Table 4 about here]

The debate on climate policy risk carried by fossil fuel firms has arisen toward the end of our sample period. Using equation (3), we therefore examine whether a fossil fuel firm's exposure to climate policy risk affects its cost of borrowing after the emergence of the discussion of the risk of stranded fossil fuel reserves. Columns (1) and (2) of Table 5 report the results when focusing on the period directly following the emergence of the «carbon bubble» discussion in 2011. The interaction term *FossilFuel×Post2011×Climate policy exposure* captures the difference in cost of credit due to a fossil fuel firms' climate policy exposure after 2011. As there

[12] In this paper, we do not examine credit rationing to fossil fuel firms (loan-level data, including loan denials, for many countries are not available). We should note, however, that the first buffer of banks toward climate policy risk should be reflected in loan pricing. Indeed, as we find limited evidence for increased lending rates, banks are unlikely to disrupt lending altogether because of climate policy exposure.

might be a time lag until the notion of the «carbon bubble» reached a wider audience, in specifications (3) and (4) we consider the equivalent effect post 2012; and in specifications (5) and (6) post 2013. However, our results on the triple interaction terms do not identify a significant relation between climate policy exposure and the firm's costs of credit in the years after the emergence of the notion of the carbon bubble.

In Table 6, we use the CCPI to measure climate policy exposure. As the CCPI covers the period 2007 to 2017, we can extend the time window of our analysis to include the most recent years. Again, specifications (1) and (2) report the results just after the emergence of the notion of a «carbon bubble» in 2011; in columns (3) and (4) we use 2013 as the threshold year; and in columns (5) and (6), we use 2015. The first four specifications yield once more insignificant estimates on the triple interaction term. However, in the post-2015 period, there is a positive and significant effect (at the 10% level). This is the first evidence that banks started pricing in the climate policy exposure of fossil fuel firms from 2015 onward. Interestingly, 2015 coincides with the Paris Agreement and the denser series of reports and academic articles on the «carbon bubble» until that time (Dyer, 2015; Jacob and Hilaire, 2015; McGlade and Ekins, 2015; King et al., 2015).

[Insert Tables 5 and 6 about here]

This analysis by itself does not provide evidence for or against the pricing of stranded fossil fuel risk. To inquire into this, we hand-collect data on the dollar value of proved reserves. Essentially, *Proved Reserves* is the standardized measure of discounted future net cash flows related to proved oil and gas reserves (see Table 1). As shown in Table 2, the mean *Proved Reserves* for the firms in our sample equals 4,679.24 million USD. At the same time, column (6) of Table 6 documents that a one standard-deviation increase in *Climate Policy Exposure* yields a

2 basis-point increase in the cost of loans to fossil fuel firms relative to firms with stable CCPI and non-fossil fuel firms in the post-2015 period. Based on this estimate and the statistics reported in Table 2.b, for the loan with the mean amount and maturity, this implies an increase in the total cost by approximately USD 188,628 (calculated from 0.0002×258,395,004.4×3.65).[13] Comparing the increase in the cost of loans to fossil fuel firms with the mean *Proved Reserves*, it seems unlikely that this extra cost covers the potential losses from stranded assets.

Could it be that an increased cost of borrowing is hiding in the loan fees and not the spreads? Berg, Saunders, and Steffen (2016) note the importance of fees in syndicate loan pricing. Even though information on fees in the global syndicate sample is limited, we do have some information on *AISU*. Figure 2 illustrates the relation of the loan's *AISU* and the exposure to climate policy but, as in Figure 1, we do not observe a strong relation between the two variables.

We then replicate our baseline regression analysis using *AISU* as dependent variable and report the results in Table 7. From this point onward, we use the CCPI given its availability for the most recent period. The estimates on the interaction term are statistically insignificant. These results are not driven by the smaller sample: redoing our baseline analysis on *AISD* and the sample where *AISU* is non-missing, yields very similar results with those of Tables 3 and 4 (the interaction term between *FossilFuel* and *Climate Policy Exposure* is statistically insignificant). We can conclude that there is no evidence that climate policy risk matters in terms of higher commitment and facility fees paid by fossil fuel firms.

