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DOCTORATE THESIS

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Declaration of Authorship

I, Josué BANGA, declare that this thesis titled, "Essays on Climate Finance" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
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- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

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AVERTISSEMENT

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"Wherever we live, whoever we are, we all share the same responsibility:
make our planet great again"

-Emmanuel Macron, President of France.

UNIVERSITÉ GRENOBLE-ALPES

Abstract

Department of Economics

Doctorate in Economics

Essays on Climate Finance

by Josué BANGA

This thesis is structured around five essays.

The first essay is a theoretical paper that investigates the nexus between climate finance and structural transformation in developing countries, through the lens of political economy. So far, climate finance and structural transformation have been analyzed separately, resulting in a gap in the literature regarding the transformation-enhancing capacity of the former on the later. Yet as this essay shows climate finance -by its very nature- could be an effective driver of a sustainable structural transformation, provided it is allocated to productive environmental driving sectors. These include, but are not limited to, potential buoyant sectors such as renewable energy, construction, ecosystem services and agriculture as well as waster and waste management.

The second essay estimates the transition risk of climate change for the constituents of Morgan Stanley Capital International Index (MSCI-Europe), using a three scenario-based analysis. The results suggest that, regardless of which scenario plays out, the implementation of an effective carbon pricing at the European level would have significant, yet differentiated impacts on the market price of MSCI Europe index's constituents. In particular, if the transformation scenario or the coordination scenario plays out, firms operating in the most carbon-intensive sectors such as utilities, electricity, transport, and oil are much more likely to suffer the bulk of financial losses due to carbon pricing, while those losses would be less significant, should the fragmentation scenario occur. Thus, there is a risk of rising lobbying strategies from carbon backed-investors against policies aimed at accelerating carbon divestment. These findings imply that, without an effective climate risk awareness among those investors, carbon pricing alone would not be enough to hasten the transition towards a low-carbon economy. The essay, therefore, suggests the incorporation of mandatory climate-risk stress testing methods into firms' investment decision-making.

The third and fourth essays of this thesis take stock of the merging green

bond market by investigating on one hand the barriers its faces in developing countries, and by examining the determinants of the spread between corporate green bonds and risk-free government bonds on the over hand on the other hand. While market barriers and institutional barriers are found to be the major obstacles to the development of green bonds in developing countries, factor such as the order of issuance, (i.e. bonds issued by the same issuer at different times), bond rating, and coupon appeared to be ones of the main determinants of the spread on corporate green bonds. In order to address the above barriers and scale the market up, development banks as well as local governments should play a proactive role in helping developing countries to issue green bonds and to manage their proceeds. Moreover, the design of an international labelling and controlling system on the use of green bond proceeds can increase transparency on green bonds while attracting new types of investors.

The fifth and last essay examines the role central banks can play in steering financial markets towards sustainable investing. This essay argues that climate stability is a determinant of financial stability in the long term. Thus, as guardians of financial stability, central banks are expected to play a proactive role in ensuring that the financial system is well prepared for the low-carbon transition. The implementation of Permanent Lending Facilities to Priority Sectors (PLFPS) could be one way for central banks to foster the transition towards a greener and cleaner economy. Although such a mechanism would require a broadened central bank mandate, it does not necessarily imply that central banks should give up on their hard-won independence. Instead, by incorporating climate change settings into their monetary policy design, central banks could contribute not only to addressing one of the biggest threats of the 21^{st} century, but also to rebuilding trust between governments and their citizens.

Résumé:

L'année 2015 a été marquée par un tournant décisif dans les négociations internationales sur le climat. Les Nations Unies ont adopté les Objectifs de Développement Durable pour remplacer les Objectifs du Millénium pour le Développement. Plus ambitieux et plus inclusifs que les OMD, les ODD sont au nombre de dix-sept et visent entre autres à éradiquer la pauvreté, assurer la paix dans le monde, et lutter contre le changement climatique. Le but de ce dernier est de placer la protection de l'environnement au cœur des activités quotidiennes des hommes (UNEP, 2018). Le Groupe d'Experts Intergouvernemental sur l'évolution du climat a montré que les activités humaines contribuaient de manière significative au changement climatique (IPCC 2014). C'est pourquoi les décideurs publics doivent prendre des mesures fortes pour réduire l'empreinte carbone de notre économie.

Trois mois après l'adoption des ODD par les Nations Unies, l'accord de Paris, signé en décembre 2015 marque une nouvelle étape décisive dans la lutte contre le changement climatique. Adopté par environ deux cent chefs d'États et de gouvernement, l'accord de Paris a réaffirmé la nécessité de soutenir les pays en développement dans leurs efforts d'atténuation et d'adaptation au changement climatique (UNFCCC, 2015).

Ensuite, la Conférence d'Addis-Abeba souligne l'importance de la mobilisation des ressources domestiques mais aussi internationales pour répondre au défis du développement durable et plus spécifiquement à celui du changement climatique (United Nations, 2015b). Dans la même veine, la Conférence des Nations Unies sur le Commerce et le Développement a souligné la nécessité pour les pays en développement d'accélérer la transformation structurelle de leurs économies afin d'assurer une mise en œuvre efficace et rapide de l'agenda 2030.

Finalement, l'année 2015 aura été marquée par un changement de grammaire dans le discours des banques centrales. Le gouverneur de la Banque

d'Angleterre, Mark Carney, a laissé entendre que le changement climatique était une «tragédie de l'horizon»: les efforts visant à lutter contre le changement climatique doivent être supportés par les générations actuelles au profit des générations futures, de sorte que les générations actuelles n'ont pas trop d'incitations à agir pour la planète. Carney souligne par ailleurs que le changement climatique est devenue une réelle menace pour la stabilité financière. Son homologue français, François de Galhau, a même qualifié le changement climatique de «nouvelle frontière» pour les banques centrales.

De ce qui précède, il ressort clairement que la finance demeure le nerf de la guerre contre le changement climatique. Cependant, il existe, à ce jour, très peu d'études sur les risques climatiques et les moyens innovants de financement permettant de réduire ces risques tout en accélérant la transition vers une économie verte.

Dans ce contexte, il est attendu de la communauté scientifique, la production de connaissances capables de guider les décideurs publics dans la mise en œuvre de l'agenda 2030. L'objectif de cette thèse de doctorat est de répondre à cette attente.

Elle se structure autour de cinq essais. Le premier essai analyse le lien potentiel entre la finance climatique et la transformation structurelle dans pays en développement, dans une optique d'économie politique. Jusque-là, finance climatique et transformation structurelle ont été étudiées de manière séparée, conduisant ainsi à un déficit de la littérature sur la capacité des financements climatiques à assurer la transformation structurelle des économies des pays en développement. Pourtant, comme ce essai le démontre, la finance climatique -de part sa nature- pourrait être un vrai moteur d'une transformation structurelle durable des économies en développement, à condition qu'elle soit allouée à des secteurs productifs à fort impact environmental. Ceux-ci incluent des secteurs porteurs tels que les énergies renouvelables, la construction, les services écosystémiques, l'agriculture ansi que la gestion de

l'eau et des déchets.

Le second essai évalue les impacts potentiels du risque de transition climatique sur les entreprises de l'indice boursier Morgan Stanley Capital International Index (MSCI-Europe), grâce à l'analyse de scenarios. Les résultats suggèrent qu'une politique de tariffication du carbone aurait des impacts significatifs, bien que differentiés, sur le cours boursier des constituants de cet indice. En particulier, si le scénario de transformation ou de coordination se réalise, les entreprises opérant dans les secteurs à forte intensité-carbone tels que les companies petrolières, l'électricité et les transports subiront les plus grandes pertes financières liées à la mise en place d'un tel prix carbone. En revanche, ces pertes seront moindre si le scénario de la fragmentation se réalise. Ces résultats impliquent d'une part que sans une véritable prise de conscience des risques climatiques de la part des investisseurs, le prix carbone restera un instrument nécessaire mais non suffisant pour accélérer la transition énergétique, et d'autre part que l'application effective d'une telle politique entraînerait l'émergence de stratégies de lobbying anti-prix carbone. Par conséquent, ce essai recommande que la prise en compte du risque climatique par les investissuers dans leurs decisions d'investissement devienne obligatoire.

Les troisème et quatrième essais de cette thèse font le point sur le marché émergent des obligations vertes en examinant, d'une part, les barrières qui empêchent le développement du marché des obligations vertes dans les pays en développement et d'autre part, en analysant les déterminants du spread sur les obligations vertes émises par les entreprises par rapport aux obligations sans risques du gouvernement. Tandis que les barrières de marché et les barrières institutionnelles ont été identifiées comme principales entraves au développement des obligations vertes dans les pays en développement, les facteurs comme l'odre d'émission, (c'est-à-dire le nombre émissions par le même émetteur à différentes dates), la notation et le coupon apparaissent,

parmi tant d'autres, comme principaux déterminants du spread des obligations vertes émises par les entreprises. Afin de lever barrières ci-dessus mentionnées et accélérer le développement des obligations vertes dans les pays en développement, les banques de développement ainsi que les gouvernements locaux devraient jouer un rôle proactif en favorisant l'émission d'obligations vertes et en appuyant leurs émetteurs dans la gestion des fonds levés. Par ailleurs, la mise en place d'un système de standards internationaux de labélisation et de contrôle des obligations vertes permettrait d'accoitre la transparence et attirer de nouveaux investisseurs sur marché.

Le cinquième et dernier essai examine le rôle que les banques centrales pourraient jouer dans la réorientation des marchés financiers vers les investissement durable. Cet essai soutient que la stabilité climatique est un déterminant de la stabilité financière à long terme. Par conséquent, en tant que garants de cette stabilité financière, les banques centrales doivent jouer un rôle proactif en s'assurant que le système financier est mieux préparé pour la transition bas-carbone. La mise en place de mécanismes de facilités de prêts permanents aux secteurs prioritaires pourrait être une façon pour les banques centrales d'accélérer la transition vers une économie plus propre et plus verte. Bien qu'un tel mécanisme nécessiterait un extension de leur mandat, il n'implique en aucun cas un abandon de leur indépendance durement acquise. Au contraire, en intégrant le changement climatique dans la conception de leur politique monétaire, les banques centrales pourront non seulement contribuer à répondre à l'un des plus grands défis du 21^{e} siècle, mais aussi restaurer la confiance entre les gouvernements et leur citoyens.

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The views and interpretations made in this thesis are those of the author only and should not be attributed to the University of Grenoble-Alpes ...

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List of Abbreviations

AAAA	**A**ddis **A**baba **A**ction **A**genda
BoE	**B**ank **o**f **E**gland
CBI	**C**limate **B**onds **I**nitiative
CCS	**C**arbon **C**apture and **S**torage
CF	**C**limate **F**inance
COP	**C**onference **O**f **P**arties
CPI	**C**limate **P**olicy **I**nitiative
DKSE	**D**riscoll **K**raay **S**tandar **E**rrors
ECB	**E**uropean **C**entral **B**ank
ECLAC	**E**conomic **C**ommission for **L**atin **A**merica and the **C**aribbean
EIB	**E**uropean **I**nvestment **B**ank
ESG	**E**nvironmental **S**ocial and **G**overnance
GBP	**G**reen **B**ond **P**rinciples
GBLT	**G**reen **B**ond **L**igue **T**able
GDP	**G**ross **D**omestic **P**roduct
GFSG	**G**reen **F**inance **S**tudy **G**roup
GHG	**G**reen **H**ouse **G**as
GVA	**G**ross **V**alue **A**dded
GWI	**G**reen **W**all **I**initiative
ICMA	**I**nternational **C**apital **M**arket **A**ssociation
INDC	**I**ntended **N**ationally **D**etermined **C**ontribution
IPCC	**I**ntergovernmental **P**anel on **C**limate **C**hange
ILO	**I**nternational **L**abor **O**rganization

IPO	**I**nitial **P**ublic **O**ffering
IT	**I**nflation **T**argeting
LDC	**L**east **D**eveloped **C**ountries
LDCF	**L**east **D**eveloped **C**ountries **F**und
MA	**M**oving **A**verage
MDB	**M**ultilateral **D**evelopment **B**ank
MSCI	**M**organ **S**tanley **C**apital **I**nternational
NGFS	**N**etwork for **G**reening the **F**inancial **S**ector
NGO	**N**on **G**overnmental **O**rganization
ODA	**O**fficial **D**evelopment **A**ssistance
OECD	**O**rganization for **E**conomic **C**ooperation and **D**evelopment
PFAPS	**P**awnbroker **F**or **A**ll **P**riority **S**ectors
PCSE	**P**rais-Winsten Panel **C**orrected **S**tandar **E**rrors
S&P	**S**tandar & **P**oor's
ST	**S**tructural **T**ransformation
SST	**S**ustainable **S**tructural **T**ransformation
TCFD	**T**ask Force on **C**limate-related **F**inancial **D**isclosure
UN	**U**nited **N**ations
UNDP	**U**nited **N**ations **D**evelopment **P**rogramme
UNEP	**U**nited **N**ations **E**nvironment **P**rogramme
UNCTAD	**U**nited **N**ations **C**onference on **T**rade and **D**evelopment
UNFCCC	**U**nited **N**ations **F**ramework **C**onvention on **C**limate **C**hange
UNIDO	**U**nited **N**ations **I**dustrial **D**evelopment **O**rganization
VIF	**V**ariance **I**nflation **F**actor
VUCA	**V**olatile **U**ncertain **C**omplex **A**mbiguous
WEF	**W**orld **E**conomic **F**orum
YTM	**Y**ield **T**o **M**aturity

To my parents...

