IRCCF HEC MONTRÉAL | International Research Centre on Cooperative Finance

WORKING PAPER

Banks and environmental sustainability: Some financial stability reflections

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October 2017

Abstract

A growing consensus exists that climate change risks have important implications for financial stability. Following Weyzig et all (2014) methodology, this paper quantifies the (syndicated) loan exposure to elevated environmental risk sectors of the banking system in the US, EU, China, Japan and Switzerland in USD 1.6 trill and highlights the importance in terms of total banking assets. Hence, the relevance of exploring prudential policy responses including a harmonized statistical and reporting framework, which could contribute to internalizing the negative externalities associated with climate risks by both banks and their supervisors. Among the prudential supervisory tools, credit registers facilitate the assessment of environmental risk drivers in "carbon stress tests" (ESRB, 2016) formulated to assess the sensitivity of loan quality to changes in climate risk factors such as disruptive technology shocks. These recommendations could contribute to make the Recommendations of the Task Force on Climate operational – related Financial Disclosures for banks (TCFD b, June, 2017).

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The views expressed here are those of the author and do not necessarily represent those of Bank of Spain or the euro system. The author thanks Kern Alexander and Willem Pieter De Groen for their comments and support to an initial draft; Marco Bardoscia and all the participants of the IWFSAS Conference in Montréal (24th-25th August, 2017), Martin Čihák, Carlos Perez for their suggestions and Anna Gorris for her valuable contribution as research assistants. Any errors are my own.

Introduction

The need for decisive policy action on climate change is broadly acknowledged. Since 1979, international agreements have intended to increase awareness of climate change risks and the associated need to reduce gas emissions. Most recently, the Paris Agreement was adopted at the Paris Climate Change Conference (December 2015) to strengthen the global response to the threat of climate change.[1]

Financial policy and regulation are increasingly recognized as important dimensions of the transition towards a low carbon economy that is consistent with the full implementation of the Paris Agreement.[2] On the one hand, the speed and the smoothness of the transition to a green economy and the adjustment costs could affect systemic financial risks. On the other hand, there is a growing recognition now that the inculcation of green guidelines and standards into bank lending, trading and investment practices are critical for achieving the core mandates of International Financial Organizations, such as the International Monetary Fund (IMF (2015) (a)) and the World Bank. Economic growth and financial development should aim to be economically, socially and environmentally sustainable (IMF (2015) (b)). Furthermore, it is widely accepted that low income developing countries (LIDCs) are especially vulnerable to the projected effects of climate change, and will need significant support in the form of concessional climate finance to support adaptation efforts (IMF (2015)(c)).

This paper quantifies the direct (syndicated) loan exposure to elevated environmental risk sectors of the banking systems in the European Union (EU), Switzerland, the US, Japan and China. Against this backdrop, this paper analyzes some of the most relevant challenges posed to banks and their regulators by the transition to a low carbon economy. Also, it explores potential prudential policy responses, which could

[1] United Nations Framework Convention on Climate Change (see http://unfccc.int/paris_agreement/items/9485.php accessed 13th December, 2016). Specifically, its objectives were to: (i) hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change; (ii) increase the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development; and (iii) to promote more consistent financial flows towards low greenhouse gas emissions and climate-resilient development." See http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf accessed 9th September, 2016.

[2] See Bank of England (BoE), 'Breaking the Tragedy of the Horizon – Climate Change and Financial Stability' (Lloyd's of London, 29 September 2015) speech given by Governor Mark Carney http://www.bankofengland.co.uk/publications/Documents/speeches/2015/speech844.pdf., See also (ESRB, 2016) and Alexander (2014), .

contribute to internalizing the negative externalities associated with climate change by both banks and their supervisors. Differently from Battiston et all (2016), who use a network analysis of the exposures of all financial actors to all climate-relevant sectors of the economy as well as the exposures among financial actors themselves across several types of financial instruments, this paper focuses on banks´ direct exposures. The paper is divided into three sections in addition to this introduction.

Section one explores the impact of the transition to a green economy on the banking system and quantifies the corporate exposures of the banking systems in the US, EU, China, Japan and Switzerland to economic sectors facing elevated environmental risks using similar methodology used by Weyzig et all (2014). The large magnitude of those bank corporate exposures and the ambitious goal of reducing gas emissions highlight the role of financial regulation and supervision when dealing with climate change as explained in Section two. In particular, the paper presents the statistical frameworks for the classification of economic activities, which allow for the identification of economic activities exposed to elevated environmental risks. Also, this section discusses the needs of supervisory reporting to assess environmental risks using the EU framework as an example. This section includes a stylized microprudential "carbon stress test" as well as a conceptual framework for potentially "new" prudential regulatory requirements to account for environmental risks. The last section concludes and reflects on future policy developments.

1. The impact of the transition to a low carbon economy on the banking sector

The analysis of the complexity of the potential risks to the financial sector is still at an early stage. The Financial Stability Board (2015) has classified climate-related risks into three broad categories: Physical, liability and transition risks. The physical consequences of climate change extend beyond the direct impact of natural disasters. Physical risks also refer to the impact on insurance liabilities and the value of financial assets that may arise from climate related events that damage property or disrupt trade. In the financial sector, these losses have consequences most immediately for the insurance and reinsurance sectors, but also extend more widely (e.g. banks);[3] liability risks arise when parties who have suffered loss or damage from the effects of climate change seek compensation from those they hold responsible. Such claims could come decades in the future, creating liabilities for carbon extractors and emitters and their insurers. In the financial sector, these losses have consequences most immediately for the insurance sector, but also extend more widely (e.g. banks). Transition risks are the financial risks,

[3] Financial institutions in the general insurance and reinsurance sectors are well ahead of other financial intermediaries in modeling catastrophe risk for the purpose of establishing regulatory capital requirements. Swiss Re Economic Research and Consulting suggests that climate change is increasingly posing a financial threat to the industry, with insured losses from weather events up globally 6.6% on average in the past 25 years and a record number of natural catastrophes in 2014 (189).

which could result from the transition to a low-carbon economy. Changes in regulation, technology and physical risks could prompt a reassessment of the value of a large range of assets. The abruptness with which such re-pricing occurs could influence financial stability. In the financial sector, these losses have consequences most immediately for the banking and asset management sectors but also extend to the insurance sector.[4]

Controlling climate change risks requires a decisive shift away from fossil fuel energy and related physical capital. At the same time, the long-term horizon of the commitment to reduce emissions (2030) and the costs of short-term action reduce the credibility of some existing commitments.[5] There are reasons why investors are less attracted to environmentally friendly projects. For example, the maturity mismatch is a particular constraint in financing environmental friendly projects because they have comparatively higher capital expenditure and considerable uncertainty exists regarding the future of technological innovation aimed at reducing carbon emissions (Weitzman (2013), EU High-Level Expert Group on Sustainable Finance (2017)). Against this background, there is considerable uncertainty about whether the shift to a low-carbon economy will be gradual and benign – or late and abrupt.

There are two scenarios for such transition to a low carbon economy, with different implications for financial stability in general and the banking sector in particular: First, a gradual and smooth transition to a low carbon economy in which governments provide market certainty and markets provide reliable signals. A smooth transition would require significant and realistic investments in infrastructure (i.e. renewable energy), new technology (i.e. energy storage) and energy efficiency, which will have an overall positive effect on the economy. This would allow the economy to smoothly endogenize changes associated with the transition (e.g. technological progress would contribute to keeping energy costs at manageable levels and physical stocks of carbon-intensive energy sources would be replenished). Overall bank credit quality and the performance of investment portfolios would be resilient during the transition (Stern, 2008; Acemoglu et all 2012). This scenario implies that policy makers intervene in one or more of the following ways:

[4] Bank of England (BoE), 'Breaking the Tragedy of the Horizon – Climate Change and Financial Stability' (Lloyd's of London, 29 September 2015) speech given by Governor Mark Carney (http://www.bankofengland.co.uk/publications/Documents/speeches/2015/speech844.pdf accessed 9th September, 2016).

[5] As of August 2015, 26 countries and territories accounting for more than 55% of global GHG emissions have submitted Intended National Determined Contributions (INDCs) with a 2030 target year (2025 in the case of the US) (Morgan Stanley, 2015). However, power plants that use combustible organic material, as oil, coal, or natural gas can operate for up to 40 years and investment in alternative energy has been dampened by unexpected changes in its regulation (e.g. retroactive government plans to curb revenues of already operating projects in Bulgaria and Romania; retroactive changes of tariffs in Germany).