[Insert Table 7 about here]

[13] This is derived from the 2 basis points (=0.0002) and the inverse logarithms of the loan amount and loan maturity (in years=3.65), respectively.

An important alternative specification comes from using *Proved Reserves over Total Assets* instead of *FossilFuel*. *Proved Reserves* are the standardized measure of discounted future net cash flow from proved oil and gas reserves (see Table 1). The advantage of this approach is that we have a continuous measure for fossil fuel reserves and thus we do not simply treat all fossil fuel firms similarly with a dummy variable: firms owning more such reserves are more exposed to climate policy risk. The disadvantage of this measure is that we have limited information for coal firms.

As we do not identify any evidence for a significant double interaction term when estimating equation (2), we focus on the results from equation (3) and especially those for the post-2015 period. We report them in Table 8. Our findings reinforce those of Table 6 (the triple interaction is positive and statistically significant at the 1% level) but provide a clearer picture on the economic significance of differential pricing based on the actual amount of fossil fuel reserves. Specifically, based on column (4), a one standard deviation increase in *Climate Policy Exposure* implies a higher *AISD* by approximately 16 basis points for the fossil firm with mean *Proved Reserves over Total Assets* in the post-2015 period vs. the non-fossil fuel firm.

Working in the same way as in Table 6, this implies an increase in the total cost of borrowing by USD 1,517,295. If we alternatively take the marginal effect with respect to *Proved Reserves over Total Assets*, we find that only a 1% point increase in these reserves implies a 6.9 basis points increase in *AISD*, or USD 650,768.

Concisely, the analysis of Table 8 indicates a considerably higher cost of borrowing for fossil fuel firms due to either increased climate policy exposure or increase in the actual amount of fossil fuel reserves. Despite the fact that this extra cost of borrowing is still small compared to the mean *Proved Reserves* of fossil fuel firms in our sample (equal to 4,679.24 million USD), the

analysis of Table 8 provides the first salient evidence that banks are aware of the climate policy issue and start pricing the relevant risk, especially for firms that own a large portfolio of proved reserves.

[Insert Table 8 about here]

A serious concern with our previous results might be that the bank*year fixed effects do not adequately capture oil price movements. Especially given that the oil price largely decreased in 2015 (see Figure 3), we additionally test if our post-2015 result is driven by the developments in the underlying commodity prices. To account for such concerns, we control for the crude oil price in the month before loan origination.[14] Table 9 reports the results. As a first reference of the effect of the oil price, in column (1) we do not use any firm-specific climate policy exposure. Subsequently, columns (2) and (3) include triple interactions with the oil price in the same fashion as in Table 6 for the post-2015 time window. In columns (4) and (5), we redo this analysis using the same specification as in Table 8. The results show that even when controlling for the oil price, our post-2015 result holds.

[Insert Table 9 about here]

4.3. Other sensitivity tests

We conduct several sensitivity tests and report the results in the Appendix. So far, we focused on firms that disclose their fossil fuel reserves at the country level. However, this automatically excludes some of the well-known fossil fuel firms (e.g., Shell, ExxonMobil), which typically operate worldwide and only disclose their aggregate fossil fuel reserves at a regional level. We conduct a sensitivity test to include these firms in our sample by splitting the regional reserves

[14] To incorporate our global data set, we use a time series of the simple average of three spot prices, namely Dated Brent, West Texas Intermediate, and the Dubai Fateh. The data are from the IMF Primary Commodity Prices.

equally to each country of the region.[15] In general, our findings are in line with our baseline results (results available on request), indicating a small increase in the cost of loans for fossil fuel firms relative to other firms in the post-2015 period. Moreover, in our main analysis, we use proved *reserves* and exclude "probable oil and gas reserves." Probable reserves are "those additional reserves that are less certain to be recovered than proved reserves but which, together with proved reserves, are as likely as not to be recovered" (US Security and Exchange Commission-SEC). Once more, our inferences are very similar to that of the baseline results (results available on request).

We also examine whether our findings are in fact due to general political and policy uncertainty in the countries examined, and not due to climate policy uncertainty in particular. We measure political instability using the State Fragility Index (SFI) from the Center for Systemic Peace, which measures countries' effectiveness and legitimacy in managing conflicts and their ability to implement public policies. The SFI varies between 0 (no fragility) to 25 (extreme fragility). Table A.6 reports the results as in Table 8, introducing triple interactions with the SFI in the fashion of (and in addition to) the triple interactions with the CCPI. The results document an insignificant triple interaction with the SFI and, if anything, make the triple interaction term involving the CCPI economically more potent.