Chapter 1

Global introduction

The year 2015 has been a year of major breakthroughs on the international agenda. The United Nations adopted the Sustainable Development Goals (SDGs) which substituted the Millennium Development Goals (MDGs), and aims to eradicate poverty by 2030 while leaving no one behind (United Nations, 2015a). More ambitious and more transformative than the MDGs, the SDGs encompass seventeen development goals, of which the thirteenth goal targeting specifically climate change action.

The aim of this goal is to put the environment at the heart people's lives (UNEP, 2018) by encouraging countries to take collective and urgent actions to combat climate change and its impacts in accordance with the recommendations of the Intergovernmental Panel on Climate Change(IPCC). The IPCC's 2014 report has confirmed that human activities are the main cause of global warming at 95 percent (IPCC, 2014). This report also showed that it is possible to stabilize global temperature rise below 2 °C relative to pre-industrial levels. However, this would require a radical shift from the business as usual scenario.

Three months after the enactment of the SDGs, the adoption of the 2015 Paris Agreement has marked a breakthrough in the international agenda on climate negotiations. Adopted by almost two hundred states and governments, the Paris Agreement is seen by many as the first effective sign of a global political will to support the environmental-related objectives of the

2030 Agenda (UNFCCC, 2015). In particular, Article 4, paragraph 5 of this accord recognizes the need to support developing countries in the reduction of their greenhouse gas emissions, in accordance with the principle of common but differentiated responsibilities (UNFCCC, 2011).

Next, the Addis Ababa Action Agenda (AAAA) adopted in the same year, has set up a new global framework for financing the 2030 Agenda in the spirit of partnership and solidarity (United Nations, 2015b). While the AAAA called on governments to mobilize funding from various sources, including public and private as well as domestic and external sources, it also reiterated the responsibility of each country for its own economic and social development. Hence, the AAAA is a formal recognition that finance, regardless of its source, is critical to achieving the 2030 Agenda.

Still, in its 2015 report for the Least Developed Countries (LDC), the United Nations Conference on Trade and Development warned that developing countries in general and the least developed countries in particular, are the battleground on which the SDGs will be won or lost (UNCTAD, 2015). This is why it is critically important for policy-markers in those countries to hasten the structural transformation of their economies so as to enhance the implementation of the 2030 Agenda.

Finally, the year 2015 has seen a major shift in central banks' discourse. A growing number of the world's major central banks, including the Bank of England (BoE), has unexpectedly recognized that climate change is both a Tragedy of the horizon and an unprecedented threat for financial stability (Carney, 2015). Some central bankers even argued that climate change has become a "new frontier" for central banks (de Galhau, 2018), suggesting that it might be time for central banks to reopen the debate on their core objectives.

From the above developments emerge three conclusions. First, climate

change has become one of the biggest challenges faced by both policy makers and the business community (Carney, 2015; Mercer, 2015; WEF, 2017) and is threatening the implementation of the SDGs, especially in developing countries. Second, without a strong structural transformation in developing countries, hopes to achieve the 2030 Agenda will be dashed at best (UNCTAD, 2015). Third, finance remains a major challenge in implementing the 2030 Agenda. However, despite the growing interest of investors for the low carbon investments, the transition in the financial markets is not happening at the required speed and scale (United Nations, Inter-agency Task Force on Financing for Development, 2019).

Against this background, the academic community is expected to play its role in helping decision-makers implement the right policies capable of achieving their development prospects while tackling climate change. This is precisely the main objective of my thesis, which is structured around five supportive essays built on theoretical and empirical methods. Such an hybrid approach is essential to understanding and addressing the challenges of our time.

The first essay (Chapter 1) investigates the potential role climate finance can play in enhancing structural transformation in developing countries. In particular, I show in this essay that climate finance- by its very nature- can be an effective driver of a sustainable structural transformation in developing countries, provided it is productively used.

The second essay (Chapter 2) assesses the transition risk of climate change for MSCI Europe's constituents while using scenario analysis. This essay assumes that the transition towards a greener and cleaner economy will become unavoidable, as climate impacts worsen. Hence, governments would have to implement climate mitigation policies such as carbon pricing to foster the transition to a low carbon economy. Such a policy would imply a climate transition risk and thus potential financial losses for investors, especially for

those operating in the most carbon-intensive sectors.

Essay 3 and Essay 4 (Chapter 3 and Chapter 4 respectively) investigate innovative financial instruments aimed at fostering the development of a greener financial system. Since the implementation of the 2030 Agenda should be a top priority for governments, it becomes urgent to align the financial system with the sustainable development goals in order to fill the financing gap faced by developing countries (UNEP Inquiry, 2015). This can be done by harnessing and scaling up the development of innovative financial instruments, such as green bonds. The two essays show that some market and institutional barriers are preventing the development of green bonds in developing countries. Furthermore, due to the relatively newness of the green bond market, issuers and investors are facing a green bond learning curve which may lead investors to require a higher spread on corporate green bonds relatively to risk-free government bonds.

The last essay (Chapter 5) investigates the role of central banks in enhancing the transition towards a low-carbon economy by both integrating climate change settings into the design of their monetary policy and spurring the development of a greener financial system. Climate change has proved challenging for investment decision-making, and above all for financial stability (Carney, 2016). It is therefore crucial that central banks recognize climate change as their new frontier (de Galhau, 2018).

Although this dissertation brings about new insights to the scientific community and more generally to climate finance practitioners, there may be some possible limitations to know. The first limitations concerns the lack of data and a limited amount of time , which did not allow for the investigation of all aspects of the topic. Climate finance is a vast and emerging topic that involves both the public and private sectors, and therefore requires more time, more granular data, and more cooperation between academics and practitioners to be thoroughly investigated. The second limitations pertains to the

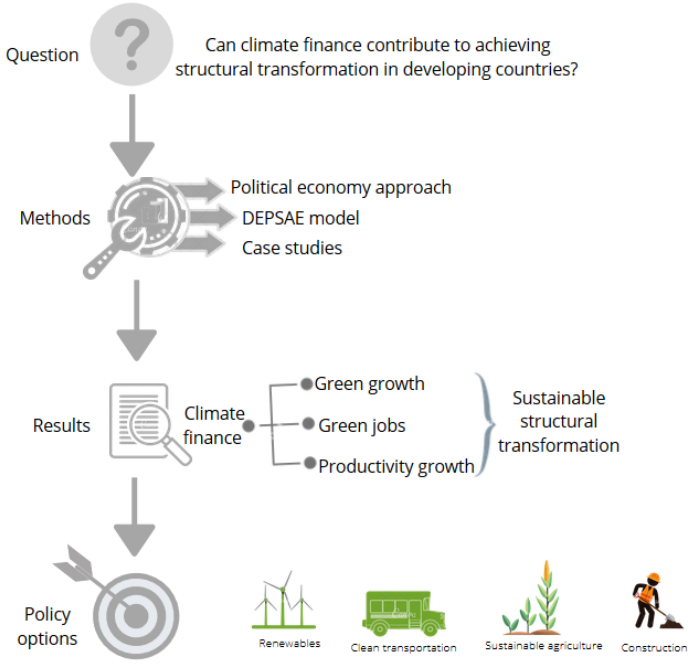
scarcity of prior research on the themes discussed in this dissertation. The lack of previous scientific publications has made it challenging in finding the right methods and theoretical frameworks to address my research questions. Further research is needed to enlighten the scientific debate on climate risks and opportunities, as comprehensive climate finance data and robust methodologies become available. Nonetheless, those limitations should not overshadow its major contributions.

Chapter 1

The nexus between climate finance and structural transformation: Towards a conceptual framework

"Climate change is the apartheid of our times... The whole world must recognise that attempting to perpetuate the status quo is to damn future generations to violence and insecurity".

- Desmond Tutu, 2019.



1.1 Introduction

Global warming has re-emphasized the importance of allocating finance to the real economy. In particular, it has made climate finance a prominent topic of the international agenda. Although the 2009 Copenhagen Conference of Parties is widely seen as a failure of international cooperation on climate change negotiations, it marked at least a breakthrough for climate finance (Castro and Betzold 2016). For the first time, developed countries have explicitly committed to providing developing countries with USD 30 billion in so-called "Fast-Start Finance" for the period from 2010 through 2012, and jointly mobilize USD 100 billion a year by 2020 onward (UNFCCC 2009). Such pledges have become, over time, the benchmark for climate negotiations between developed and developing countries (Castro and Betzold 2016).

Over the last few years, financial flows directed to climate-related investments have steadily grown from USD 360 billion in 2012 to over USD 530 billion in 2017, and are still more needed if the low-carbon transition is to materialize (CBI 2018). From the 2009 Copenhagen Conference of Parties to the recently 2015 Paris Agreement, climate finance has remained and continue to be a constant, if not the main topic of international negotiations on climate change between Parties of the United Nations Framework Convention on Climate Change (UNFCCC). There have been growing calls from both the scientist community and the political arena for the mobilization of financial resources to support an early low-carbon transition (IPCC 2018). The Global Commission on Adaptation, chaired by Ban-Ki Moon, has recently called for three revolutions, of which a revolution in finance for a better future (Global Commission on Adaptation 2019). Notwithstanding such growing popularity, climate finance is still a complex concept and is often understood differently by its stakeholders (CPI 2014). Donor and recipient countries have not

always been able to reach an agreement about its purpose and how it should be delivered or allocated (Pickering et al. 2015).

By relying on the principle of "*common but differentiated responsibilities and respective capabilities*", according to which developed countries are more responsible for climate change (UNFCC 2011), developing countries have often viewed climate finance as a moral duty of developed countries. However, the latter have often been unfriendly with such line of argument, by countering that there should be no tough distinction between their traditional official development assistance (ODA) and their climate finance commitments for developing countries (Pickering et al. 2015). As a result, climate finance has become one of the most complex and divisive topics of climate negotiations that lead sometimes to diplomatic wrangling between Parties (Haites 2011).

Several studies have attempted to investigate climate finance from different angles, including fund-raising strategies (Steckel et al. 2017; Bowen 2011), governance of international climate funds (Bird, Brown, and Schalatek 2011), climate finance disbursements, monitoring, and tracking (Barr, Fankhauser, and Hamilton 2010; Brown and Jacobs 2011; Carraro and Massetti 2012; Donner, Kandlikar, and Webber 2016; Buchner, Brown, and Corfee-Morlot 2011; Clapp et al. 2012; Lamhauge and Jachnik 2018), as well as its ethical aspects (Grasso 2011; 2010; Soltau 2009).

However, the literature on the relationship between climate finance and structural transformation in developing countries remains scant hitherto. In most cases, it is as if the debate on climate finance was reduced to how developing countries could adapt to what developed countries have caused (Lopes 2019). Seldom, climate finance is seen as an appropriate tool for hastening the sustainable structural transformation of recipient countries. This has led to a gap in the literature regarding the potential virtuous circle between climate finance and structural transformation. However, ignoring the potential benefits of climate-related projects in development strategies could lead to

sub-optimal planning and decision-making (Chiabai et al. 2018). Though there should be a *climate justice* for the world's lowest carbon-emitting countries, these countries need to have a clear vision of how funding received from developed nations can unlock their productive capacities and hasten their structural transformation.

In 2015, Parties to the UNFCCC have recognized the importance of finance in achieving the Paris Agreement. Yet many questions around it remain open (Castro and Betzold 2016), especially its relationship with structural transformation in recipient countries.

According to Mac Millan et al.(2017), developing countries are facing two development challenges -the «*structural transformation challenge*» and the "«*fundamentals" challenge*». The structural transformation challenge refers to the capacity of developing countries to allocate resources to modern and productive sectors that operate at higher levels of productivity, while the «fundamentals challenge» focuses on building skills and institutional capabilities needed to generate and sustain strong economic growth over time.

This essay seeks to address the shortcoming in the literature regarding the nexus between climate finance and structural transformation. It aims to address the following fundamental question: can climate finance contribute to achieving a sustainable structural transformation in developing countries?