(i) technology standards where regulators specify the technologies that potential polluters may adopt (e.g. emission limits).[6] This is a centralized form of pollution control which is typically applied uniformly across emission sources due to administrative and enforcement costs;

(ii) emission taxes as per unit of pollutant (prices).[7]

(iii) quotas or transferable permits in a centralized government created market. An emission permit is a permission to pollute. The total number of permits and the initial distribution among the various polluters are assigned by government agencies and polluters emitting in excess of their allowances are subject to monetary penalties that incentivize trade (cap and trade): Emission Trading System (ETS). Carbon trading schemes for emission rights (ETS) are the most popular pricing mechanisms.[8]

Second, although policy makers encourage reductions of emissions, the market signals for future investment are unclear. Newell et all (2014) argue that the evolving nature of carbon markets and associated design changes imply that governments cannot provide market certainty, increasing the likelihood of a late and abrupt transition to a low carbon economy. The consequences of an abrupt transition would be a sharp rise in energy costs; a severing of the energy supply; sudden depreciation of fossil reserves and economic obsolescence of investments and other capital stocks; as well as a downward revaluation of the market value of firms according to their exposure to carbon-intensive resources and technology.

In particular, such an adverse scenario could affect banks' exposure to systemic risk via the following transmission channels:

- GDP growth as a result of supply and/or demand disruptions caused by (1) the adverse effects of direct environmental hazards (e.g.

[6] For example, Morgan Stanley (2017) expects car OEMs to add new technology (hybrid or electric) to meet planned EU emission standards of annual reduction of 3% and 1% of gCO2/Km respectively from 2016-2020. Otherwise, car OEMs face heavy fines up to € 3 bill and almost 10% of the market capitalization for some EU manufacturers.

[7] Countries adopting emission taxes include Mexico, Japan, Denmark, Finland, France, Norway, Portugal, Sweden, S. Africa (2017) and Chile (2018).

[8] Jurisdictions undertaking carbon trading schemes include: the EU, California and China (merging seven regional pilots into a national ETS (2017)). The combined value of the regional, national, and subnational carbon pricing instruments in 2015 is estimated at just under US$50 billion globally, of which almost 70 percent is attributed to ETSs and about 30 percent to carbon taxes. The existing carbon prices vary significantly—from less than US$1 per tCO2 e to US$130 per tCO2 e. The 85 percent of emissions are priced at less than US$10 per tCO2 e, which is considerably lower than the price that economic models have estimated is needed to meet the 2°C climate stabilization goal, which according to CISL (2015) ranges from USD50 to more than USD300 per tCO2 e (World Bank , 2015).

drought) or severe natural or man-made disasters (e.g. deforestation); (2) regulatory and other policy initiatives that seek to mitigate or prevent said environmental hazards (e.g. carbon taxes) and, (3) disruptive technological shocks related to the management of environmental risks (e.g. improvements in technology of solar panels);

- Direct exposure to "stranded assets" and high environmental risk sectors: financial assets whose underlying value depends on the extraction or usage of combustible organic material such as oil, coal, or natural gas
- Second round effects due to the financial system indirect exposures to carbon intensive assets and the global nature of climate change risks

1.1 Impact on GDP growth.

Economic growth is dependent on an adequate supply of energy. Disorderly transition to a green economy could result in reductions in the supply of energy, resulting in increased energy prices and production costs with effects equivalent to a large and persistent macroeconomic shock (ESRB, 2016). Increased energy costs would be particularly disruptive in carbon intensive industries (e.g. mining and unregulated utilities and power companies). Other sectors could face similar risks, albeit at a lower level (e.g. automobile manufacturers; oil and gas; steel; chemicals; building materials and power generation projects). Historical analysis of oil prices shocks shows that even small shocks to the cost of energy have substantial effects on real GDP growth (Killian, 2014). Changes in the price of fossil energy sources are one of the inputs in macroeconomic forecasts.

For example, the National Institute's Global Econometric Model (NiGEM),[9] often used in macroeconomic forecasts, is an integrated large global macroeconomic model, which assesses the impact on GDP,[10] inflation and unemployment of changes in the price of fossil sources of energy including oil, gas and coal as well as in the price of agricultural raw materials and global food. The impact on macro-economic variables is assessed using changes of the above mentioned prices, both separately or in combination, over forty four countries, six regions of the world, which include those most affected by climate change (e.g. Malaysia and South America) as well as the world economy.[11]

[9] See https://nimodel.niesr.ac.uk/index.php?t=1&b=1 accessed 16th March, 2016.

[10] Intensity of output (coal); Intensity of output (gas); Intensity of output (oil gas and coal); Intensity of output (oil).

[11] NiGEM has discrete models for 44 countries: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Russia, Slovakian Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, U.K.,

Common shocks include among others changes in commodity prices.[12] The NiGEM macroeconomic model also includes the technological progress instrument among its supply variables.

The IMF uses this model to simulate a multi-period scenario of GDP shocks that mirrors the impact of natural disasters on GDP.[13] For example, in the case of Samoa, the IMF's World Economic Outlook allows for the simulation of shocks that mirror the cyclone event of 2014 and its impact on GDP growth. The multi period scenario solvency stress test is based on shocks that mirror the cyclone event of 2014 and its impact on GDP growth. In these forecasts, it is generally assumed that GDP growth recovers to baseline growth over the forecast time period.[14] Acevedo Mejía (2016) estimates the relation between hurricane wind speeds and damages in the Caribbean. The author estimates that the average annual hurricane damages in the Caribbean will increase between 22 and 77 percent by the year 2100, in a global warming scenario of high CO2 concentrations and high global temperatures.

GDP growth can also be affected by changes in the cost of capital, which, in turn, might be negatively affected by uncertainty about temperature shocks due to climate change. The cost of capital represents a new channel that may contribute to the cost of climate change assessment. Using the Arbitrage Pricing Theory (APT), in which temperature shocks are a systemic risk factor, Balbers et all (2016) assess the weighted average increases in the cost of equity capital attributed to uncertainty about temperature changes as well as its impact on GDP growth in the US.

Brazil, Canada, Mexico, U.S.A., Australia, China, Hong Kong, India, Indonesia, Japan, Rep. of Korea, New Zealand, Singapore, Taiwan, Vietnam) and 6 regions of the world Africa, Middle East, Latin America, Developing Europe, Central Independent States, East Asia South Africa.

[12] See https://nimodel.niesr.ac.uk/index.php?t=1&b=3 accessed 16th March, 2016

[13] See https://www.imf.org/external/pubs/ft/scr/2015/cr15192.pdf accessed 16th March, 2016.

[14] Most exposed to natural disasters are developing economies with limited capability to develop technological solutions to manage environmental risks (e.g. carbon capture storage, renewable energy), countries with low GDP/ per capita or those where the agricultural sector exposed to climate change represents a high share of GDP. Under a 2°C warming scenario, the share of the land surface affected by extreme heat is projected to be 30 percent in the Middle East and North Africa, 30– 40 percent in Latin America/Caribbean, and 45 percent in Sub-Saharan Africa (SSA), as compared, for example, with 10–15 percent of land in Europe and Central Asia. Projected global warming is expected to lead to higher precipitation variability and increased evapotranspiration in warmer climates: in a 2°C warming scenario, water runoff is expected to fall by 30–50 percent in SSA and 10–30 percent in Latin America (IMF, 2015). Insurance cannot offset all of the economic impact of a natural disaster. Even with insurance coverage at 100% because it takes time to rebuild infrastructure and other capital investment. During that time, government spending is likely to be at least as high as in the absence of a natural disaster while tax receipts will fall comparatively short, leading to a deterioration of the fiscal position (S&P, 2015).

1.2 Banks' direct exposure to "stranded assets" and economic sectors facing elevated environmental risks

Rapid downward revaluation of carbon intensive assets due to very rapid obsolescence would have an impact on banks with direct exposure to companies with high environmental risk (mining, oil and gas, etc.). Such carbon intensive assets would become "stranded assets", constraining the ability of some companies to refinance their debt when it matures (Carbon Tracker, 2013).[15] The so called "carbon bubble" is one of the most studied risks to the financial system. It refers to the over valuation of fossil fuel reserves and, more generally, to assets of high environmental risk sectors in the event of the world's economies meeting the agreed objective of limiting yearly carbon.

Companies in these sectors are very much debt financed either by the bond markets or by the banks. Moreover, they have increased their indebtedness since the financial crisis, especially in the US and emerging markets. For example, companies in the oil and gas sectors almost tripled their levels of debt from 2006 to 2014.[16] High leverage will increase the severity of the credit losses and debt repricing in the face of a large fall of these asset prices.

Weyzig et all (2014) have estimated equity, bond and credit exposures of EU financial institutions to firms holding fossil fuel reserves (oil, gas and coal) and to fossil fuel commodities. In this section, we analyze the involvement of the banking system in the United States (US), EU, Japan, China and Switzerland in loans issued to corporates in high environmental risk sectors as per Moody's (2015b) classification, which also includes, among others, automobile manufacturers, independent oil and gas exploration and production, mining, steel, commodity chemicals.

Moody's (2015)(b) has quantified the rated market debt issued by sectors exposed to immediate elevated environmental risks (coal and unregulated power and utility companies) over the next three to five years in USD 512 billion (November, 2015).[17] Lower demand for coal and increasing cost to mine and use coal together with the policy support for renewable energy will put pressure on producers' margins. At the same

[15] Stranded assets whose underlying value depends on the extraction or usage of combustible organic material as oil, coal, or natural gas.