Further, to rule out that our findings capture the general market perceptions as these are reflected by firm ratings, we rerun our baseline models controlling for the S&P ratings. Table

[15] For instance, Royal Dutch Shell Plc discloses its 2014 proved reserves at a continental level, for Europe, Asia, Oceania, Africa, USA, Canada, and South America. In Europe, Shell estimates total proved reserves of 2,728 million barrels of oil equivalents and further reports its upstream operations in Europe to take place in 10 countries (Albania, Denmark, Germany, Greenland, Ireland, Italy, Netherlands, Norway, the UK, and Ukraine). Therefore, for Shell we assign 272.8 million barrels of oil equivalents (dividing the total reserves in Europe by the number of European countries in which Shell operates) to each of the 10 European countries in which it operates. Table A.3b reports the additional firms used in the extended data set. Firms that disclose fossil fuel reserves by region own reserves in up to 36 countries. *Proved Reserves over Total Assets* are not available for any of the additional firms; thus, there is no change over the results in Table 8.

A.7 reports the results. Despite the significant loss in observations (due to the unavailability of ratings for several firms) our baseline findings continue to hold. Again, even after controlling for the crude oil price post-2015, the results hold (Table A.16).

Furthermore, we use an alternative measure of public attention/awareness of the risk of stranded fossil fuel reserves (compared to simply using the pre-post-2015 variation). Specifically, we use a Google-search of the term «carbon bubble» to infer public awareness on this issue. We also experiment with the terms "stranded carbon" and "unburnable carbon" but these are used more infrequently. Via Google Trends,[16] Google provides the Search Volume Index (SVI) of search terms and divides the search frequency data by the total search in the region and time period. The resulting time series is scaled on a range of 0 to 100 by the search term's popularity compared to all other searches. For our analysis, we match our data with the monthly time series from 2007 to 2016 of the Search Volume Index corresponding to the keywords. Figure A.2 shows the evolution of the resulting index over time.

We find statistically significant results on the triple interaction between the SVI of the term carbon bubble, the CCPI, and *Proved Reserves over Total Assets* (results in Table A.8). The positive triple interaction term is intuitive, indicating an increase in the cost of credit for fossil fuel firms with higher CCPI and public awareness of the «carbon bubble» issue. Taking the derivative of column (4) with respect to *Attention* and holding *CCPI* and *Proved Reserves over Total Assets* at their mean levels, we find that a unitary increase in attention increases AISD by approximately 1.2 basis points. Thus, the response is economically small.

Measuring a fossil fuel firm's exposure to the risk of stranded fossil fuel reserves using the climate policy stringency of the countries in which the firm holds its fossil fuel reserves is probably the best approximation. A critique against this choice might be that the risk of unusable

[16] http://www.google.com/trends.

fossil fuels is actually driven by environmental stringency in the firm's headquarter country. Thus, we redo our analysis using the respective climate policy stringency. The results are in line with our baseline findings and, if anything, a bit more pronounced (Tables A.9 to A.13). This finding is in fact expected, because the average firm extracts fossil fuel reserves also in its headquarter country, while the average fossil fuel firm in our sample holds reserves in 1.39 countries.

4.4. A role for loan maturity?

In this section, we consider the role of loan maturity in both the relation between climate policy exposure and loan pricing and as an outcome variable of climate policy exposure. Our premise is that loans with a relatively long maturity will bear higher environmental policy risk for the banks, because of the underlying uncertainty on relevant policy innovations in the more distant future. The mean maturity in the full sample is 48.4 months and for the fossil fuel firms 43.8 months.