By using a « *Driver, Exposure, Pressure, State, Action, Effect model (DEPSAE)*», I argue that, through and beyond adaptation and mitigation projects, climate finance can help address the structural transformation challenge faced by developing countries in a sustainable way. What is more, it could help address the «*fundamentals challenge*» through its indirect spillovers. However, this requires that developing countries are ready for climate finance, that is, they are able *to plan for, access, allocate, deliver and make use of climate finance resources, both domestic and international, as well as monitor, track, and report of its use and results* (UNDP, 2015). There is no doubt that the lack of a clear

climate investment readiness framework will prevent developing countries from making efficient use of climate finance (Agbemabiese et al, 2018; Barr et al. 2010)

It should be noted that the choice to focus on the link between climate finance and structural transformation does not mean that the fundamentals challenge should be neglected or regarded as a background priority. In fact, any sustained economic development should and must reckon with the social infrastructure to remain viable in the long run. Nonetheless, though the fundamentals are critically important for a holistic development process, this essay focuses on the relationship between climate finance and the structural transformation challenge for at least two reasons:

First, history suggests that it takes more time for investment in the fundamentals of developing countries to translate into economic outcomes that can nurture structural transformation. Over the past decades, massive investments in the fundamentals of developing countries have proven to be ineffective in creating a ground for a sustained economic transformation (Mc Millan, Rodrik, and Sepúlveda 2017), thereby rebutting what conventional wisdom has taken for granted. In *Beating the Odds*, Lin and Monga (2017) argue that: "*contrary to conventional wisdom, countries that ignite a process of rapid economic growth almost always do so while lacking what experts say are the essential preconditions for development, such as good infrastructure and institutions*". Furthermore, it likely that strategic climate investments in the productive sectors can bring about some co-benefits in the fundamentals (Chiabai et al, 2018).

Second, it has been recognized that without a deep structural transformation of their economies, developing countries - which are the battleground on which the 2030 Agenda will be won or lost (UNCTAD 2015; p.14) - are unable to reach the sustainable development goals. Therefore, there is a need to rethink the core purpose of climate finance, given that developing

countries need to undergo both, a rapid decarbonization and a rapid structural transformation to reach the sustainable development goals (Traeger and Kingombe, 2016).

This essay is therefore original, since it is to the best of one's knowledge, the first to investigate the nexus between climate finance and structural transformation through the lens of political economy. The proposed framework aims to serve as a platform for multidisciplinary studies on the nexus between climate finance and structural transformation in developing countries.

The remaining of the essay proceeds as follows. Section 2 reviews the literature on climate finance and structural transformation while bringing into light the research gap that steered the current analysis. Section 3 lays out the methodology and the framework used to investigate the nexus between climate finance and structural transformation. Section 4 provides an overview of climate finance flows to developing countries while highlighting two biases: an investor home bias and a mitigation bias. Section 5 scrutinizes the climate finance-structural transformation nexus by highlighting the conditions under which, climate finance can play a transformative role in developing countries. Section 6 provides a summary of some case studies supporting the virtuous-circle hypothesis between climate finance and structural transformation. Section 7 provides concluding remarks and policy recommendations for strengthening the climate finance-structural transformation nexus.

1.2 Literature review

This section reviews the literature on the definitions of climate finance and structural transformation as separate concepts and highlights the scantiness of research on the relationship between both topics. Taken separately, climate finance and structural transformation have been thoroughly analyzed by both scholars and practitioners.

1.2.1 *Climate finance*

Climate finance (CF) has gradually become a mainstreamed concept in the literature over the last decade, backed by international negotiations on climate change and the sluggish yet growing awareness of climate risks among investors. Nevertheless, it still suffers from the lack of a commonly agreed definition (Watson and Schalatek 2019) and limited evidence about the potential linkages between climate-related investments and structural transformation in developing countries.. According to Watson and Schalatek (2019), climate finance refers to the *financial resources mobilized to fund actions that mitigate and adapt to the impacts of climate change, including public climate finance commitments by developed countries under the United Nations Framework Convention on Climate change (UNFCCC)*.

Höhne et al. (2012) argue that climate finance includes two concepts: mitigation finance and adaptation finance. While mitigation finance refers to financial flows invested in projects and programs that contribute to reducing or avoiding greenhouse gas emissions (GHGs), adaptation finance relates to investments that contribute to increasing the adaptability of goods and persons to the adverse impacts of climate change. According to the UNFCCC, *climate finance aims at reducing emissions, enhancing sinks of greenhouse gases, reducing the vulnerability, maintaining and increasing the resilience of human and ecological systems to negative climate change impacts* (UNFCCC 2014). A broader definition from the Climate Policy Initiative (CPI) considers climate finance as "financial resources paid to cover the cost of transitioning to a low-carbon global economy and to adapt to, or build resilience against current and future climate change impacts" (CPI 2014).

There have been some heated debates about climate finance additionality as compared to traditional development assistance which, for several decades, has targeted many sectors, including climate-friendly activities (Brown,

Bird, and Schalatek 2010).

According to Pickering (2009), there are two levels of additionality. The first level - *additionality of resources* - refers to the provision, beyond traditional official development assistance, of additional financial resources to developing countries, which purposely seek to help them mitigate or adapt to climate change. The second level of additionality- *additionality of action*, which involves the provision of "goods that would not have otherwise been provided, but could be diverted from existing funding purposes". However, empirical evidence on climate finance additionality has been mixed at best, due to the complexity of measurement and monitoring of climate finance flows (Gouett and Bhushan 2017).

Furthermore, although the UNFCCC claims that adaptation and mitigation should be given the same priority (UNFCC 2011), there is still a strong bias towards mitigation within current pattern of climate finance flows directed to developing countries (Abadie, Galarraga, and Rübbelke 2013; Buchner et al. 2014; Donner, Kandlikar, and Webber 2016; CPI 2018). An in-depth analysis of those flows reveals that the majority of climate finance flows are invested in the same country in which they originated. According to CPI (2018), over the period 2015-2016, about 81% of climate finance was invested in the country where it was raised. Yet, despite such an "*investor home bias*", there is a formal recognition that climate finance is critical to achieving the 2015 Paris climate agreement (Bagozzi 2015; Watson and Schalatek 2019) and should come from various sources, including public and private as well as domestic and international sources (Bird and Glennie 2011).

Moreover, climate finance has been often used interchangeably with overlapping concepts such as green finance, sustainable finance, carbon finance or environmental finance (Elderson 2018). It is worth noting, however, that climate finance, which can also be referred to as environmental finance, is a

subcategory of sustainable finance, which broadly considers how the financial sector interacts with social, economic and environmental issues (Schoenmaker 2017). And just like traditional development assistance, climate finance is usually delivered to recipient countries through bilateral or multilateral channels and can take the forms of grants, guarantees, loans, government revenue support schemes, and fiscal incentives (CPI 2018).

The above definitions suggest that the ultimate goal of climate finance to developing countries would be to only provide them with financial resources so they can reduce their greenhouse gas emissions or adapt to the adverse impacts of climate change (UNFCCC 2009). However, this is a narrow view of the role climate finance can play in developing countries.

1.2.2 *Structural transformation*

Since Lewis (1954), structural transformation (ST), also often referred to as structural change, was seen as a simple reallocation of economic activities across three main sectors: agriculture, industry, and services. According to this development theory, structural transformation is a transition of an economy from low productivity and labor-intensive activities - mainly the agricultural sector- towards higher productivity and skill-intensive activities such as manufacturing and services (Lewis 1954; Herrendorf et al. 2014; UN-HABITAT 2016; Cevik et al. 2019). Such a definition suggests that structural transformation encompasses different dimensions, ranging from changes in the composition of output and employment to rising per capita income and the diversification of exports and aggregate demand (UNCTAD 2014).

However, with the recent outbreak of global inequalities and the growing disruptions of climate change, structural transformation has gradually evolved from this purely economic-centered definition to a broader one, which

incorporate sustainability and social inclusion issues (Lopes 2019). However, McMillan and Rodrik (2011) point out that structural transformation can be *growth-enhancing* or *growth-reducing* depending on the sectors where the transformation process takes place.

When seen through the lens of sustainability, structural transformation could appear as a double-edged sword (UNCTAD 2012). While it is essential to growth and poverty alleviation in the developing world, structural transformation can also mean significant damages on the environment, especially when the governments fail to incorporate sustainability criteria into their policy-making (Islam and Iversen 2018).

At first sight, this suggests that there could be a tension between structural transformation and sustainable development, as the first can be achieved at the expense of the second. Such arbitrage is a source of major concerns for many developing countries, who fear that their development prospects would be stalled by their climate mitigation commitments while their contribution to global greenhouse gas emissions remains very marginal, so far (Bagozzi 2015; Althor, Watson, and Fuller 2016).

However, although such claims can be ethically warranted given the historical responsibility of developed countries for global temperature increase (UNFCCC, 2009), it is also in the interest of developing countries to undertake a sustainable development path. The pace of the low-carbon transition in developed countries suggests that global demand for developing countries' polluting products (such as oil, gas, etc.) would likely slow down over the coming decades. To avoid this trap, developing countries need to implement smart climate policies that could help them not only adapt to climate change but also foster their sustainable structural transformation (Lopes, 2019). In other words, it means that structural transformation and sustainable development could go hand.

So far, however, there is scantiness of research regarding this potential virtuous circle between climate finance and structural transformation.

The question of whether developing countries are ready for climate finance remains under-explored (UNDP 2015). Yet the recent advances in clean technologies and the relentless calls for urgent climate actions (IPCC, 2018; Global Commission on Adaptation 2019), suggest that climate finance could be not only a vital tool for tackling climate change or adapting to its impacts, but also an effective driver of a sustainable structural transformation in developing counties, where rapid population growth rates compounded with low labour productivity, rising inequalities, and massive unemployment are challenging policy-makers (UNCTAD 2013).

1.3 Methodology and framework

This section briefly elaborates on the methodology and the framework used to investigate the nexus between climate finance and structural transformation.

First and foremost, it is worth recalling that this essay is a political economy paper that aims to bring about new insights on the relationship between sustainable development and structural transformation in developing countries. Climate finance stands as the key variable that serves to connect both topics. The essay relies on the findings of Mc Millan et al. (2017), that developing countries are facing both a «*structural transformation challenge*» and a «*fundamentals challenge*», and then argues that climate finance can help address both challenges in a sustainable way, through and beyond adaptation and mitigation projects.

Second, due to the lack of complete series of climate finance data for empirical modeling, the summary of some case-studies is carried out to highlight the potential virtuous circle between climate finance and structural transformation. Furthermore, an innovative concept is brought in by the author to enlighten the analysis: *sustainable structural transformation*. A Sustainable structural transformation (SST) is a process of economic transformation that is pro-environment, pro-growth, pro-job creation, and pro-poor, and can materialize locally or on a countrywide scale.

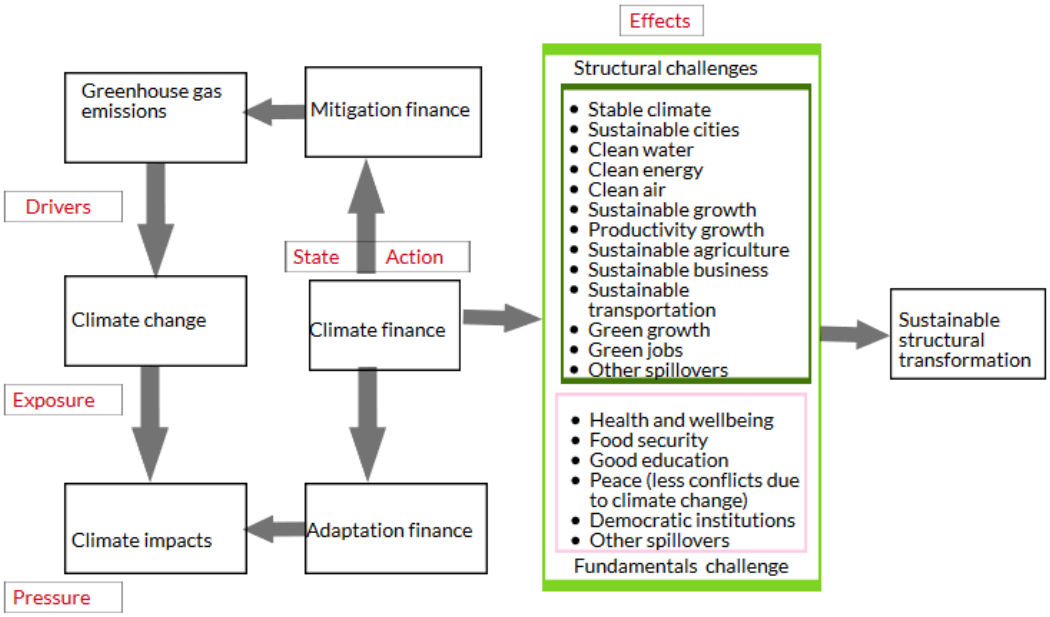


FIGURE 1.1: The DEPSAE model

I propose a theoretical model called « *Driver Exposure, Pressure, State, Action, Effect model (DEPSAE)*». This model is derived from the ecosystem enriched Driver, Pressure, State, Exposure, Effect Action model (eDPSEEA), which has been developed by Chiabai et al. (2018), based on Reis et al.(2015). The DPSEEA model was primarily developed by the World Health Organization to evaluate the health impacts of climate mitigation strategies (WHO, 2011). I purposely modified the eDPSEEA model to ingrate climate change, climate finance and structural transformation (see Figure 1.1). This allows me to show how greenhouse gas emissions (drivers) create climate change,

which in turn exposes developing countries to increased vulnerability (exposure) and puts pressure on their development prospects through its impacts (pressure). The Government (State) responds to that pressure by mobilizing climate finance, including mitigation and adaptation finance (action) to address climate change impacts and reduce the state's greenhouse gas emissions. When mitigation finance and adaptation finance are allocated to productive projects, the outcomes (effects) of such a response from the government can foster a sustainable structural transformation. The DEPSAE model shows that climate finance could not only be a tool for addressing climate change, but also a means to achieving the development prospects of developing countries (Ayers and Dodman 2010).