[16] See data in CISnet.com (http://csimarket.com/Industry/industry_Financial_Strength_Ratios.php?ind=107, accessed 29th August, 2017).

[17] For the purpose of assessing its impact on credit quality and ratings, Moody´s defines environmental risk as falling broadly into two categories: (a) adverse effects of direct environmental hazards, such as pollution, drought or severe natural or man-made disasters and (b) regulatory and other policy initiatives that seek to mitigate or prevent direct environmental hazards or perceived hazards.

time, coal terminals that benefit from long-term contracts are exposed to counterparty risk and the underlying economics of project contracts, which may need to be renegotiated at or even before maturity. In contrast to their regulated peers, unregulated power and utility companies such as coal plants and gas filled plants are directly exposed to the market impact of environmental regulations and do not receive the benefit of cost recovery from taxpayers. All of which poses higher financial risks.

Moody's also identifies eight further sectors as facing "emerging, elevated risks" over the next three to five years: automobile manufacturers, independent oil and gas exploration and production, mining, steel, commodity chemicals, building materials, oil and gas refining and marketing and power generation projects. These sectors account for about $1.5 trillion of rated debt. Since the credit impact is not as immediate, issuers in these sectors have more flexibility in responding to regulations, in developing or adjusting to technology, in the timing for required capital expenditures to remedy or prevent environmental hazards (assuming governments can provide market certainty), and in passing on expected cost increases to customers or taxpayers. This risk could be reassessed given that the long-term impact on demand from policies to reduce carbon emissions remains difficult to predict in scope and pace in spite of the specific target set by the United Nations Framework Convention on Climate Change (UNFCCC) given the uncertainty surrounding global policies in this area.

Sectors exposed to high environmental risks also obtain financing from banks. Table 1 shows total estimated value of outstanding loans to high environmental risk sectors as of December 2014. In light of the lack of clear internationally agreed definition of "green" vs "brown" industries, this paper follows Moody's (2015)(b) classification of rated debt for the following industry sectors with immediate or emerging elevated exposure to environmental risks.

- Mining - coal
- Unregulated Utilities and Unregulated Power companies
- Power generation
- Oil and gas: refining and marketing; independent exploration and production.
- Building materials
- Chemicals-commodity.
- Steel
- Mining-Metals and other materials excluding coal
- Automobile manufacturers

Annex I shows NACE 2 Rev (two to four digits) and SIC[18] (four digits) codes corresponding to these economic activities with immediate and emerging elevated

[18] SIC 1987 is the classification used by Thomson One BANKER for the syndicated loans.

environmental risk used in the loan classification.

In order to assess the exposure of the banking systems of the US, EU, Japan, China and Switzerland to loans issued to corporates in the above-mentioned high environmental risk sectors, I have used Thomson ONE financial database for syndicated loans.[19] Similarly to Weyzig et all (2014), I have used financial databases on the banks' role as book runners for syndicated loans; that is, as the lead arrangers who also provide a large share of the actual lending. Loans are outstanding on 31 December, 2014 and I have assumed linear amortization of loans issued before that date and with maturity after that date. This study includes the largest banks from the above-mentioned countries with financial information available in SNL Financial and EU banks with financial information available in the ECB database on 31 December, 2014.[20] By assessing the relative share of the ten largest (or total reporting if less) banks´ exposure to each high environmental risk sector in relation to their total assets, these findings can be extrapolated across sectors in the respective country (US, EU, China, Japan, Switzerland) to give an indication of the respective country banking system total loan exposure to high environmental risk sectors. Comparisons are limited by differences in accounting frameworks between countries.

The total estimated value of the outstanding loan exposures to high environmental risk sectors in the US, EU, Japan and Switzerland account for about USD 1.6 trillion. See Table 2. Overall, approximately 32.5% of the total value of the facilities to high environmental risk sectors was provided to companies involved in the exploitation of oil and gas and 27% of that same value was lent to power generation companies. Automobile manufactures were recipients of 13.2% of the total estimated value of outstanding loans to high environmental risk sectors as of December 2014. The remainder was financing chemicals, building materials, steel, unregulated utilities and mining (coal and metals).

The value of outstanding loan exposures to high environmental risk sectors account for approximately 3.8% of the total assets of US banks; 1.4% of the total assets of EU banks; 0.5% of the total assets of Chinese banks; 2.2 % of the total assets of Japanese banks and 2.1 % of total assets of Swiss banks. In the US, the highest exposure of an individual institution is 6.1%[21], while in the EU the highest exposure of an institution is 8.7%.[22] In

[19] Syndicated loans are considered the bulk of the bank financing to the high environmental risk sectors.

[20] We have excluded subsidiaries and branches of banks from foreign countries.

[21] PNC Financial Services Group, Inc.

[22] Podravska Banka

China, the highest exposure is 0.8%.[23] In Japan, the highest exposure is 3.7%.[24] In Switzerland, the highest exposure is 3.4%.[25]
The EU shows the largest value of outstanding loans to high environmental risks sectors followed by the US, with approximately 72% of the EU exposure, followed by Japan, China and Switzerland. In the US, EU, Japan and Switzerland, the largest proportion of high environmental risk corporate loans is concentrated in oil and gas companies followed by power generation companies. In China, the largest proportion of high environmental risk corporate loans is concentrated in power generation companies followed by oil and gas companies. Table 2 shows total estimated value of outstanding loans to high environmental risk sectors in the EU countries as reported to Thomson ONE Banker on December 2014. The UK shows the largest exposures, in particular to the oil and gas sectors followed by Germany with largest exposures to power generation followed very closely by the automobile sector. In France, the largest exposure to high environmental risk sectors is to oil and gas followed by power generation sectors.

The environmental risk assessment of bank exposures should go hand in hand with the understanding of the credit risk involved (e.g. type of lending instrument, whether revolving facilities vs. project finance). Table 3 shows the breakdown of corporate loan exposures by type of loan to high environmental risk sectors in the US, China, EU, Japan as reported to Thomson ONE Banker in December 2014. The largest value by type of loan corresponds to revolving credit facilities, overdraft facilities and floating rate notes (approximately 60% of the total loan exposure), which provide companies with the option to take up financing from a bank (often a banking syndicate). The value of revolving credit facilities in Table 3 represents total committed amounts, not necessarily fully called upon. The typical maturity of revolving facilities is five years and they are often renewed; but many companies renegotiate (interest rates, fees) their revolving credit facility every year. Term loans are next important in terms of value (approximately 35%) followed by bridge loans and working capital and acquisition facilities (approximately 3%), which are generally used for general corporate purposes. Trade finance, which is short term and low credit risk, accounts for approximately 1.2% of the analyzed syndicated loans. High credit risk project finance[26] and senior unsecured long term debt account for less than 1% of total syndicated loans.

[23] Bank of China Limited

[24] Mizuho Financial Group, Inc.

[25] Credit Suisse Group AG

[26] Acknowledging that project finance may involve large risks for the environment, the Equator Principles were established in 2003 to provide banks with voluntary guidance for incorporating environmental and social risks into the bank's assessment of credit and operational risks in large infrastructure investment projects. As a result, many large global banking institutions have mainstreamed environmental governance principles into project finance (see http://www.equator-principles.com/resources/equator_principles_III.pdf accessed 5th January, 2017).

In the EU, close to 80 percent of loans to high risk carbon assets have remaining maturity within the next five years, which is comparable to Moody's time horizon to assess the impact of environmental risks on credit quality of market issued rated debt.

Not only banks will suffer because of the deterioration of the credit quality of loans. The same could happen to pension funds and insurance companies because of the asset repricing due to an abrupt transition to a low carbon economy, which would have a negative impact on the debt value and stock price of companies operating in those sectors.

1.3 Second round effects due to the financial system indirect exposures and the global nature of the climate change risks

In addition to the first round effects due to direct exposures of the banking system to carbon intensive sectors, the sudden and disorderly re-pricing in a "hard landing" transition to a low carbon economy could trigger systemically relevant second round effects. These could extend to the corporate bond and leveraged loan markets, reflecting uncertainty about the extent to which firms of other sectors of the economy could be affected directly or indirectly by the disorderly re-pricing (ESRB, 2016; Schoenmaker and Van Tilburg, 2016). We should bear in mind that, for the most part, corporations exposed to environmental risk show high leverage ratios (e.g. power generation, oil and gas, mining and coal as well as chemicals).[27]

Not only banks but other financial intermediaries (pension and insurance funds, investment funds and other credit institutions) also have major direct exposures to high environmental risk sectors. Moreover, there are large indirect exposures of banks and other financial intermediaries to high environmental risk sectors (e.g. interbank obligations, pension funds holdings of equity shares of investment funds, bonds and bank loans; investment funds holdings of equities and bonds), which could increase considerably the direct environmental risks. Battison et all (2016) make an assessment of this indirect exposures for the euro area and concludes that pension funds have more indirect than direct exposures to climate risk.