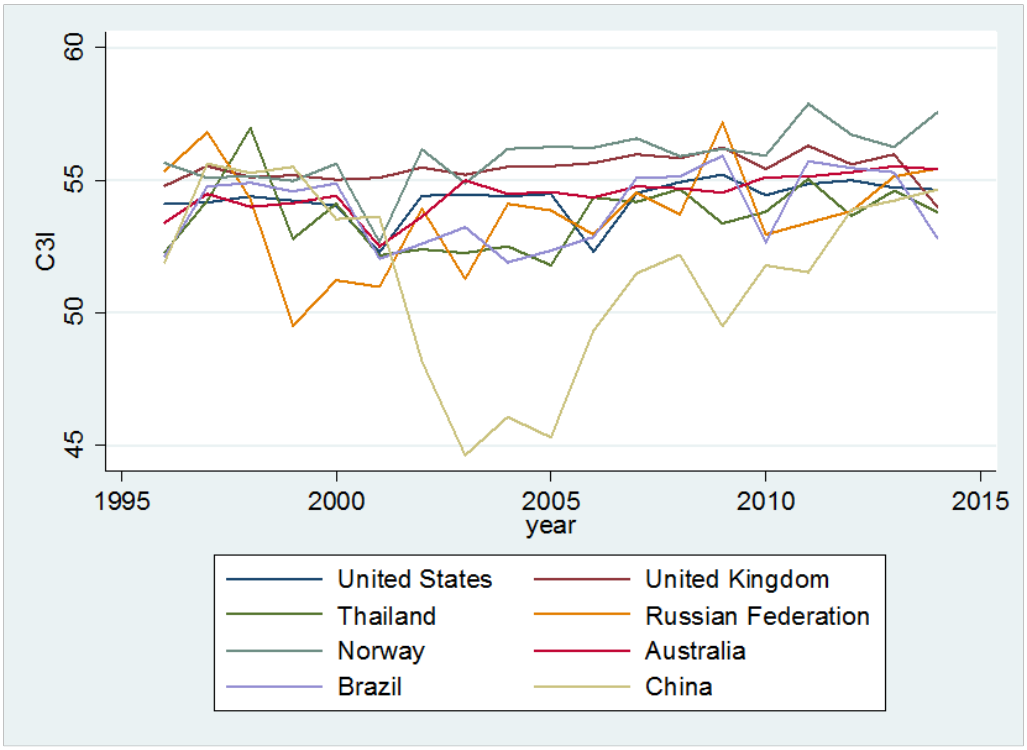
We first examine loan-pricing equations, where we use only loans with maturity longer than four years. We choose four years as a cutoff to focus on loans with a maturity longer than the usual tenure of legislative bodies around the world and thus more prone to political uncertainty.[17] Table A.14 (Appendix) reports specifications equivalent to those in Table 4. Our findings show that, similarly to the loans with a mean maturity, loans with longer maturity are not assigned higher prices due to environmental policy risk. The results are quite similar when we use *Proved Reserves over Total Assets* instead of the *FossilFuel* dummy (Table A.15). When repeating the analysis for the rest of our baseline results (e.g., for the C3I), we again draw very

[17] We also examine the same specifications using loans with maturity longer than five years, without observing substantial differences.

similar inferences

Figure A.1
The Climate Policy Indices over time

The figure illustrates the evolution of the two climate policy indices, C3I and CCPI, over time for eight countries.