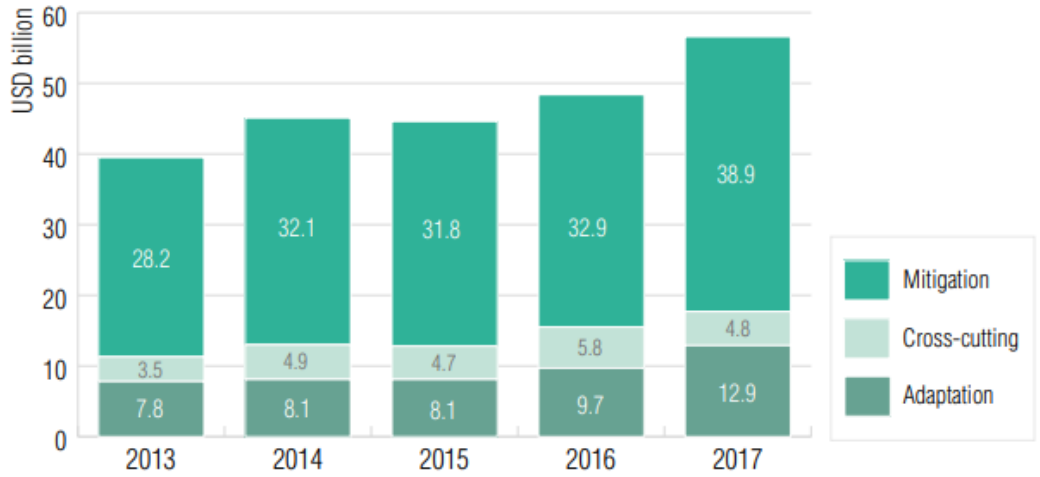
1.4 Overview of climate finance to developing countries

The aim of this section is to provide an overview of climate finance flows to developing countries. Due to the lack of relevant information about domestic climate finance and international private climate finance, a focus is made on international public climate finance flows. Although, such a choice is restrictive to some extent, it does invalidate our main argument that climate finance should target the structural transformation challenge rather than the fundamentals'.

1.4.1 Climate finance flows to developing countries

According to CPI (2018), developing countries are the dominant destination of developed countries' external climate investment. In its 2018 assessment of public climate finance flows direct towards developing countries, the OECD showed that adaptation finance has risen sharply from USD 7.8 billion to

USD 12.9 billion (a 65% increase), mitigation finance from USD 28.2 billion in 2013 to USD 38.9 billion in 2017 (a 38% increase). Finance for cross-cutting activities rose from USD 3.5 billion to USD 4.8 billion (a 37% increase). Figure 1.2 below displays the thematic split of developed countries' public climate finance to developing countries, and highlights a mitigation bias at the expense of adaptation.



Source: OECD (2018)
FIGURE 1.2: Adaptation and mitigation finance from developed to developing countries.

Still, according to the OECD's estimates, total public climate finance from developed to developing countries has risen by 44% from USD 39.5 billion in 2013 (OECD, 2018). In 2017, public climate finance from developed to developing countries totaled USD 56.7 billion, up 17% from USD 48.5 billion in 2016. Table 1.1 below shows the different sources of public climate finance to developing countries, from 2013 to 2017. These include bilateral public climate-related aid, multilateral climate finance, and officially supported climate-related export credits from developed countries. Over a five-year period (2013-2017), bilateral climate finance to developing countries grew from USD 22.5 billion to USD 27.0 billion (a 20% increase), multilateral climate finance (attributable to developed countries) from USD 15.5 billion to USD

27.5 billion (a 77% increase), and climate-related export credits from USD 1.6 billion to USD 2.1 billion (a 31% increase). Estimates of private climate finance from developed to developing countries remain limited and are only available for the years 2013 and 2014.

The next subsections provide further details on the institutions involved in the delivery of climate finance and the instrument used to deliver it.

Source: OECD (2018).
TABLE 1.1: Public finance provided and mobilized by developed countries for climate action in developing countries (USD billion).

*Note: The sum of individual components may not add up to sub- and grand totals due to rounding.	**2013**	**2014**	**2015**	**2016**	**2017**
1. Bilateral public climate finance from developed countries	22.5	23.1	25.9	28.0	27.0
2. Multilateral public climate finance attributed to developed countries	15.5	20.4	16.2	18.9	27.5
Subtotal (1+2)*	**37.9**	**43.5**	**42.1**	**46.9**	**54.5**
3. Officially-supported export credits (climate-related) from developed countries	1.6	1.6	2.5	1.5	2.1
Subtotal (1+2+3)*	**39.5**	**45.1**	**44.6**	**48.5**	**56.7**
4. Private climate finance mobilised by developed countries	12.8	16.7	n/a	n/a	n/a
Total (1+2+3+4)*	**52.2**	**61.8**	**n/a**	**n/a**	**n/a**

1.4.2 Climate finance institutions

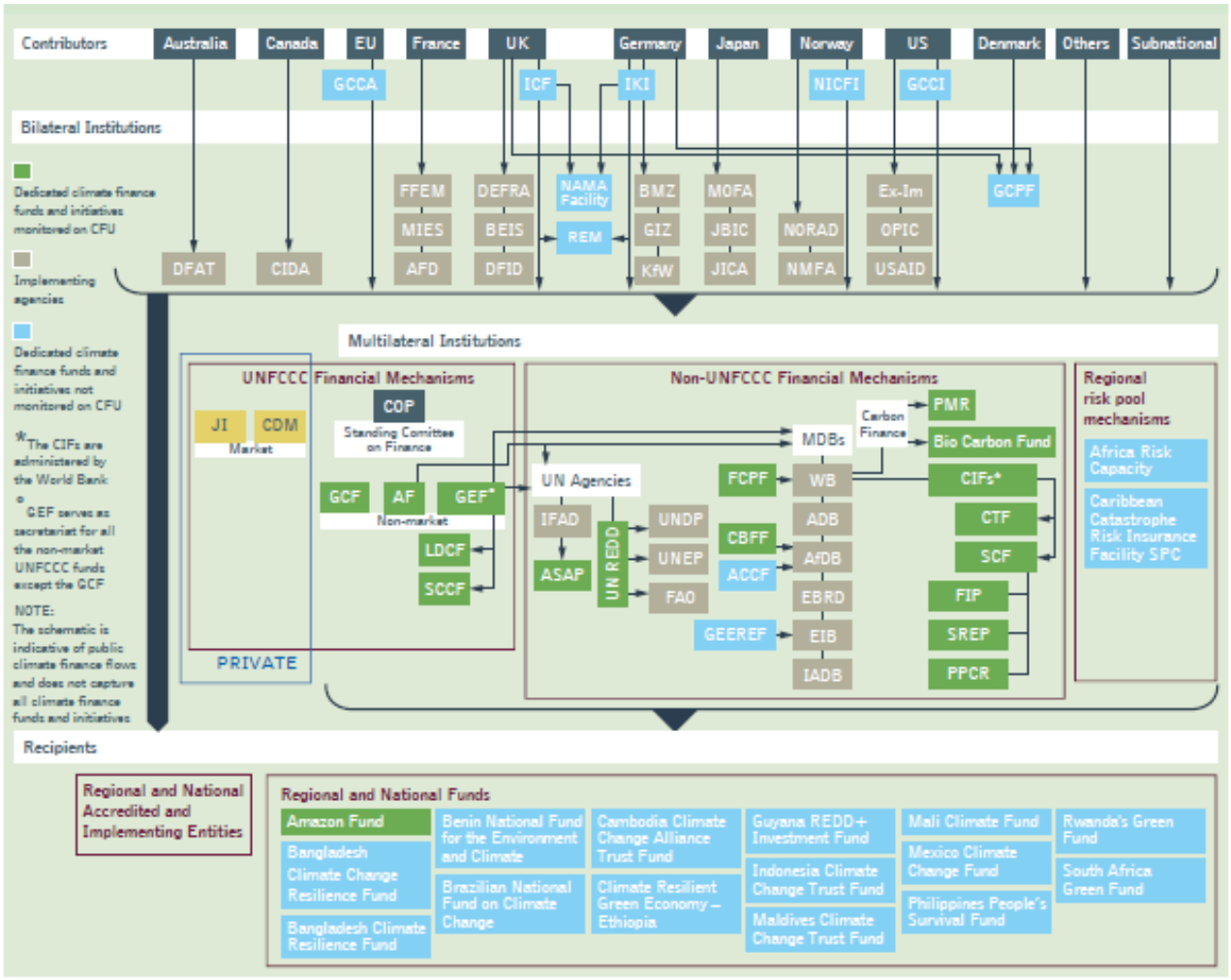
Climate finance institutions are flourishing[1] and encompass both public and private actors as well as philanthropists (see Figure 1.3). The public sector include national, multilateral and bilateral development financing institutions, local governments and agencies as well as climate funds. Multilateral development banks (MDBs) are ones of the major providers of climate finance to developing countries.

The private sector- which was the largest climate finance contributor in 2015 and 2016 (up to 54% globally) according to CPI (2018)- includes commercial financial institutions, corporations, project developers, private equity, venture capital, infrastructure funds, households, as well as institutional investors.

The *"glut"* of climate finance institutions and their often diverging delivery mechanisms, however, can make climate finance reporting and tracking

[1]For an extensive literature review of climate finance institutions, see Watson and Schalatek (2019)

very challenging and time-consuming for both recipient and donor countries.



Implementing Agencies and Institutions	
AfDB	African Development Bank
AFD	French Development Agency
ADB	Asian Development Bank
BEIS	Department for Business, Energy & Industrial Strategy
BMZ	Federal Ministry of Economic Cooperation and Development
CIDA	Canadian International Development Agency
DEFRA	Department for Environment, Food and Rural Affairs
DFAT	Department of Foreign Affairs and Trade (Australia)
DFID	Department for International Development
EBRD	European Bank for Reconstruction and Development
EIB	European Investment Bank
Ex-Im	Export-Import Bank of the United States
FAO	Food and Agriculture Organisation
FFEM	French Global Environment Facility
GIZ	German Technical Cooperation
IADB	Inter American Development Bank
IFAD	International Fund for Agricultural Development
JBIC	Japan Bank of International Cooperation
JICA	Japan International Cooperation Agency
KfW	German Development Bank
MIES	Inter-ministerial Taskforce on Climate Change
MOFA	Ministry of Foreign Affairs
NMFA	Norwegian Ministry of Foreign Affairs
NORAD	Norwegian Agency for Development Cooperation
OPIC	Overseas Private Investment Corporation
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
USAID	US Agency for International Development
WB	World Bank

Multilateral Funds and Initiatives	
AF	Adaptation Fund (GEF acts as secretariat and WB as trustee)
ACCF	Africa Climate Change Fund
ASAP	Adaptation for Smallholder Agriculture Programme
CBFF	Congo Basin Forest Fund (hosted by AfDB)
CDM	Clean Development Mechanism (implemented under the Kyoto Protocol)
CIF	Climate Investment Funds (implemented through WB, ADB, AfDB, EBRD, and IADB)
CTF	Clean Technology Fund (implemented through WB, ADB, AfDB, EBRD, and IADB)
FCPF	Forest Carbon Partnership Facility
FIP	Forest Investment Program (implemented through WB, ADB, AfDB, EBRD, and IADB)
GCCA	Global Climate Change Alliance
GCF	Green Climate Fund
GEF	Global Environment Facility
GEEREF	Global Energy Efficiency and Renewable Energy Fund (hosted by EIB)
JI	Joint Implementation (implemented under the Kyoto Protocol)
LDCF	Least Developed Countries Fund (hosted by the GEF)
PMR	Partnership for Market Readiness
PPCR	Pilot Program on Climate Resilience (implemented through World Bank, ADB, AfDB, EBRD, and IADB)
SCCF	Special Climate Change Fund (hosted by the GEF)
SCF	Strategic Climate Fund (implemented through WB, ADB, AfDB, EBRD, and IADB)
SREP	Scaling Up Renewable Energy Program (implemented through WB, ADB, AfDB, EBRD, and IADB)
UNREDD	United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation

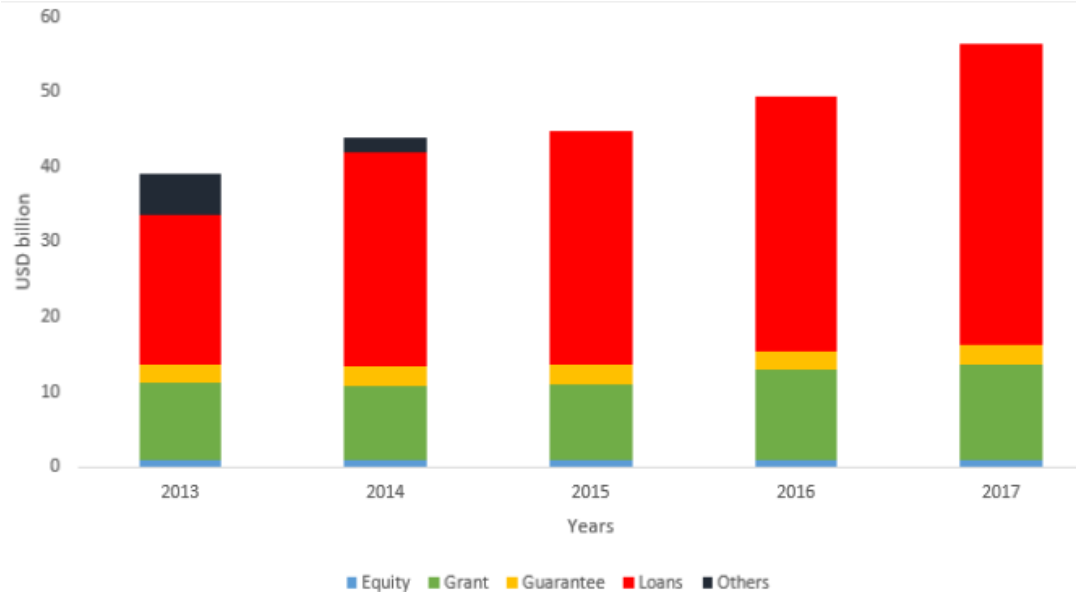
Bilateral Funds and Initiatives	
GCCI	Global Climate Change Initiative (US)
GCPF	Global Climate Partnership Fund (Germany, UK and Denmark)
ICF	International Climate Fund (UK)
IKI	International Climate Initiative (Germany)
NAMA facility	Nationally Appropriate Mitigation Action facility (UK and Germany)
NICFI	International Climate Forest Initiative (Norway)
REM	REDD Early Movers (Germany and UK)

Source: Watson and Schalatek (2019)

FIGURE 1.3: Global climate finance architecture.