2. What role for financial policy?

The overriding objective of financial policy is to safeguard financial stability and

[27] See data in CSI Market.com (http://csimarket.com/Industry/industry_Financial_Strength_Ratios.php?ind=202 accessed 25 August, 2016).

build resilience to shocks, wherever the shocks may come from.[28] Policy makers are encouraged to use a systemic approach to identifying, assessing and managing the potential risks that climate change could pose to financial stability. Policy action in response to the potential systemic risk involved in the transition to a low carbon economy could have short and medium term horizons.

2.1 Short term policy responses: Some proposals

The short-term policy response heavily relies on better understanding of: (i) banks' and other connected financial firms' direct exposures to non-financial firms with environmental risks and (ii) the consequences of a disorderly transition to a low carbon economy. Better disclosure of bank exposures would facilitate a timely assessment of potential risks to financial stability and promote a "smooth rather than an abrupt transition towards a lower-carbon economy."[29] The following regulatory framework and policy initiatives would better support understanding of climate risks:

2.1.1 A reliable and fully harmonized statistical framework as well as effective disclosure

Such a statistical framework would allow business, financial institutions, governments and rating agencies to have access to reliable and comparable statistical data. To that end, it is vital that the various categories for classifying economic activities are interpreted uniformly. The NACE Rev 2 (two to four digits) and the International Standard Industrial Classification (SIC) (four digits) classification frameworks allow for a relatively precise identification of economic activities exposed to risk in the transition to a low carbon economy. For example, in the European Economic Association (EEA) countries, the NACE Rev 2 classifies economic activities and subsectors of the economy and it is directly linked to the SIC of all economic activities as adopted by the Statistical Commission of United Nations (Rev 4).[30]

However, a good statistical classification method is not enough. Effective disclosure requirements is being set up for banks and other financial intermediaries playing a key role in improving governance by improving transparency for investors regarding their

[28] G20 Communique Pittsburgh Summit Sept 2009 (see http://www.g20.utoronto.ca/2009/2009communique0925.html); Seoul G20 Summit (see http://www.g20.utoronto.ca/2010/g20seoul.html). Accessed 4th October, 2016.

[29] See FSB, Developing Climate-related Financial Disclosures http://www.fsb.org/what-we-do/policy-development/additional-policy-areas/developing-climate-related-financial-disclosures/ accessed 4th January, 2017.

[30] Regulation (EC) No 1893/2006 of the European Parliament and of the Council of 20 December 2006 establishing the statistical classification of economic activities NACE Revision 2 and amending Council Regulation (EEC) No 3037/90 as well as certain EC Regulations on specific statistical domains (OJ L 393, 30.12.2006, p. 1).

involvement in unsustainable economic activity. Institutional investors are often questioning banks´ efforts to mainstream sustainability challenges into their business models as well as their strategies.[31] In this regard, the EU requires disclosure of non-financial information, referring, inter alia, "to environmental aspects such as renewable and/or non-renewable energy land and water use, air pollution, greenhouse gas emissions and the use of materials."[32] The obligation to disclose applies only to large listed credit institutions and large listed insurance companies, which are parent undertakings of a large group, in each case having an average number of employees in excess of 500, in the case of a group on a consolidated basis. This obligation does not prevent Member States from requiring undertakings and groups' disclosure of non-financial information other than that subject to this requirement by the Directive. In fact, there is a wide diversity of institutions covered by this disclosure requirement across European countries. Some countries have implemented the minimum requirements, but others, implicitly or explicitly, have included a number of other entities such as investment companies, large non-listed companies according to precise size criteria, state owned companies, pension funds, etc. Such reporting should be based on current best practices both at national but also international level.[33]

[31] Transparency is just one dimension of banks´ good corporate governance. The Basel Committee's Corporate Governance Guidelines for Banks adopted in 2015 include a number of key concepts that are directly aligned with the consideration and management of environmental and social issues, namely: (i) a recognition of the impact of banks on the broader setting in which they operate ("*the board should actively engage in the affairs of the bank and keep up with material changes in the bank's business and the external environment*"); (ii) a recognition of banks' accountability to a broad array of stakeholders ("*either code of ethics or a code of conduct is intended to foster a culture of honesty and accountability to protect the interest of its customers and shareholders")*; (iii) an emphasis on the need for an enhanced risk culture ("*The sophistication of the bank's risk management and internal control infrastructure should keep pace with changes to the bank's risk profile, to the external risk landscape and in industry practice*"); and (iv) the call for ethical and responsible behavior ("*reinforcing appropriate norms for responsible and ethical behavior")*. (See https://www.bis.org/bcbs/publ/d328.pdf accessed 5th January, 2017).

[32] Whereas clause 17, Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups (L330, OJ 15.11.2014).

[33] Union-based frameworks such as the Eco-Management and Audit Scheme (EMAS), or international frameworks such as the United Nations (UN) Global Compact, the Guiding Principles on Business and Human Rights implementing the UN 'Protect, Respect and Remedy' Framework, the Organisation for Economic Co-operation and Development (OECD) Guidelines for Multinational Enterprises, the International Organisation for Standardisation's ISO 26000, the International Labour Organisation's Tripartite Declaration of principles concerning multinational enterprises and social policy, the Global Reporting Initiative, or other recognised international frameworks.

Despite inaction at the international level, the Financial Stability Board (FSB) convened a public-private conference in London in September 2015 to enhance the understanding of the implications of climate-related issues for the financial sector and discuss the potential contribution of early regulatory action to address financial stability risks can make, in particular enhanced disclosures about carbon and related climate risks and exposures.[34] The dedicated Task Force on Climate-related Financial Disclosures (TCFD) delivered final recommendations to the G20 on climate related financial disclosures adoptable by all organizations and supplemental Guidance for the financial sector (including banks) in June, 2017 (TCFD a) and b) 2017). The TCFD recommends that financial disclosures should be provided in banks' main stream or public financial fillings, with strong focus on banks' credit, liquidity, market and operational risks as well as opportunities related to transition to a lower –carbon economy, and that financial disclosures should be designed to solicit decision useful forward looking information on financial impacts.[35]

In the particular case of banks, this paper defends that the TCFD (2017)(b) recommendations could be articulated via (a) improvements in the supervisory reporting with focus on exposures to high environmental risk sectors as well as (b) the performance of a "carbon stress test" as a forward looking exercise to assess the environmental risks short term impact on the transition to a low carbon economy.

2.1.2 Supervisory reporting and other prudential tools to account for environmental risks

This section explores the demands of supervisory reporting that allow for an accurate assessment of the environmental risks, which, in turn, would allow prudential supervisors to assess banks' capital needs. This section focuses particularly on the experience of the EU and, in particular, the recent set up in the euro area. Successful prudential reporting rests on three pillars: (a) regular call reports with granular information on economic activities exposed to elevated environmental risks including concentration risks; (b) banks' assessment of their *Internal Capital Adequacy Assessment Process (ICAAP)* and (c) credit registers requesting regularly granular credit risk data:

[34] Following the London meeting, on 4 December 2015, the FSB created the Enhanced Disclosure Task Force (EDTF) consisting of representatives from private financial institutions to assess what role voluntary disclosure of climate change risks can play in encouraging banks to disclose their climate change risks to regulators, investors, lenders and insurance underwriters. See http://www.fsb.org/what-we-do/policy-development/additional-policy-areas/developing-climate-related-financial-disclosures/ accessed 18 February 2016 and "Task Force on Climate Related Financial Disclosures: Phase I Report of the Task Force on Climate –Related Financial Disclosures" April, 1 (https://www.fsb-tcfd.org/phase1report/ accessed April 1, 2016.

[35] See https://www.fsb-tcfd.org/publications/ accessed 4th August, 2017.

(a) *Call reports to assess the financial condition of banks as well as the sufficiency of their own funds* that allow an accurate assessment of environmental risks require information on credit exposure to sectors with immediate and emerging elevated risks associated with the transition to a low carbon economy. [36] Similarly, the analysis of large exposures to individual creditors with elevated risk in the transition to a green economy would demand granular information at the level of two to four digits in the NACE Rev 2 classification and four digits in the SIC Classification.[37]

For example, in the EU common rule book for the regulatory requirements on equity capital, [38] individual banking groups are required to submit harmonized, consolidated and IFRS consistent quarterly financial statements: FINREP (balance sheet and income statements including the breakdown of loan advances to non-financial firms) and COREP (own funds) do not require detailed information on credit exposure to assess the immediate and emerging elevated risks associated with the transition to a low carbon economy. The classification by sector (18 sectors) is too broad.[39] In COREP, the reporting of large exposures to individual creditors also requires reporting by sector, which, as explained above, is insufficient to identify large exposures to economic activities at risk in the transition to a green economy. The call reports of EU banks would require revision along the above described lines if economists and prudential regulators want to give consideration to environmental risks.