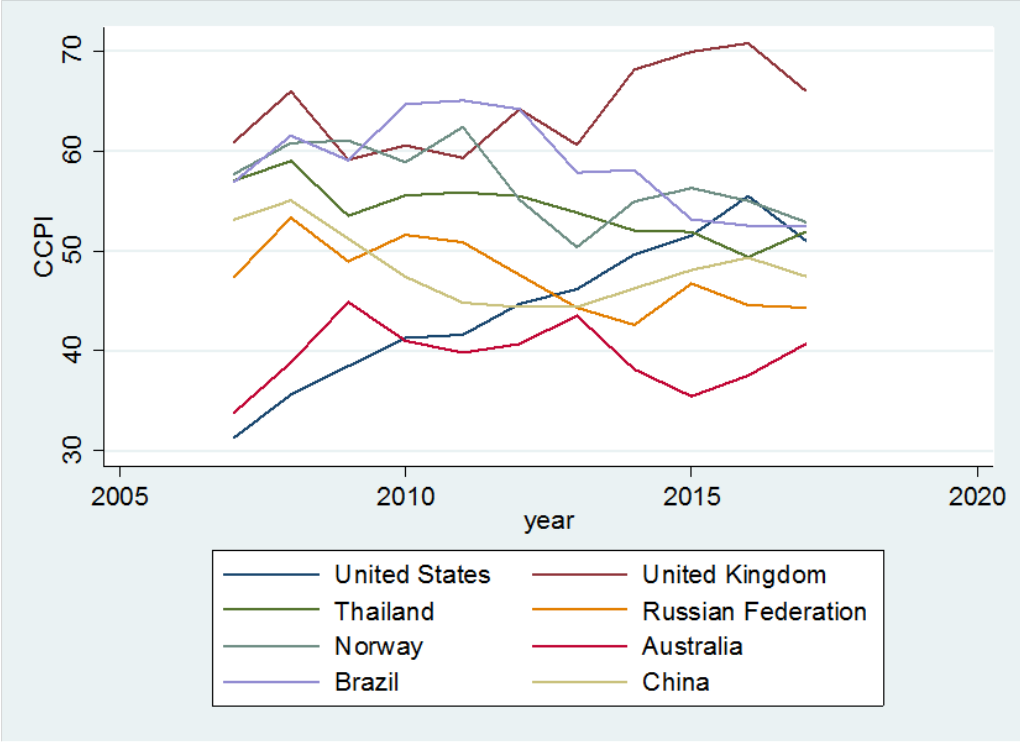
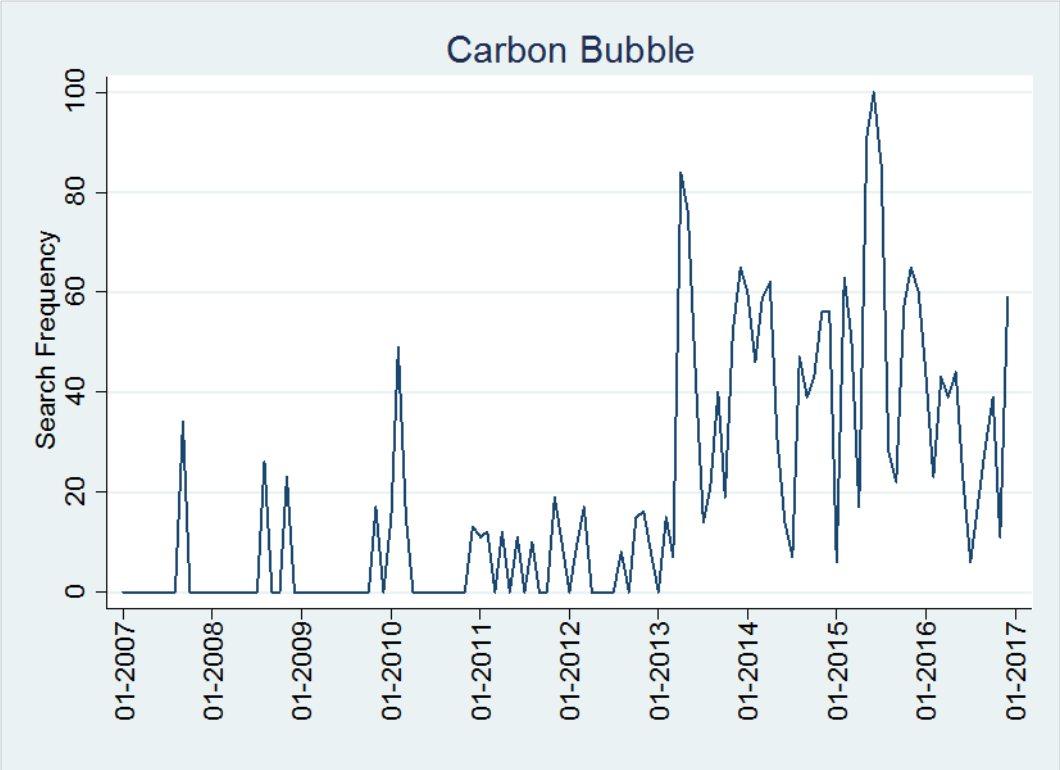


Figure A. 2
The Google Search Volume Index over time

The figure illustrates the evolution of the search terms «carbon bubble» (Accessed 23 April, 2018)