1.4.3 Climate finance instruments

There is a wide range of financial instruments used to channel climate finance to developing countries. These include grants, loans (concessional and non-concessional), guarantee, equity, and many other instruments.



Source: OECD (2018)
FIGURE 1.4: Public climate finance flows to developing countries by instrument type.

According to OECD (2018), climate finance to developing countries delivered in the form of grants has increased by 25% between 2013 (USD 10.3 billion) and 2017 (USD 12.8 billion). Climate finance flows channeled through loans have doubled over the same period from USB 20 billion in 2013 to USD 40.3 billion in 2017. Guarantees and equity-related climate investments have remained stable (USD 2.5 billion and USD 0.9 billion in 2017 respectively).

Over the period 2013-2017, climate finance flows have shown a 'hiccup' pattern depending on which instruments were used to channel it. Nonetheless, loans represent the main channel through which climate finance is delivered to developing countries (see Figure 1. 4), thereby raising some concerns about the debt sustainability and the sustainable development prospects of these countries in the long run.

1.5 The climate finance-transformation nexus

1.5.1 Peculiarities of developing economies

The analysis of the role climate finance can play in enhancing structural transformation in developing countries would be biased without a close look at the nature and peculiarities of their development process. Although some developing countries have recently enjoyed strong growth rates, thereby narrowing down the development gap between them and developed countries, such a performance was mainly driven by export of primary commodities, making it unsustainable (Diao, McMillan, and Rodrik 2017; Mc Millan, Rodrik, and Sepúlveda 2017).

Moreover, climate change is likely to wipe this trend out, since developing countries are the most vulnerable to its impacts, which however are becoming frequent and violent. It is therefore important to scrutinize the structure of the economies of developing countries, so as to explain how climate finance can make a difference where other forms of finance have failed.

First, for several decades, experts have taken for granted the idea that addressing the «fundamentals challenge» faced by developing countries is a prerequisite for development. Yet structural transformation, which is critical to achieving the sustainable development goals set by the United Nations, has been slow to happen in developing countries (Brahmbhatt et al. 2016), despite several decades of massive investments into their social sectors. The recent strong growth rates experienced by many developing countries have not been translated into more industrialized and diversified economies, especially in Africa where exports are still dominated by primary goods (Higuchi and Shimada 2019). For those countries that have ignited their economic transformation, there are still growing concerns about the long-term viability of their structural transformation process (Jayne, Chamberlin, and Benfica 2018), especially in a time of a changing climate. This suggests that growth

is necessary, but not a sufficient condition to development (Berr, Monvoisin, and Ponsot 2018). It must be environmental-friendly in order to remain viable and allow for the long-term growth of per capita income (Herrendorf, Rogerson, and Valentinyi 2014).

The sluggish economic transformation recorded in developing countries suggests that there is a weak nexus between investment in social infrastructure and structural transformation. Over the last six decades, developing countries have received massive investment in their social sectors. Yet the reward in terms of economic transformation, poverty reduction and employment generation has been disappointing, to the say the least (Moyo and Ferguson 2009; Guillaumont and Wagner 2014). This suggests that it is possible to have a rapid structural transformation without having all the fundamentals, which are expected to materialize later in the transformation process (Lin and Monga, 2017).

Several examples corroborate this argument.

- The first case in point is China, where governance and human capital have lagged significantly behind the country's manufacturing prowess (McMillan et al., 2017), suggesting that, although the «fundamentals challenge» is important, nothing guarantees that massive investments in it would lead to many rewards in terms of sustainable structural transformation. After decades of reforms in their fundamentals, developing countries have achieved only mixed results in terms of productivity growth, poverty reduction, and employment generation (Aksoy 2018).

- The second case in point is the Least Developed Countries as a group, where the social sector has been absorbing the bulk of ODA received from developed countries (United Nations, Inter-agency Task Force on Financing for Development and Department of Economic and Social

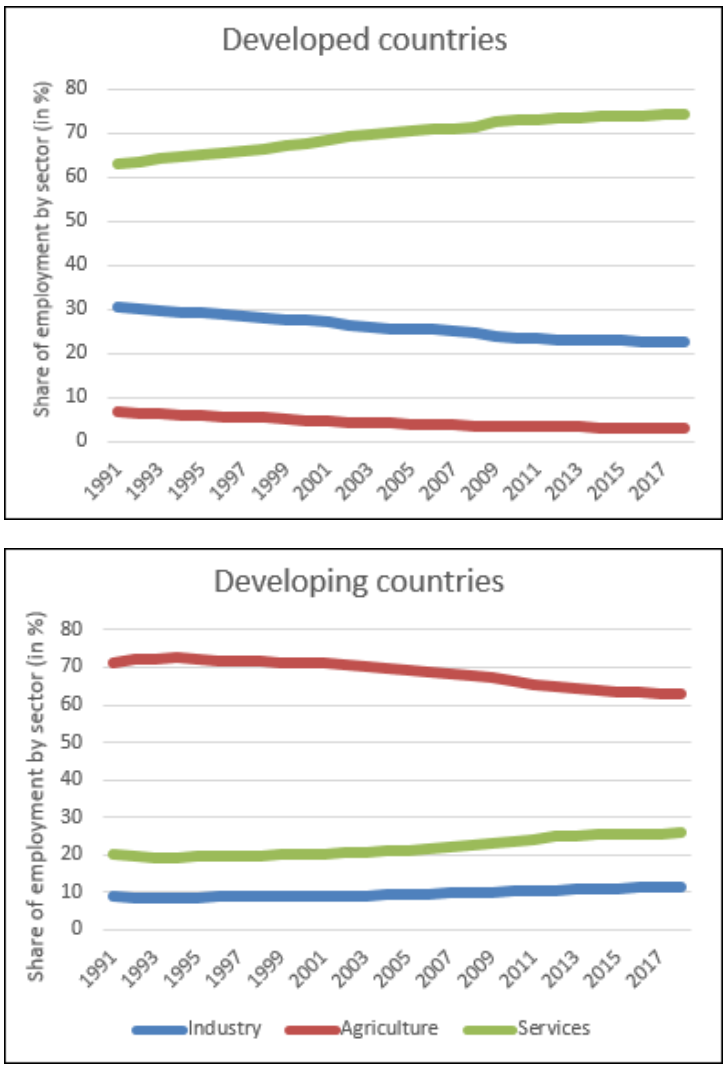
Affairs 2019). Yet little has been achieved in terms of structural change (McMillan et al., 2017). For instance, in recent years, over 45% of LDCS' external development finance were allocated to social sectors, compared to 14% and 8% respectively for economic infrastructures and production sectors (UNCTAD 2019). Over the past decades, official development assistance has been criticized for not having significant impacts on the productive sectors, and for not being aligned with the development priorities of developing countries (Ritchie and Roser 2017; UNCTAD 2019).

- The third case in point comes from Latin American countries, which provide a good example of how positive changes in the fundamentals did not necessarily lead to significant yields in terms of structural transformation. Despite some relative improvements in the institutional frameworks of those countries, there have been little rewards in terms of productivity growth and diversification of the production systems, thereby supporting the argument that positive changes in the "fundamentals" are not necessarily a reliable predictor of a sustained economic growth (McMillan et al.; 2017). However, China's example suggests that, when inspired and led by the government, a strong structural transformation can also bring about significant improvements in the fundamentals. In essence, this implies that developing countries should not wait for the materialization of the ideal social-infrastructures before igniting their structural transformation (Lin and Monga 2017).

There is another characteristic of developing countries, which can make climate finance become a potential driver of structural transformation. This characteristic stems from the fact that adaptation and mitigation projects, by their very nature, have huge potentials in accelerating the implementation of the sustainable development goals in those countries.

According to UNCTAD (2009), from a macroeconomic perspective, climate change mitigation and adaptation projects can have a growth-stimulating effect in many developing countries. For instance, between 47% and 59% of jobs in developing countries depend directly on adaptation and mitigation projects, such as protection against storms, floods, wind, the purification of air and water, the pollination of crops, as well as the control of agricultural pests (ILO 2018). Furthermore, those ecosystem services, although often unrecorded, can generate important economic values, through indirect spillover effects. According to (Costanza et al. 2014), the contribution of ecosystem services to global GDP was estimated at USD 75.2 trillion in 2011. In Costa Rica, for instance, forestry and ecosystem services contribute to 2 percent of the country's GDP (WAVES 2015). According to ILO (2018), green infrastructure investments can create a *multiplier effect* on output and employment (see Section 1.6). Conversely, an unchecked climate change is likely to negatively affect these sectors, leading to lower labor productivity, weak growth, and massive unemployment.

The last reason why it makes sense to investigate the nexus between climate finance and structural transformation in developing countries derives from the fact that the development process of those countries does not follow the traditional pattern taught in many economic textbooks (see Lewis 1954). It seems as if the model of Lewis (1954) overlooked some fundamental characteristics of developing countries' economies, by opposing modern to traditional sectors. In doing so, the model of Lewis did not capture all the diversities and complexities of developing economies. While paying tribute to Philippe Hugon, one of France's prominent political economists, Egg et al. (2018) argue that the analysis of Lewis (1954), which usually opposes modern sectors to the traditional ones, does not resist when confronted with different societies of different realities. This argument seems to perfectly apply to developing countries when it comes to analyzing structural transformation as



Source: Author's construction based on data from World Development Indicators of the World Bank.
FIGURE 1.5: Share of employment by sector in developed versus developing countries.

a process of labor force reallocation across different economic sectors.

By comparing the structural transformation patterns of developing and developed countries, Bah (2007) found that structural transformation in the former deviates from that followed in the latter. Even in the former, there are significant disparities across countries (Rodrik 2018; Diao, McMillan, and Rodrik 2017). While Lewis (1954) describes structural transformation as a classical move of the labor force from agriculture to the industry, and from industry to the service sector, such a development process is not strictly followed by developing countries. Instead, structural transformation in those

countries have been characterized by a shift from low productivity activities in rural areas to low productivity activities in urban areas, leading to a sluggish economic transformation (UNCTAD, 2015).

The agriculture sector remains the main source of employment in developing countries (Busse, Erdogan, and Mühlen 2019), accounting for approximately 65% of total employment, compared with less than 5% in developed countries in 2018 (Figure 1.5). The industry sector represents merely 11% of total employment compared with 22% in developed countries for the same year. While the service sector is growing, it still accounted for less than 27% in 2018 compared with 75% in developed countries. This development pattern suggests that the drivers of structural transformation in developing countries are much more vulnerable to the impacts of climate change. Thus, investing in those sectors can help reduce the pressure and exposure components of the DEPSAE model, while mitigating its drivers.

1.5.2 Climate finance as an SST-enhancing tool

This section details the DEPSAE model and shows how it can lead to a sustainable structural transformation, through climate finance.

Developing countries are at a higher risk of climate change impacts, although their contributions to global greenhouse gas emissions (drivers) remain marginal (IPCC, 2018). An unchecked climate exposes the productive sectors of developing countries to increased vulnerability, and thus threatens their development prospects. Temperature increase and sea-level rise would lead to increase in extreme weather events such as floods, drought, and heatwaves. Those extreme weather events would expose developing countries to consequences such as water scarcity, biodiversity losses, food shortage, the rise of vector-borne diseases, loss of working hours, increased stress at work, and loss of productivity (IPCC 2018; ILO 2018; Chiabai et al, 2018). These

consequences would have negative effects on structural transformation in developing countries. The climate crisis is therefore a crisis for development (Ackerman 2009).