(b) *Banks' assessment of their internal capital adequacy*, which is later assessed by their prudential supervisors, allows regulators to identify material risks and describe their management control. This would include environmental risks.

[36] Only exposures to individual creditors and not to groups of related companies.

[37] TCFD (2017 b) supplemental Guidance for banks recommends disclosure of significant concentration of credit exposure to carbon-related assets (p. 24) broken down by industry, geography, credit quality and average tenor (p.26).

[38] Commission Implementing Regulation (EU) Nº 680/2014 of 16 April, 2014 laying down implementing technical standards with regard to supervisory reporting of institutions according to Regulation (EU) Nº 575/2013 of the EU Parliament and of the Council (L191, OJ 28-6-2014) (http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0680&from=EN accessed 23th February, 2016); keeping the option for supervisors to ask for a less frequent reporting.

[39] Agriculture, forestry and fishing, Mining and quarrying, Manufacturing, Electricity, gas, steam and air conditioning supply, Water supply, Construction, Wholesale and retail trade, Transport and storage, Accommodation and food service activities, Information and communication, Real estate activities, Real estate activities, Administrative and support service activities, Administrative and support service activities, Education, Human health services and social work activities, Arts, entertainment and recreation and Other services.

Banks assess their regulatory capital requirements in the context of a stress test exercise under two plausible scenarios (baseline and stress). This exercise encompasses business risks associated with the transition to a low carbon economy under various hypotheses of what impact such a transition could have on GDP growth (Section 2.2.2 presents the rationale behind the "carbon stress test"). For example, at present, in the EU, banks generally do not assess the impact of risks involved in the transition to a low carbon economy on their loan or bond portfolios. These portfolios are not regularly subject to shock simulations (e.g. sudden economic obsolescence of capital stocks, sudden revaluation of fossil fuel reserves), which would help assess the impact of environmental risk factors on banks' portfolio and eventually on their profits and solvency.[40]

(c) *Credit registers that regularly collect granular credit risk data from banks and other credit institutions.* These databases are composed of detailed and individual pieces of information about instruments giving rise to credit risk, including classification of counterparties according to their economic activities and subsectors of the economy exposed to elevated environmental risks. Credit registers can also provide important breakdowns and details, such as information on the structure (e.g. project finance) and risk patterns of credit granted by the financial sector (e.g. probabilities of default, impairments, maturity, currency, interest rates). In section 2.2.2, the paper analyses the applicability of credit registers in stress testing. For example, in the euro area, the ECB has launched a credit register called Anacredit, which fulfils these requirements to assess the risks associated with the transition to a low carbon economy. [41]

2.2 Medium term policy response

The medium term policy response relies heavily not only on better governance of banks and other financial institutions but also on an effective prudential framework, which would take into consideration the importance of the environmental risks.

[40] TCFD (2017) (b) supplemental Guidance for banks recommends to characterize banks´ climate related risks in the context of risk categories such as credit, liquidity, market and operational risks.

[41] The ECB has the power to impose sanctions on reporting agents that fail to comply with statistical reporting requirements defined or imposed in ECB regulations or decisions. Regulation (EU) 2016/867 of the European Central Bank of 18 May, 2016 on the collection of granular credit and credit risk data (ECB/2016/13) (L144 OJ 1.6.2016).
(see http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R0867&from=ES accessed 5th January, 2017).

2.2.1 Governance of banks' prudential supervision: Revision of the Basel Core Principles for Effective Banking Supervision (BCPs)

The Basel Core Principles (BCPs) last revision in 2012 aimed at promoting best practices in bank prudential regulation and supervision. The BCPs are used as a benchmark for assessing the quality of their supervisory systems and for identifying future work to achieve a common ground of sound supervisory practices.[42] The compliance assessment of BCPs is part of the regular financial sector stability assessments of the IMF and World Bank.

A comprehensive approach to an orderly transition to a low carbon economy would require prudential supervisors of banks to internalize environmental risks in their governance systems and procedures as well as in the prudential framework. Hence, environmental aspects should be included in frameworks for:

- the governance of bank supervision (e.g. licensing criteria; supervisory techniques and tools; internal control and audit);
- the definition of capital adequacy (e.g. Pillar 3 disclosures);
- the risk assessment process of banks (e.g. risk management process that takes into account loan exposures to sectors with immediate or emerging elevated environmental risks and identify, measure, evaluate, monitor, report and control or mitigate concentrations of risk including risks related to the transition to a low carbon economy on a timely basis). For example, in the US, the Office of the Comptroller of the Currency's (OCC) has issued guidelines for supervisors in connection with the supervision of banks "Oil and Gas Exploration and Production Lending." These are guidelines on prudent credit, interest rate, liquidity, operational and reputational risks management;[43]
- the disclosure and transparency requirements (e.g. bank disclosures that reveal among others the processes, including environmental risk assessments and business strategies to incorporate the adjustment costs to the transition to a low carbon economy) and;
- the international coordination among prudential supervisors (e.g. cooperation also encompasses home and host supervisors' assessment of banks' risks exposure to environmental risks as well as systemic risks related to the disorderly transition to a low carbon economy).

Along these lines, it could be argued that the guidelines for assessors of the BCPs should be further revised to require bank supervisors to consider the risk associated to

[42] See http://www.bis.org/publ/bcbs230.pdf (accessed 11 March, 2016).The BCPs were complemented a few years later by similar codes for the supervision of securities operations (IOSCO) and insurance supervision (IAIS).

[43] See https://occ.gov/publications/publications-by-type/comptrollers-handbook/pub-ch-og.pdf accessed 4th October, 2016.

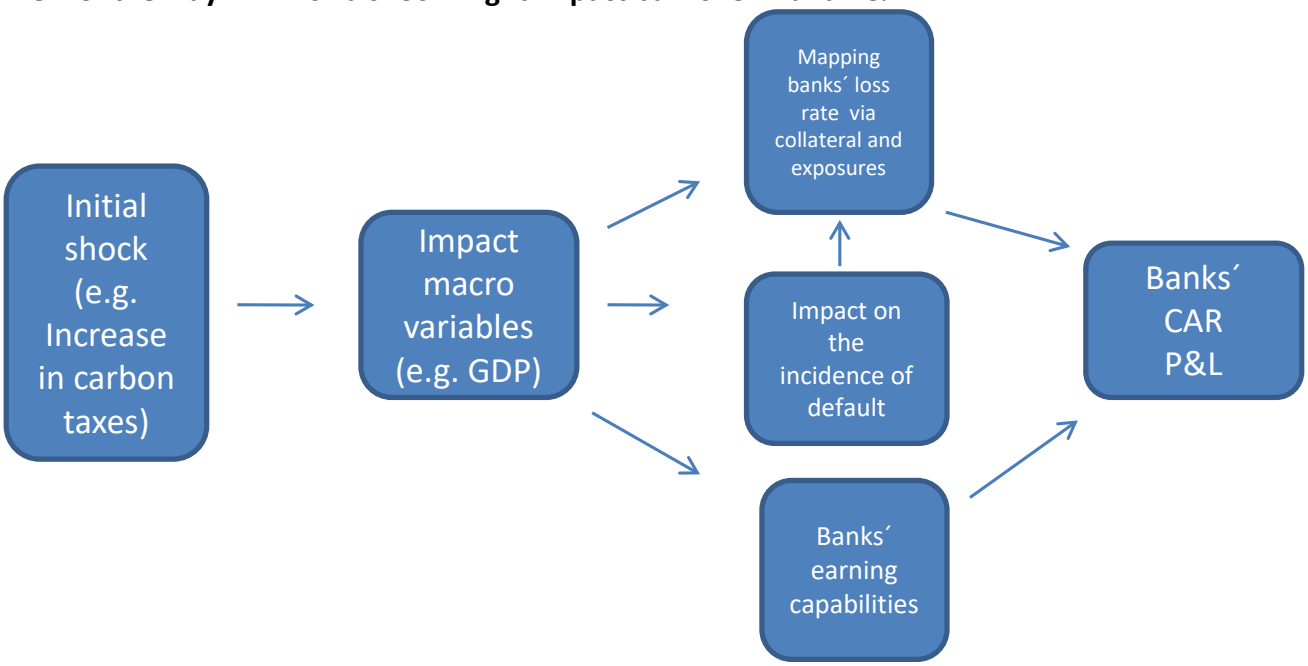
the transition to a low carbon economy in their supervisory practices as well as in the prudential framework.[44]

2.2.2 "Carbon stress test" for banks

ESRB (2016) and Schoenmaker and Van Tilburg (2016) argue that prudential regulators could run "carbon stress tests" to assess the impact on banks' capital and profitability of an adverse scenario consisting in a disorderly transition to a low carbon economy that could affect systemic risk. Hence, the importance of well-articulated models that provide a coherent and consistent framework for assessing to what extent environmental risks pose a challenge for financial stability. Figure 1 shows a stylized representation of the credit risk channel in a "carbon stress test." Note that other channels include market and liquidity risks.