It is the responsibility of the government to act by mobilizing climate finance to address not only the causes of climate change (concentrations of greenhouse gas emissions), but also to help adapt to its adverse impacts. Those investments could lead to significant growth gains.

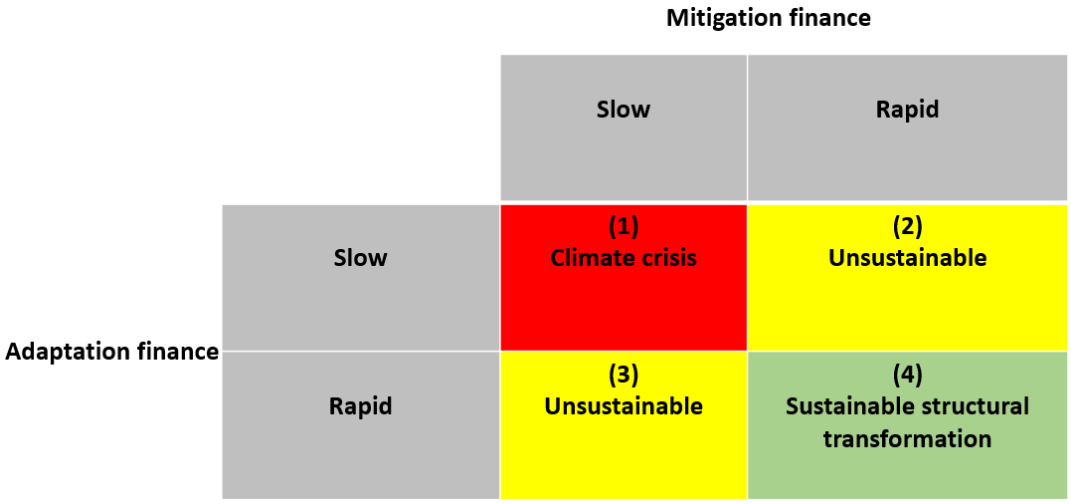


FIGURE 1.6: The climate finance - structural transformation nexus

Figure 1.6 shows the conditions under which, government actions can lead to a sustainable structural transformation. A low adaptation and mitigation finance (quadrant 1), would result in a climate crisis that would wipe out the development prospects of developing countries. In the same vein, quadrants 2 and 3 (rapid mitigation finance coupled with low adaptation finance, and rapid adaptation finance coupled with low mitigation finance) stand both as unsustainable solutions for developing countries. When the focus is made adaptation while the causes of climate change are not properly addressed, this would lead to a waste of resources in adaptation projects. Similarly, when the focus is made on mitigation at the expense of adaptation, this could lead to a stable climate in the long term. However, developing

countries would continue to suffer the impacts of climate change, since the current concentrations of greenhouse gases in the atmosphere are expected to continue causing temperature increase in the short to medium terms, even if their sources were totally removed (Burke et al. 2015).

The only optimal solution for developing countries to achieve a sustainable structural transformation is through rapid mitigation and rapid adaptation (quadrant 4). In other words, given the limited contribution of developing countries to global greenhouse gas emissions (Ritchie and Roser, 2017), adaptation and mitigation projects should be given the same priority when allocating climate finance. Paradoxically, there still a strong bias towards mitigation finance within the current patterns of climate finance flows directed towards developing countries (see Section 4.1).

This means that the world's most vulnerable countries to the impacts of climate change- whose contributions to global greenhouse gas emissions remain negligible- are not benefiting from current international climate finance flows. Yet adaptation projects usually have immediate synergies with development and are often designed to improve public health protection, conservation of farmland, and improvements in disaster preparedness (Michaelowa and Michaelowa 2007).

It is possible to distinguish between two forms of adaptation: reactive adaptation and proactive adaptation. On one hand, reactive adaptation consists of implementing emergency measures aimed at limiting the scale and magnitude of the damages caused by climate-related disasters. Although essential in time of crisis, reactive adaptation is unlikely to bring about significant changes in the productive sectors of developing countries. It usually consists of repairing what has been damaged. On the other hand, proactive adaptation consists of identifying some core vulnerable sectors and of

undertaking a set of preventive adaption measures well before the occurrence of climate disasters. By anticipating the potential impacts of climate-related hazards on the economy, proactive adaptation can nurture a sustainable structural transformation. Such an adaptation can be done by investing in green infrastructure projects with higher spillover effects in terms of jobs, growth, and productivity. Potential sectors include, but are not limited to, renewable energy, sustainable agriculture and fishing, construction, energy efficiency, clean transportation, waste and water management (ILO, 2018).

Recipient and donor countries should, therefore, pay due attention to the allocation of climate finance (Steckel et al. 2017). Since the informal economy is still dominant in most developing countries (OECD 2012; UNCTAD 2015), this pattern needs to be taken into account while allocating climate finance. Local green projects built on local synergies and knowledge have the potential of lifting millions of poor out of poverty while enhancing the development of productive capacities.

The above developments suggest that climate finance can be an effective engine of structural transformation in developing countries, provided it is efficiently used and targets sectors with higher spillover effects. The next section provides some case studies.

1.6 Some case studies

Given the scarcity of granular data for empirical investigations, this section provides some success-stories of climate-related investments to support the main argument advocated in this essay. Although the scale of the projects involved in those case studies might be limited, they do have the potential of highlighting the transformative capacities of climate-related investments on developing economies.

1.6.1 Case study 1: Climate finance and employment

Source: ILO (2018b).
TABLE 1.2: Jobs relying on ecosystem services, 2014 (thousands).

Sectors	Example of ecosystem services	Africa	Americas	Asia and the Pacific	Europe	Middle East	World
Most activity in the sector is related to biodiversity and ecosystem services							
Agriculture	Genetic resources and stock availability, freshwater, pollination, seed dispersal	217 263	42 600	670 476	42 108	4 248	976 694
Forestry		1 634	1 103	11 866	2 061	36	16 700
Fishing		5 118	2 264	36 491	603	252	44 728
Food, drink and tobacco	Food, fibre and freshwater	3 267	10 470	46 141	11 083	510	71 471
Wood and paper	Fibre, water purification and waste control	487	3 605	7 789	3 694	126	15 701
Renewable energy	Fibre for biofuels	123	292	1 842	737	107	3 101
Water	Freshwater supply, recycling, regulation, purification and natural hazard regulation	23	136	414	320	57	950
Most activity in the sector relies on biodiversity and ecosystem services, but they do not determine the nature of the sector							
Textile	Fibre, water purification and waste control	595	5 409	39 423	4 263	165	49 855
Chemicals	Genetic resources, biochemical diversity, freshwater	247	2 254	10 938	1 388	<0.5	14 827
Environment-related tourism	Food, freshwater, air quality, education, aesthetic and cultural value	2 282	7 110	23 081	4 828	357	37 657
Total by region		**231 039**	**75 244**	**848 461**	**71 084**	**5 856**	**1 231 684**
Share of total regional employment (%)		**59**	**17**	**47**	**16**	**15**	**40**

The exact impacts climate change would have on the job market is hard to estimate. There is no doubt, however, that climate change will negatively affect the world of work. According to ILO (2018), some 1.2 billion jobs (40% of the world employment), most of which are in developing countries, depend on ecosystem services, which are vulnerable to climate change impacts. These jobs are related to sectors such as agriculture, forestry, fishing, food, drink and tobacco, wood and paper, bio-fuels and renewable energy sources, the pharmaceutical and chemical industries, and environment-related tourism. It, therefore, means that an unchecked climate would severely affect the pattern of employment and productivity in those sectors, thereby creating a ground for increased vulnerability of local communities to climate change. Conversely, strategic climate-related investments could help address the massive unemployment rates faced by developing countries while harnessing structural transformation through labor productivity growth and the development of green jobs. In their recent study, Montt et al. (2018) found that climate related-investments could create over 24 million jobs across the world by 2030. Given the pattern of employment in developing countries, the bulk of this job creation is likely to materialize on sectors such as agriculture, fishing, water and waste management as well as renewable energy (see Table 1.2).

In the same vein, the renewable energy sector has proven successful in creating green jobs in countries such as China. A study carried out by UNEP (2010) showed that the clean energy sector in China has generated output worth USD 17 billion and employed an estimated 1.5 million at the end of 2009, of which 600,000 were in the solar thermal industry, 266,000 in biomass generation, 55,000 in solar photovoltaics and 22,200 in wind power. In 2009 alone, an estimated 300,000 jobs were created thanks to renewable energy projects. Although the contributions of the energy sector to value-added,

employment and exports are limited in most developing countries, it remains nevertheless essential to structural transformation through its positive spillover effects on other productive sectors (UNCTAD 2017). Adequate financing scheme for the clean energy sector, beyond households' basic needs, has the potential of unlocking other productive sectors that can, in turn, nurture a sustainable structural transformation.

Next, the construction sector also provides a good example of how climate-related investments could create an employment multiplier effect. Table 1.3 below displays the multiplier effect of the construction sector on output and employment in selected developed and developing countries. It shows that an investment of USD 1 million in the construction sector can yield between two and five times more output, and create between 19 and 647 green jobs.

Source: ILO (2018a). * The estimates of the multipliers for Argentina are based on ECLAC and ILO (2018) and are for the year 2011.

TABLE 1.3: Climate change impacts on the work world in selected developed and developing countries, 2014.

Country	Construction sector output multiplier	Construction sector employment multiplier (for every US$ 1 million invested)
Argentina*	2.6*	*
Australia	4.8	19.4
Brasil	4.9	162.3
Canada	3.6	17.6
China	4.2	198.6
France	4.1	12.7
Germany	3.8	15.1
India	3.9	646.7
Indonesia	3.3	157.5
Italy	4.6	20.7
Japan	4.8	23.3
Korea, Republic of	4.8	57.4
Mexico	2.5	84.4
Russian Federation	4.4	120.6
Turkey	2.5	41.8
United Kingdom	4.9	20.7
United States	5.0	21.0

1.6.2 Case study 2: Ethiopia's Productive Safety Net Program

Sustainable agriculture can tackle unemployment in developing countries while enhancing within-sector productivity growth, which is essential to structural transformation (Diao et al., 2017). Ethiopia's Productive Safety Net Program (PSNP) is a case in point. The PSNP is a food security program implemented in 2006 by the Ethiopian government, with the support of its international partners following a severe drought in the country. The primary goal of this program was to provide cash and food to poor and vulnerable communities, who were experiencing food insecurity due to droughts, delayed rains, and flooding. The implementation of the project led to significant positive spillover effects for the whole country, as it allowed for the resilience of more than 8 million farmers through land rehabilitation and improvement of water sources, and contributed to the country's climate change mitigation program through its greenhouse gas reduction co-benefits. According to Pugacheva and Mrkaic (2018), the beneficiaries of this program have experienced a 25% smaller drop in consumption after droughts relative to those not in the program. The program has also contributed to reducing soil losses by more than 40%, and to improving water availability. The total net reduction of greenhouse gas emissions from land management strategy at the national level, attributable to the PSNP, is estimated at 3.4 million Mg CO2e/year, approximately 1.5% of Ethiopia's Nationally Determined Contribution (NDC) for the Paris Agreement (Woolf et al., 2018).

More importantly, the program has fueled a local structural transformation through within-sector and inter-sectoral productivity growth. For instance, land productivity has increased, while the program also allowed for the construction of new productive infrastructures such as roads and hospitals. Such improvements in labor productivity have been profitable for the country's economy (Day et al. 2019).

The above case studies suggest that, when allocated wisely, climate finance can be pro-environment, pro-growth, pro-jobs, and pro-poor, which are some of the main characteristics of a sustainable structural transformation.

1.7 Conclusion

Climate change is challenging the development prospects of developing countries. Over the last international climate negotiations, it has been recalled that developed countries should increase their financial support to developing countries for their mitigation and adaption to climate change. Such a financial commitment, known as climate finance, can be an effective driver of a sustainable structural transformation, provided it is productively allocated. However, the literature on climate finance has often neglected the transformative role it can have on developing economies.

In this essay, I argue that beyond adaptation and mitigation, climate finance - by its very nature, could help and must be used to address the structural transformation challenge faced by developing countries. This does not mean that the fundamentals challenge should be viewed as a background priority. Good and democratic institutions, for instance, are a vital lever to a holistic development strategy. However, lessons learned from decades of investments in the social sectors of developing countries suggest that their fundamentals are a weak driver of structural transformation, at best. After decades of mixed reforms in the "fundamentals" of developing countries, the yields in terms of structural transformation have fallen short of expectations.

By contrast, climate-related investments in the productive sectors of developing countries are much more likely to generate strong economic growth and green jobs, while indirectly contributing to addressing their "«*fundamentals* challenge». Several success stories support such an argument. A case in

point is the potential of climate-related investments in creating millions of jobs across the world, especially in developing countries where the world of work is heavily dependent on ecosystem services. In the same vein, strategic and productive climate investments are much more effective in lifting millions of poor out of poverty, while contributing to achieving the greenhouse gas reduction commitments made by developing countries. The Ethiopian Productive Safety Net Program stands as an illustrative example.

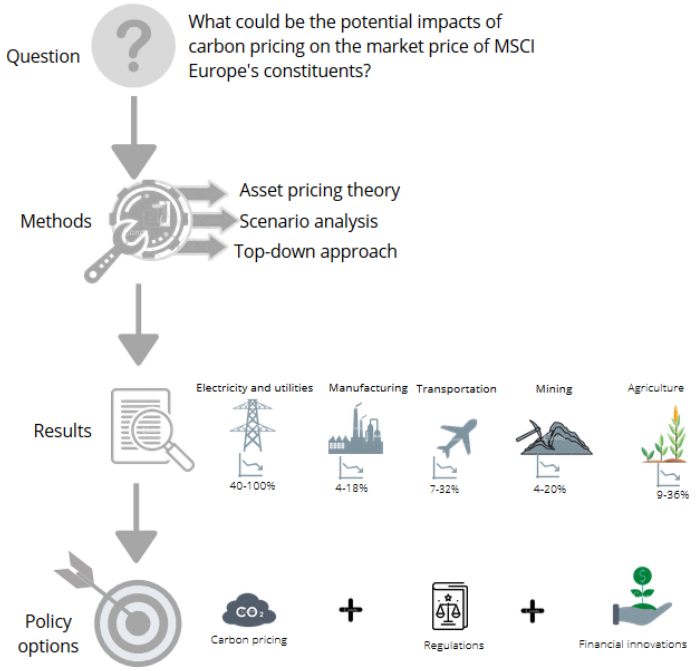
However, the challenge ahead for policy makers in developing countries is to determine which sectors of their economies are much more likely to harness their sustainable structural transformation. Potential sectors include, but are not limited to, renewable energy, energy efficiency, sustainable agriculture and fishing, construction, clean transportation, waste and water management. Furthermore, massive investments in these sectors can help address climate risks.

Chapter 2

Estimating the transition risk of climate change for the MSCI Europe Index.

"Climate risks....could destabilise markets, spark a pro-cyclical crystallisation of losses and lead to a persistent tightening of financial conditions: a climate Minsky moment".

- Mark Carney (2016), Bank of England.



2.1 Introduction

[1]

Climate change would have significant yet differentiated impacts on human and natural systems across the world. From investment perspectives, climate change has become a real threat for investors, especially for those whose portfolios rely massively on carbon-intensive assets (Caldecot et al, 2013; Carney, 2016; Mercer, 2015; WEF, 2018). Climate change has become therefore a financial risk, which could likely alter the foundations of our economies if nothing is done to curb greenhouse gas emissions (Zenghelis, 2016; Christophers, 2019).

As global surface temperatures rise, the impacts of climate change would be detrimental for unprepared investors (Mercer 2015). In its two consecutive year reports on global risks, the World Economic Forum (WEF) has identified climate change as one of the ten top global risks by likelihood and impacts (WEF, 2018; WEF, 2017). Furthermore, Stern (2007) argued that climate change is likely to have long-lasting impacts on growth if nothing is done to mitigate it. According to Stern's estimates, a business-as-usual scenario could cost between 5% and 20% of global GDP.

For the insurance industry, increased climate-related hazards mean potential portfolio losses in their liability and assets (Farid et al., 2016; Ravina, 2017; Dietz et al., 2016). Climate risk is, therefore, a new investment variable, which deserves peculiar attention from investors all over the world (Mercer, 2016).

However, when it comes to risk analysis, most investors usually focus on

[1] This essay is an elaborated and updated version of a work undertaken at the Rotterdam School of Management under the supervision of Professor Dirk Schoenmaker, from April 9th to June 30th, 2018.

traditional risks such as credit risk, market risk, contentious elections, referendums, or monetary policy decisions (BlackRock, 2016). Climate risk has often been less visible and is usually seen as a distant variable (EY, 2017). Consequently, the shareholder investment model, which looks for profit maximization only, still dominates firms' investment decision-making (Schoenmaker, 2017). Such an investment approach, however, is not compatible with the Sustainable Development Goals (SDGs) launched by the United Nations in 2015.

As a consequence of human activities (IPCC, 2014; IPCC, 2018), climate change and climate policies aimed at addressing it are expected to disrupt the business models of many firms across the world (Mercer, 2015). Therefore, investors may need to shift from the shareholder investment model to the stakeholder model which aims to create not only a financial return, but also social and environmental outcomes (Schoenmaker, 2017).

So far, however, only a small handful of investors have started to incorporate climate risk assessment into their investment decision-making (EY, 2017). The vast majority still rely on the traditional investment model, which assumes that «the future will continue to mirror the past» (Mercer, 2015). In other words, this investment model assumes that past performance is the best metric of future performance. However, although such an assumption may still hold under certain circumstances, climate change is likely to call it into question. The growing human, economic and financial losses ascribed to climate change, suggest that good performance today could no longer be a guarantee for future performance, especially when the performance is backed by carbon-intensive assets. Thus, climate change requires investors to revisit their approach to risk assessment and management by henceforth taking into account climate risks (Battitson et al., 2017; Subramaniam, 2016).

During the 2015 Paris Agreement, the world's political leaders have reached

an agreement to limit global warming to well below 2° Celsius above pre-industrial levels, and promote a resilient and low-carbon economy (UNFCCC, 2015). The implementation of this accord would require a radical technological shift at both domestic and international levels. From investment perspectives, such a shift would imply a transition risk for investors (Carney, 2016; Caldecott et al., 2014; Campiglio et al. 2018), especially for those whose portfolios rely on carbon-intensive assets (Mercer, 2015; Cahen-Fourot et al.,2019). The transition risk means that as soon as governments decide to effectively push forward the agenda on the low-carbon economy, through the implementation of carbon pricing for instance, firms would have to adapt their investment models so as to comply with the new national and international climate regulations. The magnitude of the impacts this policy measure would have on firms' portfolios would depend on whether it has been anticipated by the market (Pastor and Veronesi, 2011).

A growing number of papers have tried to investigate the exposure of financial institutions to climate risks (Battiston et al., 2017; Hjort, 2016; Mercer, 2015), the social cost of carbon (Ricke et al., 2018), and the links between transition risk and market failure (Thomä and Chenet, 2017). By investigating whether stock markets efficiently price climate risks, Hong et al. (2019) conclude that financial markets are today inexperienced with those risks. While adopting a network approach to financial dependencies and using stress-testing methods, Battiston et al. (2017) showed that investment and pension funds are exposed to climate policies. So far, however, there is little evidence about how an effective carbon pricing would affect the market price of Stock-listed companies, based on their carbon emissions.

The main objective of this essay is to empirically assess the potential impacts of climate transition risk on the market price of MSCI Europe index's constituents, using both top-down approaches and scenario analysis. The essay is based on the theory of asset pricing according to which, changes in

government policies can affect stock prices in important ways (Pastor and Veronesi, 2011). The implementation of an effective carbon price by the local governments, or at the international level is likely cause significant financial losses for stock-listed companies backed by carbon-intensive activities. According to Pastor and Veronesi (2011), policy change announcements can cause stock prices to rise or fall sharply depending on the level of uncertainty linked to those announcements. When those changes in policy are favorable to the market, stock prices would naturally rise and fall otherwise. Moreover, when investors anticipate bad announcements well before, their impacts on stock prices can be minimized.

By relying on this theory, this essay seeks to address the following question: what would be the potential impact on the market price of MSCI Europe's constituents, if the European Union decides to implement an effective carbon pricing? We estimate this transition risk based on their carbon emissions for the year 2015 for which data was available.

Thus, the essay is therefore original since it provides new insights about the exposure of Europe's biggest companies to climate mitigation policies. It is also original in the sense that it contributes to the literature on climate risks.

The remainder of this essay is structured as follows. Section 2 reviews the literature on climate risks and scenario analysis. Section 3 provides a detailed description of our methodology and the data used to assess the transition risk. Section 4 presents and discusses our key findings. Section 5 concludes.

2.2 Literature review

This section reviews the literature on both climate risks and scenario analysis. It identifies the key salient climate risks for investors and provide a thorough review of scenario analysis methods.

2.2.1 Climate risks

The literature on climate change as investment risk is relatively new. In his seminal speech delivered at the Arthur Burns Memorial Lecture, Mark Carney, the Governor of the Bank of England, argued that climate change is a tragedy of the horizon, since its cost is bore by current generations for future generations, so that current generations have no real incentives to deal with it (Carney, 2016). According to Carney, climate change is likely to affect investors through three mains channels: (i) physical risk, (ii) liability risk, (iii) and transition risk.

The physical risk refers to the physical impacts on properties of severe climate hazards such as storms, wildfires, hurricanes, flooding, and droughts (Carney 2016). Extreme climate-related events such as hurricanes, floods, and droughts are already hitting investment plans across the world (BlackRock, 2015), thereby creating and amplifying uncertainty for businesses and financial markets (Subramaniam, 2016). Without urgent actions, climate change is expected to reshape the world economy by amplifying financial instabilities, and accelerating economic and human losses (IPCC, 2018; Carney, 2016; BlackRock, 2015; Ricke et al., 2018). According to IPCC (2014), global mean surface temperature and sea-level rise are expected to continue over the 21st century at a faster rate than previous changes observed from 1971 to 2010. By the end of the 21st century, global mean surface temperature would likely reach up to 4.8°C, while global sea level rise is expected be in the range of 0.26 to 0.82 meters for all scenarios.

Extreme climatic events are expected to become more frequent due to global warming (Forzieri et al., 2018). As a result, physical and financial losses would increase due to those events. When these losses are insured, they would have a direct impact on the insurance and reinsurance industry, implying potential portfolio losses for insurance companies. However, when

they are uninsured, their repair cost would be bored either by individuals who own the damaged properties or by the government (De Nederslanche Bank, 2017).

For instance, the damages caused by hurricanes in 2017 in the United States were estimated between USD 65 billion and USD 190 billion (Irfan, 2017). In Europe, climate hazards such as floods, sea-level rise, and winter storms are increasingly impairing the insurance industry, with estimated insured losses of USD 3.11 billion in 2017, due only to floods and winter storms. Forzieri et al. (2018) estimate that climate-related damages could triple by the 2020s, multiply six-fold by mid-century in sectors, such as industry, transportation, and energy. Recent research shows that even if greenhouse gas were completely removed, it is likely that the 2° goal will not be achieved, and climate-related physical events will continue hitting the global economy (Raftery et al. 2017).

Next, the liability risk originates from parties who claim to suffer losses from increased climate change impacts. The recent advances in climate knowledge are likely to prop up climate litigation and laws (Marjanac and Patton, 2018). With more climate laws adopted at the Conferences of Parties (COP) or at the national or sub-national levels, carbon-intensive companies are facing greater legal proceedings (Bloomberg, 2018). Parties who suffer losses from climate change- be them individuals or organizations such as NGOs or social civil organizations- could ask for financial compensations to those they hold responsible for their losses. Such claims are likely to become more frequent in the medium to long terms, as extreme climatic impacts increase. Many Non-Governmental Organizations (NGOs) are already at the forefront of such activism across the world.

According to UNEP (2017), more than 894 climate litigation cases have been recorded in 25 countries across the world over the last decades, with 654 cases reported in the United States alone. This suggests that climate

lawsuits against carbon-intensive investors are likely to become common, as climate awareness increases. A case in point is Exxon, which has been sued by the state of New York for misleading investors on climate change risks (Reuters, 2018). The surge of greenhouse gas emissions in Europe has also led several families to sue the European Union at the European General Court, while claiming the violation of their fundamental rights to health, occupation, property and equal treatments (Bloomberg, 2018).

A logical consequence of the liability risk could be a radical change in consumers' preferences. Schoenmaker and Schramade (2019) argue that preference changes in households' consumption, helped by increased responsible investment advertising campaigns, are also an important risk that would affect firms' business models. Consumer's behaviors regarding the goods and services they consume fluctuate over time, implying that an increased climate-awareness from the public, backed by aggressive *don't buy campaigns*, could weaken the demand for carbon-intensive products. A case in point is the declining demand for child labor-intensive products (Schoenmaker and Schramade, 2019).

Finally, the transition risk, the focus of this essay, is about how a success story could turn out to a failure one following a change in policy or technology. This risk stems precisely from sudden adjustments in policy and technology, as the transition to a resilient and low-carbon economy becomes inescapable. The implementation of climate-friendly policies that lead to a sudden shift towards renewables, for instance, could affect the value of a wider range of carbon-backed financial assets (Mercer, 2015; Battiston et al., 2017). In other words, beyond the physical impacts of climate change, government led-policies meant to mitigate it could also prove very harmful for carbon-intensive investors. While hurrying climate actions could be considered as an insurance policy against the "unknown future", they also expose investors to the transition risk of climate change (Denny and Weiss, 2015).

It worth noting however that the above-mentioned risks are not isolated. Instead, they are interconnected, complex, non-linear, and dynamic. The magnitude of their impacts on investment portfolios would depend on asset owners' preparedness and time horizons (BlackRock, 2016), as well as on the speed at which modern policy makers decide to move towards a low-carbon society. Nonetheless, Guyatt (2011) argued that policies aimed at mitigating and adapting to climate change are the most important risk factors for investors. Furthermore, investors are likely to suffer losses from second-round impacts of climate change. As Cahen-Fourot et al (2019) argue, all forms of capital linked to fossil fuels and industrial plants whose output requires fossil fuels as material inputs would be affected in a rapid low-carbon transition. A weaker economic growth, and increased political instabilities as a consequence of climate change, would also lead to weaker investment returns for investors (De Nederlansche Bank, 2017). The declining costs of clean technologies, for instance, has forced several businesses and asset owners in energy production to adopt sustainable behavior codes (BlackRock, 2016b). A case in point is the collapse of Peabody Energy, as a result of declining costs of rival energy sources (Reuters, 2016).