"Carbon stress tests" run by banks can be an effective process by which management is informed about climate related issues, monitors climate related issues and assesses the short term impact of the risks related to the bank´s transition to a green economy (TCFD, 2017 b, p. 23).

Figure 1: Stylized representation of the credit risk channel in a "carbon stress test": View of the way in which a shock might impact banks' CAR and P&L



Source: Author's analysis

[44] See www.bis.org/publ/bcbs130.pdf (accessed 3rd February, 2017). The Core Principles Methodology (2006) is used for assessments of compliance with the BCPs.

However, such models are based on historical experience and do not represent any "best guess" of the way the economy might evolve in the new circumstances (Čihák, 2007). Furthermore, as argued by Battiston et all (2016), climate policies (especially policy inaction) impact on climate change as much as climate change impacts on policies themselves. The intrinsic uncertainty emanating from this interdependence undermines the knowledge of the underlying probability distributions of asset returns, leading in particular to fat tails.

In contrast, in this paper approach to stress testing, correlations and common exposures are of secondary importance. This approach assumes that environmental risks are exogenous. The impact assessment of microeconomic factors or drivers behind individual creditors' default related to the transition to a green economy could greatly benefit from granular credit risk data from banks and other credit institutions. Credit registers provide historic data on risk patterns, ideally over a complete business cycle, which contains valuable information of the historical default frequency distributions and allow the assessment of average PD through the business cycle. The "carbon stress tests" could assess the impact of a driver of environmental risks (e.g. fines for failing to achieve CO2 targets) on the average PD and the stressed PD.

The stressed losses given default (LGD) is the other building block of credit risk modeling in the context of the "carbon stress tests." LGD of credit exposures to environmental risk require an assessment of recovery rates and cure rates.[45] Cure rates take into consideration the probability of recovery of defaulted loans before defaulting (e.g. made possible by sharp declines in technology costs of solar photovoltaic panels). Insurance is not recognized by bank prudential regulation (Basel III) as having impact on recovery values, hence, on LGD.

As is the case with typical bank stress testing, in the "carbon stress tests" for each bank and category of credit risk exposure to environmental risk the losses can be computed by combining the stressed PDs with the stressed LGDs once the timeframe has been defined (generally one to three years) and the shock has been calibrated. Shocks should also take account of path dependencies (e.g. empirics show that a downgrade is more likely after a previous downgrade).[46] The losses can be measured on an incremental basis (in percentage points) against the losses obtained for the projected baseline scenario and/or against losses obtained from PDs and LGDs observed in a reference year. The presentation of outcomes of the "carbon stress tests" exercises is based on two metrics: (a) impact on regulatory capital requirements and (b) the impact on after-tax profits over the defined time frame (provisioning, write-offs, and income arrears).

[45] LGD = (1- Recovery Rate) * (1- Cure Rate).

[46] Asset correlations tend to increase in periods of economic distress. This increases the likelihood of default correlations.

An example of a model to assess the sensitivity of loan quality, for each loan across loan portfolio categories, to changes in macroeconomic conditions as well as climate risks factors is as follows:

$$NPLi,t = \alpha_0 + \beta(Climate\ factor)_{i,t} + \alpha_1\, NPLi,t\text{-}1 + \sum_{s=0}^{K} \beta \mathrm{F}, \mathrm{t} - \mathrm{s}\ \ \mathrm{MACRO\ F,t\text{-}s} + \varepsilon_{i,t}$$

Where *NPLi,t* stands for the logit transformation of non-performing loans as a ratio over total loans of credit institution *i* in year *t*, α_0 stands for the fixed-effect for credit institution i, β gauges the specific climate factor i in year t and MACROF,t-s stands for macroeconomic factor F, in period t-s (s is the time lag). The typical macroeconomic specifications include GDP growth and long-term interest rates but could also include sector economic variables. An example of climate factor for a particular sector/firm is the value of stranded assets due to new disruptive technologies or the value of penalties for failing to achieve CO2 targets over profits before taxes of that particular sector/firm.[47] The regression analysis would show the statistical significance of this environmental factor. Moody's (2015(b)) highlights three primary credit risk factors from carbon-reduction policies for non-financial corporates: Regulatory risks; disruptive technology shocks that would have a negative impact on incumbents with limited capability to adapt their business models and direct costs such as the imposition of carbon taxes or purchase of carbon permits.

- Regulatory risks: Environmental regulations have the greatest potential to change credit profiles of issuers and sectors, primarily in the private sector but also in the public sector. The credit impacts of changes in environmental regulations may be the result of prohibition on certain activities. Also, regulations may permanently alter market dynamics or create incentives for certain technologies or production modes at the expense of others. When regulations are known and transparent, the future credit impact is reasonably visible; moreover, this impact could generally be managed when there is a known transition period before regulations become effective (e.g. like the planned closure of all German nuclear generating stations in 2022). This is not the case when regulations set a target (e.g. to achieve a certain percentage of power from renewable sources or percentage reduction in emissions) with unclear repercussions if targets are not met because there may be political interests that affect the timing and method of implementation as well as the rigor of enforcement. All of these considerations may create uneven playing fields or reduce visibility regarding which issuers' credit profiles will be affected. Thus, it is important to assess a country's institutional framework, its effectiveness and political credibility.

[47] European car OEMs failing to meet the EU 95g CO2/Km target by 2030 from 2016 levels could face penalties of up to €3.1 bn. (VW), €1.9 bn. (BMW), €1,5 bn. (Daimler), €2,3 bn. (Renault) and €1.4 bn. (PSA) (Morgan Stanley, 2017).

- Disruptive technology shocks that would have a negative impact on incumbents with limited capability to adapt their business models. For example, coal producers face long-term demand for carbon-intensive energy but also suffer from other more immediate factors, such as the impact of the US shale gas boom; car original equipment manufacturers (OEMs) are expected to add new technology to meet planned emissions standards, thus accelerating the shift towards electric vehicles.

- Direct costs such as the imposition of carbon taxes or purchase of carbon permits. For example, regulated electricity and gas utilities are exposed to risks of generation plants that face higher economic hurdles resulting from penalties or taxes on their operation or environmental upgrades that are required (e.g. carbon-emitting plants that incur carbon taxes, plants that must buy emissions credits to operate and plants that must install environmental equipment to continue to operate). Although the impact of taxes, credits or upgrades is not as severe as to require plant's likely closure, such direct costs are sufficient to have a material impact on those plants' competitiveness. The differences could be relevant not only among plants but also relative to other generators. The costs could also influence the utility's rates and require environmental expenditures or further expansion of the asset base.

Indeed, further analysis is needed to define climate change risks and understand transmission. Credit risks related to the transition to a low carbon economy merit continued attention as additional information becomes available to inform credit risk assessments.[48] Against this background, the design of consistent and comparable environmental risk exposure data across countries as well as reliable and efficient climate related financial disclosure rules are paramount. At present, although most G20 jurisdictions have some type of rule or regulatory guidance that requires climate-related disclosure for at least some corporations, a limited number pertain directly to climate related financial risks. This can be explained partly by the lack of a generally agreed-upon definition of "material" climate risk that triggers disclosure requirements (TCFD, 2016 p. 15) comparable to the Moody's (2015)(b) definition of sectors exposed to elevated environmental risk.

2.2.3 Conceptual framework for (new) prudential regulatory requirements: Environmental aspects: is there a case for prudential regulation?

If the impact of environmental risks results in credit losses of certain bank exposures (e.g. due to the negative impact on the borrower credit standing as a result of the obsolescence of the technology used for the production of solar panels), such losses

[48] At present, direct climate change hazards are, in general, not a material driver for credit ratings (Moody´s, 2015).

would be covered with loan loss provisions, which would have a negative impact on banks' after-tax profits.[49]

If environmental risks have a permanent impact through the economic business cycle and permanently increase the long term PD of exposures to elevated environmental risk sectors or sovereigns, prudential regulators should consider a revision of the minimum capital requirements. Such revision should be based on the carbon intensity of individual exposures via the increase of the asset risk weights in order to curb banks' incentives to accumulate exposures subject to elevated environmental risks; hence, a penalizing prudential regulation. Indeed, it could be argued that large uncertainty exists about the particular quantification of the impact of the environmental risks, which makes the calibration of risk weights difficult. This subsequent increase of the minimum capital requirement associated to that asset class (including off balance sheet exposures) should cover any unexpected losses due to climate risks. However, it might not be sufficient to promote change in bank behavior and to absorb shocks due to abrupt transition.

If environmental risks have a permanent impact through the economic business cycle and permanently increase the long term PD of exposures to elevated environmental risk sectors or sovereigns, prudential regulators should also consider a revision of banks' large exposures framework. The goal of these measures is to place quantity-based or price-based constraints (or a combination of both) on the amount of exposures to sectors/sovereigns with elevated environmental risk. A quantity-based large exposure limit sets a hard limit on exposures relative to a bank's Tier 1 capital at a level which would trigger a supervisory response.[50] Price based constraints set risk-weight add-ons based on the amount of a bank's exposures to individual corporate / sovereigns exposed to high environmental risk relative to a bank's Tier 1 capital in order to disincentive a build-up of exposure concentration above certain minimum threshold. Disincentives could be based on risk-weight add-ons on incremental steps as large exposures increase as a percentage of Tier 1 capital instead of a flat risk-weight add-on.[51] Alternatively, disincentives in the form of incremental risk weight add-ons could be designed to trigger above certain minimum exposure relative to a bank's Tier 1 capital. Such incremental risk weight add-ons would trigger up to a "hard" concentration limit also defined in terms of bank's Tier 1 capital, which would be calibrated to act as a prudential backstop for outliers prohibiting holdings beyond that threshold level. The calibration of risk

[49] In the context of the IFRS9:
LLP_e (environmental risk provisions) are added to LLP_{cr} (credit risk provisions) and provisions would have a 1 year (normal) or life time horizon (special surveillance).
[50] The existing regulatory threshold is 25%.

[51] The calibration and number of thresholds and risk weight add ons would be determined in the context of a quantitative impact study, with a view to accommodating diversity across countries.

weights and number of thresholds present the same limitations as in the minimum capital requirements.

Last but not least, prudential supervisors should consider transparency requirements via enhancements to the Pillar 3 disclosure requirements in the context of Basel III framework, which could include semi-annual disclosure requirements related to environmental risk exposures to corporate and sovereigns as well as, if appropriate, their risk weights in line with the recommendations of the TCFD (2017)(b).

At present, most supervisory agencies in the G20 countries do not believe that minimum capital requirements (or prudential regulatory requirements in general) should be used to limit environmental risks (Alexander, 2014). Brazil and China have begun to investigate under Pillar 1 of BaseI III whether environmental risks are a material driver for credit and other types of financial risks.

3. Conclusions and some policy reflections

The analysis of the financial stability implications of the potential climate change risks is still at an early stage. The banking sector is most immediately affected by the financial risks associated with the disorderly transition to a low-carbon economy, which could affect banks' exposure to systemic risk both via impaired GDP growth and via banks' exposure to elevated environmental risk assets. Banks are slowly growing aware of these considerations. For example, in November 2016, France's Société Generale has announced that it will stop financing coal-powered electricity plants starting from January 2017 and increase its support for renewable energy projects and scale back outstanding loans to the coal industry.

Following Weyzig et all (2014), this paper assesses the (syndicated) loan exposure to elevated environmental risk sectors of the banking system in the US, EU, China, Japan and Switzerland, which amounts to approximately USD 1.6 trillion as of December, 2014. Overall, approximately 32.5% of the total value of the facilities was provided to companies involved in the exploitation of oil and gas and 27% of that same value was lent to power generation companies. These sectors show high leverage ratios, a fact which aggravates potential systemically important second round effects. Those exposures account for a non-negligible percentage over total assets of the banking systems in the respective countries although comparisons are limited by the differences in the accounting frameworks. In addition, banks are exposed to environmental risks in their bond (corporates and sovereigns particularly in Latin America, the Caribbean and Asia Pacific) and equity portfolios.

Against this background, the objective of prudential policies should be to internalize the potential negative externalities associated with climate change by both banks and their

prudential supervisors. Short term policy action should aim at better understanding the direct exposures to high environmental risk sectors, which demands a reliable and fully harmonized statistical framework that allows both banks and their supervisors for detailed identification of sectors exposed to high environmental risks along the SIC –four digits- (and NACE in the EEA –at least two digits and ideally four-) classification frameworks.

Among the supervisory tools, this paper highlights the importance of credit registers as a tool that facilitates the assessment of environmental risk drivers in microprudential "carbon stress tests" formulated to assess the sensitivity of loan quality to changes in climate factors such as regulatory risks, disruptive technology shocks and/or direct costs such as the imposition of carbon taxes / purchase of carbon permits. Going forward, the identification and calibration of climate change risk factors as well as the calibration of their impact on creditors´ probabilities of default should be matters of priority in future work on "carbon stress tests." To the extent that environmental risks could permanently increase the long-term probabilities of default of homogeneous loan portfolios through the business cycle, prudential regulators should consider a revision of banks' minimum capital requirements and concentration risks.

Last but not least, a comprehensive approach to an orderly transition to a low-carbon economy would require prudential supervisors and banks to internalize environmental risks in their governance systems. Revisions of the assessment methodology of the Basel Core Principles for Effective Bank Supervision should be considered to take into consideration environmental aspects.

In sum, this paper's recommendations would contribute to make the June, 2017 recommendations of the Final Report of the Task Force on Climate –related Financial Disclosures (TCFD) to G20 countries operational.

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Annex 1: Sectors exposed to immediate and emerging elevated risks associated with the transition to a low carbon economy: NACE REV 2 and SIC 1987[52] codes[53]

	NACE REV 2		ISIC 4		SIC 1987	
SECTOR SOLICITADO	Code	Definition			Code	Definición
1.Mining:coal	5,1	Mining of hard coal	510	Mining of hard coal	1221	Bituminous Coal and Lignite Surface Mining
					1222	Bituminous Coal Underground Mining
					1231	Anthracite Mining
					1241	Coal Mining services
					1920	Manufacture of refined petroleum products
					2999	Products and coal products, nec
2.Unregulated Utilities and Unregulated Power companies	35,2	Manufacture of gas; distribution of gaseous fuels through mains	3520	Manufacture of gas; distribution of gaseous fuels through mains	4923	Gas transmission and distribution
					4924	Natural gas distribution
					4925	Gas Production and/or Distribution
					4932	Gas and Other services Combined
3.Power generation	35,1	Electric power generation, transmission and distribution	3510	Electric power generation, transmission and distribution	4911	Electric services
					4931	Electric and other servicies combined
4.Oil and gas: refining and marketing	6,1	Extraction of crude petroleum	610	Extraction of crude petroleum		
	6,2	Extraction of natural gas	620	Extraction of natural gas	1311	Crude Petroleum and Natural Gas (except gasifying, liquefying, and py
	9,1	Support activities for petroleum and natural gas extraction	910	Support activities for petroleum and natural gas extraction	1321	Natural Gas liquids
					1381	Drilling Oil and Gas Wells
					1389	Oil and Gas Field Services, nec
					1382	Oil and Gas Exploration Services
5.Building Materials	23,3	Manufacture of clay building materials	2392	Manufacture of clay building materials	3251	Brick and Structural Clay Tile
					3253	Ceramic Wall and Floor Tile
					3259	Structural Clay Products, nec
					3261	Vitreous Plumbing
	23,4	Manufacture of other porcelain and ceramic products	2393	Manufacture of other porcelain and ceramic products	3262	Vitreous China Table and Kitchenware
					3263	SemiVitreous China Table and Kitchenware
					3264	Porcelain Electrical Supplies
					3269	Pottery Products, nec
	23,5	Manufacture of cement, lime and plaster	2394	Manufacture of cement, lime and plaster	3241	Cement, Hydraulic
					3274	Lime
					3275	Gypsum Products
	23.6	Manufacture of articles of concrete, cement and plaster	2395	Manufacture of articles of concrete, cement and plaster	3271	Concrete Block and Brick
					3272	Concrete Products, nec
					3273	Ready-mixed Concrte
					3275	Gypsum Products
					3292	Asbestos Products
	2013	Manufacture of other inorganic basic chemicals	2011	Manufacture of basic chemicals	2869	Industrial Organic Chemicals, nec
					2819	Industrial Inorganic Chemicals, nec (uranium oxides; radioactive elem
					2869	Industrial Organic Chemicals, nec (organic nuclear fuels)
	2014	Manufacture of other organic basic chemicals			2812	Alkalies and Chlorien
					2813	Industrial Gases
					2816	Inorganic Pigments
					2819	Industrial Inorganic Chemicals, nec
					2861	Gum and wook chemicals
					2865	cyclic crudes and intermediates
					2869	Indsutrial organic chemicals, nec
					2874	Phosphatic Fertilizers
					2895	Carbon Black
					2819	Industrial inorganic chemicals, nec
					2842	Polishes and sanitation goods
					2843	Surface active agents
					2869	Industrial organic chemicals; nec
					2891	Adhesives and sealantas
					2892	Explosives
					2899	Chemicals preparations, nec
					2992	Lubricating Oils and Greases
					3482	Small arms ammunition
					3695	Magnetic and Optical Recording Media
					3861	Photographic Equipment and Supplies
					3952	Lead Pencils and art goods

[52] SIC 1987 is the classification used by Thomsom One BANKER.

[53] Note the equivalence is not identical. For example, NACE-Rev 2014 20.14 equivalent SIC codes includes 20.84 (wines, brandy spirits) and 20.85 (distilled and blended liquors), which have been excluded. Further details available upon request.

	NACE REV 2		ISIC 4		SIC 1987	
7.Steel	241	Manufacture of basic iron and steel and of ferro-alloys	2410	Manufacture of basic iron and steel	3312	Blast Furnaces and steel Mills
					3313	Electrometallurgical products, excep steel
					3315	Steel wire and relates products
	242	Manufacture of tubes, pipes, hollow profiles and related fittings, of steel			3316	Cold-fishing of steel shapes
					3317	Steel pipe and tubes
					3321	Gray and ductile iron foundries
					3399	Primary metal products, nec
	243	Manufacture of other products of first processing of steel			3449	Miscellaneous metal work
					3492	Fluid power valves and hose fittings
					3494	Valves and pipe fittings, nec
					3496	Miscellaneous fabricated wire products (coated wire)
8.Mining-metals and other materials excluding coal	0710	Mining of metal ores	710	Mining of iron ores	1011	Iron Ores
			721	Mining of uranium and thorium ores	1094	Uranium-Radium-Vanadium Ores
					1099	Metal Ores, nec
			729	Mining of other non-ferrous metal ores	1021	Copper Ores
					1031	Lead and Zinc Ores
					1041	Gold Ores
					1044	Silver Ores
					1061	Ferroally Ores, except Vanadium
					1094	Uranium-Radium-Vanadium Ores
					1099	Metal Ores, nec
9.Oil and gas: independent	610	Extraction of crude petroleum	610	Extraction of crude petroleum	1311	Crude Petroleum and Natural Gas
	620	Extraction of natural gas	620	Extraction of natural gas	1321	Natural Gas liquids
10.Automobile Manufacturers	291	Manufacture of motor vehicles	2910	Manufacture of motor vehicles	3519	Internal Combustion Engines, nec
					3711	Motor Vehicles and Car bodies
					3713	Truck and Bus Bodies
					3714	Motor Vehicles Parts and Accessories
					3716	Motor homes
					3743	Railroad Equipment
					3799	Transportation Equipment, nec
					7538	General Automotive Repair Shops
	292	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	2920	Manufacture of bodies (coachwork) for motor vehicles; manufacture of trailers and semi-trailers	2451	Mobiles Homes
					3537	Industrial Trucks and Tractors
					3711	Motor Vehicles and passenger Car Bodies
					3713	Truck and Bus Bodies
					3715	Truck Trailers
					3792	Travel Trailers and Campers
					3799	Transportation Equipment, nec
	293	Manufacture of parts and accesories for motor vehicles	2930	Manufacture of parts and accesories for motor vehicles	3714	Motor Vehicle Parts and Accesories
					3465	Automotive Stamping
					3592	Carburetors, pistons, rings, valves
					3714	Motor vechicle parts and accesories
					3799	Transportation equipment, nec

Table 1: Total estimated value of outstanding loans to high environmental risk sectors as of December 2014 ($ mil)

Sector	US United States	EU European Union	CN China	JP Japan	CH Switzerland
Mining:coal	7,490	12,601	3,543	4,165	678
Unregulated Utilities and Unregulated Power companies	20,970	25,192	1,192	9,275	2,266
Power generation	120,979	201,931	23,547	79,976	14,819
Oil and gas: refining and marketing	199,107	215,285	14,470	83,903	20,581
Building Materials	10,861	24,303	828	26,768	1,326
Chemicals-commodity	44,224	62,178	7,316	43,613	7,010
Steel	19,348	22,867	2,019	15,464	2,286
Mining-metals and other materials excluding coal	19,656	27,318	6,797	12,427	3,329
Automobile Manufacturers	63,121	110,349	9,490	26,374	6,563
Total	505,755	702,024	69,202	301,964	58,858

Source: Thomson ONE Banker- Syndicated loans (bilateral loans are considered of marginal relevance). Exposure is expressed in value terms ($ mil.), and it is the outcome of extrapolating to the whole national banking sector, the same percentage of the 10 largest banks' exposure to high environmental risk corporate exposures to their total assets. Data refer to consolidated banks' balance sheets. The 10 largest banks as per their total assets reported to SNL as of 31 December, 2014 (if, in any country, less than 10 banks report to SNL, we extrapolate those banks' exposures to the entire banking sector of that particular country). We have excluded subsidiaries of foreign banks in our account of the 10 largest national banks. Our focus is on outstanding loans on the banks' balance sheet on 31 December, 2014 assuming the linear amortization of loans from the time of issuance, which is the information provided by Thomson ONE Banker. For each loan, the share of one or more of the analysed banks in the provision of the loans issued to high risk environmental sectors was estimated depending on their role as book runner or common participant following the same methodology as Weyzig et all (2014).

Table 2: Total estimated value of outstanding loans by EU Country and High Environmental Risk Sector ($ mil) December, 2014

Sector	AT Austria	BE Belgium	DE Germany	DK Denmark	ES Spain	FR France	GR Greece	GB United Kingdoom	IE Ireland	IT Italy	NL Netherlands	PT Portugal	SE Sweden
Mining:coal	705	87	3,053	-	883	2,452	316	2,674	-	605	1,245	-	112
Unregulated Utilities and Unregulated Power companies	12	118	3,425	23	1,939	6,134	-	5,739	122	5,874	1,318	297	190
Power generation	1,578	3,989	48,932	386	17,084	35,804	166	59,641	2,968	15,862	8,812	2,134	2,993
Oil and gas: refining and marketing	2,997	816	38,460	954	17,157	50,100	114	66,137	749	10,406	16,587	343	8,715
Building Materials	978	330	5,054	488	4,013	4,892	160	4,380	242	2,097	1,064	102	504
Chemicals-commodity	969	449	20,424	40	3,436	10,209	16	16,868	705	4,282	2,947	875	937
Steel	602	131	6,987	234	1,259	4,348	-	4,582	92	2,279	1,583	97	672
Mining-metals and other materials excluding coal	164	286	2,630	6	1,815	8,439	-	10,319	-	1,395	1,425	-	104
Automobile Manufacturers	4,457	281	47,626	825	5,314	12,686	3	21,995	339	11,904	3,201	47	1,671
Total	12,463	6,487	176,593	2,957	52,900	135,063	775	192,335	5,216	54,703	38,184	3,895	15,899

Source: Thomson ONE Banker. Countries not reporting data either to SNL or Thomson ONE Banker: Czech Republic, Estonia, Latvia, Luxembourg, Slovakia, Cyprus. Countries with no exposure to high environmental risk sectors: Finland, Lithuania, Malta, Romania and Slovenia. Other countries not included in the table that report exposures: Bulgaria ($ 195.58 mil Oil and gas); Croatia ($ 544,71 mil Power generation) and Hungary ($109.74 mil Power generation; $313.87 mil Gas and refining).

Table 3: Total value of outstanding loans by type of lending instrument ($ mil) (US, EU, China, Japan and Switzerland) December 2014

Sector	Term Loan, Multi Loan Facility	Revolving and Overdraft Facility, Float rate nts.	Project finance	Bridge Loan, capital and working capita facilities, adquisition	Trade finance	LT Debt (mezzanine, sub, boll) performance bonds
Mining:coal	16,091	10,665	-	199	1,522	-
Unregulated Utilities and Unregulated Power companies	16,415	39,763	132	2,234	350	-
Power generation	159,515	266,330	2,120	6,462	6,150	122
Oil and gas: refining and marketing	173,461	337,735	-	15,774	5,350	140
Building Materials	28,207	31,733	16	2,337	781	35
Chemicals-commodity	65,709	85,434	-	10,784	653	180
Steel	25,808	32,739	-	1,602	1,812	21
Mining-metals and other materials excluding coal	21,010	46,943	-	567	1,004	4
Automobile Manufacturers	72,586	129,745	-	11,584	1,814	151
Total	578,801	981,087	2,269	51,543	19,436	654

Source: Thomson ONE Banker. Other loans not included in the Table are construction financing, Islamic financing and construction loans ($ 3.99 bill) mostly to the chemical, building material and oil and gas sectors.

The classification by type of instrument is as follows:

- Term Loan and Multi Loan Facility
    - Term loans (A to E)
    - First and Second Lien Term Loans
    - Delayed Draw Term Loan
    - Work capital /Term Loan
    - Multi Loan Facility

- Revolving and Overdraft Facility, Float rate notes
    - Revolving Credit Facility
    - Standby Facility
    - 364D Revolver
    - Revolving Credit/Term Loan
    - Overdraft Facility
    - Float rate Notes
- Project Finance
- Bridge Loan, capital and working capital facilities, acquisition facilities
    - Bridge Loan
    - Capital Expenditure Facility
    - Working Capital Facility
    - Acquisition Finance
- Trade finance
    - Export Credit
    - Guarantee Facility
    - Commercial Letter of Credit
    - Committed Credit Facility
    - Letter of Credit
    - Standby Letter of Credit

- Long Term Debt
    - Mezzanine Debt
    - Subordinated Debt
    - Collateralized Debentures
    - Performance Bonds