The Paris agreement aims to limit the global surface temperature increase to well below 2°C. Meeting this target implies that global CO_2 emissions peak no later than 2020, and gross emissions decline from 40 $GtCO_2$/year in 2020 to around 5 by 2050 (Rockström et al., 2017), implying a huge transition risk for investors. Sectors such as coal, electricity and gas, manufacturing, transportation, and water supply will be the most affected by the transition risk. A quick and hard transition toward the low carbon economy could result in many assets becoming stranded, (Carney, 2016; Caldecott et al., 2013; Caldecott, 2017). Thus, the transition risk should be a major concern for both investors and policy-makers, as it could pave the ground for sudden climate

Minsky moments (Carney, 2016). This is why investors should conduct scenario analysis to assess their exposure to climate risks.

2.2.2 Scenario analysis

Scenario analysis is a description of possible future states of a given variable under different assumptions (Kosow and Gabner, 2007). More specifically,

> *'Scenarios are descriptions of journeys to possible futures. They reflect different assumptions about how current trends will unfold, how critical uncertainties will play out and what new factors will come into play' (UNEP, 2002, Chapter 3, p320).*

It is worth noting, that the objective of scenario analysis is not to provide a precise description of the future. Instead, the main purpose of scenario analysis is to identify different possible forces that could affect the dynamics of a given variable of interest. Thus, scenarios are «hypothetical constructs», which do not accurately represent the reality. Nevertheless, they have the benefit of drawing attention about the future states of the variable being analyzed. Hence, scenario analysis stands as a useful method that can help investors reduce their exposure to climate risks.

According to Kosow and Gabner (2007), there are at least three types of scenario techniques, including (i) trend extrapolation scenarios, (ii) systematic-formalized scenario, and (ii) creative-narrative scenarios.

The core of extrapolation scenarios consists of trend analysis and trend extrapolation. These scenarios assume that the future is "predictable" based on our knowledge of the present and past. Systematic-formalized scenarios are techniques that combine different variables of interest and vary them one with another to get a scenario funnel which provides different possible outcomes. Carrying out such an analysis requires two important steps: the

identification of the key variables of interest and the analysis of their interconnections. Finally, creative-narrative scenarios, on which the essay relies, are characterized by intuition and implicit knowledge. They are mostly used for normative analysis and obey the same logic as systematic-formalized scenarios (Kosow and Gabner 2007).

The literature on scenario methods suggests that the process of elaborating a scenario analysis generally encompasses three important steps across techniques (Kosow and Gabner, 2007; De Ruijter, 2014).

The first step consists of specifying plausible and internally consistent scenarios in one hand, and formulating the question to be addressed, in the other hand. In other words, the researcher should be able to put forward different plausible hypotheses regarding the future, even though that future is clouded by uncertainty. The choice of the number of scenarios depends on how much each scenario differs from the others. Furthermore, the selection of the variables of interest and their values, if quantitative variables, depends on what the researcher is interested in finding out (Kosow and Gabner, 2007).

The second important step in conducting a scenario analysis, consists of identifying the key risk factors that are likely to have a significant impact on investors' portfolios.

The last step for a scenario analysis according to De Ruijter (2014), is to represent the specified scenarios to make them captivating storytelling. In our analysis case, the main task regarding this step will consist of estimating the potential impact of the transition risk of climate change on market price of MSCI Europe's constituents.

2.3 Methodology and data

2.3.1 Scenario elaboration

To assess the potential impacts of the transition risk on the market price of MSCI Europe's constituents, we started by specifying different scenarios that could play out. There has been increasing interests for scenario analysis methods in different fields of research, especially in climate change sciences. When faced with radical uncertainties such as those yielded by climate change, scenario analysis is one of the techniques researchers can rely on to lay down different possible outcomes of the future. With this in mind, we adopt a three scenario-based analysis borrowed from Mercer (2015) to assess the potential impacts carbon pricing could have on the market price of MSCI Europe's constituents. Our three scenarios are specified as follows: (i) transformation scenario, (ii) coordination scenario, and (iii) fragmentation scenario.

Transformation: the transformation scenario is a scenario which demands significant changes from the status quo (Nalau and Handmer, 2015), and assumes that there would be strong and sudden shifts towards low carbon societies with aggressive climate-mitigation policies. A violent and disruptive event related to climate change is expected to happen, and therefore force governments, investors, civil society organizations, and other stakeholders to work hand in hand to deliver a no more than 2°C world. Greenhouse emissions under the transformation scenario are assumed to peak at 2020, decline from 40 $GtCO_2$/year in 2020 to around 24 by 2030, 14 by 2040, and drop to 5 by 2050 (Rockström et al., 2017). Energy generation from fossil fuel sources would decrease to 4O% from its 2012 levels (Mercer, 2015). The transformation scenario is therefore associated with a higher carbon price that would lead investors to drastically reduce their carbon emissions.

Coordination: Policies and climate actions in this scenario are assumed to be aligned and mutually supportive, allowing for global warming of 3°C above pre-industrial levels. Under this scenario, greenhouse gas emissions are assumed to peak after 2030 and then fall by 27% , relative to the 2010 level, by 2050. Fossil fuel would nevertheless continue to represent around 75% of the world energy mix, and annual CO_2 emissions would drop by 37 $GtCO_2$e, by 2050. Although the coordination scenario is the most likely scenario, there are many uncertainties tied to that it. For instance, Finus et al. (2013) argue that:

> *'there are inherent difficulties associated with climate change negotiations, ranging from which countries should bear most responsibility for a given emission reduction target to the assessment of a globally efficient time path for pricing harmful greenhouse gas emissions (GHGs). These difficulties become even more complex and challenging under the pervasive uncertainty of climate science and the uncertainty about the feedback loop between climate change damages and economic growth.'*

This is to say that without a strong political will, the coordination scenario may not deliver the expected outcomes. The recent withdrawal of the United States from the Paris climate agreement illustrates all the difficulties associated with coordination in climate negotiations. Thus, a medium carbon price was chosen for this scenario.

Fragmentation: In this scenario, there are limited incentives to adopt some coordinated climate mitigation policies in order to curb greenhouse gas emissions. However, some countries may still implement individual climate policies regardless of what other countries do. As a result, global warming could reach 4° Celsius or more by the end of this century. Global emission would increase at 33% above 2010 levels, and peak after 2040. Fossil fuel energy

in this scenario dominates the global energy mix, reaching over 85 % of it. Annual CO_2 emissions would more than double its level in the coordination scenario (67 $GtCO_2$e), by 2050. The fragmentation scenario is "the worse climate scenario over the very long term" (Mercer, 2015). We assigned a lower carbon price for this scenario.

As stated in the literature review, scenario analysis also requires the identification of different relevant risk factors for each scenario specified. According to (Mercer, 2015), there are four climate-risk factors that investors should bear in mind when making their investment decisions, namely, technology, resource availability, physical impacts, and climate policies. Our analysis focuses on the latter.

Policy uncertainty is defined as uncertainty about international, national or sub-national legislation and regulations meant to mitigate or adapt to climate change. The above scenarios are likely to provide investors with a long-term view of how the next few decades might play out.

Intuitively, if the transformation scenario plays out, the transition risk is likely to be more disruptive for investors, while the physical risk is expected to be more harmful under the fragmentation scenario. In the same vein, if there are no real incentives to address climate change, the impact of the fragmentation scenario is likely to be higher than that of the transformation and coordination in medium to long term. Consequently, investors would be facing increased physical impacts ascribed to climate change hazards under this scenario. Tables 2.1 and 2.2 below summarize respectively the salient risks and their relative expected magnitude under each scenario.

TABLE 2.1: Scenarios and corresponding relevant risks.

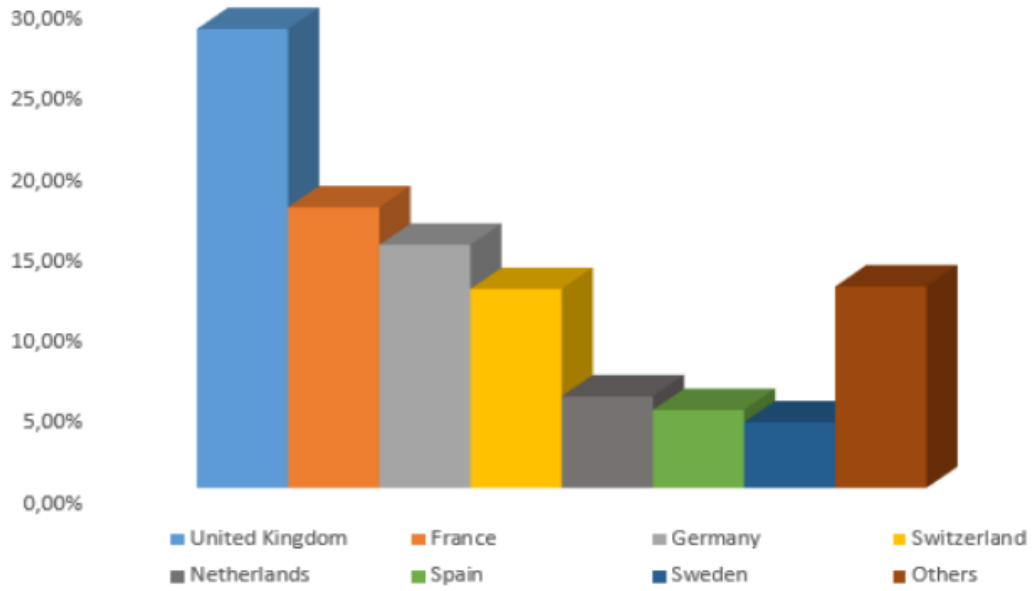
Climate change scenarios			
Scenario Name	Salient risks by scenario	Impact on investment	Remarks
Transformation	Transition risks (policy and technology)	I_1	Hard policies and technology changes
Coordination	Transition risks (policy and technology)	I_2	Soft policies and technology changes
Fragmentation	Physical risks (temperature increase, sea level rise, droughts, CO_2 concentrations)	I_3	Individual policies at country level, no coordination

TABLE 2.2: Risk impact table.

Expected overall impact table			
Risk type/ Scenario	Transition risk	Physical risk	Liability risk
Transformation	*high*	*low*	*minor*
Coordination	*high*	*low*	*minor*
Fragmentation	*low*	*high*	*high*

2.3.2 Data

Our sample includes 423 out of 445 constituents of the MSCI Europe index, as of June 2018. A dozen of constituents have been excluded due to lack of data and holding issues. The MSCI Europe index is a European equity index, which tracks the return of stocks within 15 European developed markets. It represents around 85% (around USD 9 trillion) of the total market capitalization of developed European markets. The United Kingdom represents the largest share in the MSCI Europe index (around 28.36%), followed by France (17.34%) and Germany (15.02%). Countries such as Switzerland and the Netherlands represent respectively 12.29% and 5.66% of this index. Figure 2.1 shows the breakdown of the MSCI index by country weight.



Source: Authors' construction based on MSCI data, as of June 2018. The United Kingdom, France and Germany represent around 60% of this index.
FIGURE 2.1: The weight of the MSCI Europe index by country.

Since we are interested in estimating the potential impacts of the transition risk on the market price of MSCI Europe's constituents, two variables

are of particular interests to our study: the Co_2 emissions and the annual operating profits of those constituents. The ratio between the cost of the Co_2 emissions and the annual operating profit of a given constituent, multiplied by its index weight, gives an estimate of the transition risk's impact on the market price of that constituent. In other words, this metric estimates the portfolio loss each constituent would incurred under each scenario.

Since we do not have individual carbon emission data for all the constituents included in our sample, we adopted a top-down approach to derive such emissions, based on the carbon intensities of the European core economic sectors. Those carbon intensities are extracted from Eurostat for the year 2015, for which complete data was available at the time of writing this essay. To do so, we classified the 423 companies included in our sample according to the statistical classification of economic activities in the European Community (NACE). Furthermore, to avoid double-counting issues with holding companies (i.e., companies with more than one activity), each constituent was classified according to its main economic activity.

Top-down approaches represent a reasonable method that can be used when there is no granular publicly available data (Kapinos and Mitnik, 2016). However, it also has the potential cost that industry-level aggregate data may overlook firms' specific characteristics. The top-down approach assumes that the amount of carbon emissions per unit of gross value added is the same for all companies belonging to the same economic sector. Although this assumption is subjective, it has the benefit of allowing for the estimates of the carbon emissions of individual companies. Based on this method, we estimate individual carbon emissions for each constituent included in our sample, focusing on the year 2015, for which complete data on carbon intensities and annual operating profits were available. We estimate for each constituent its

gross value added (GVA) for the same year, using the following formula :

$$GVA_i = S_i - P_i \tag{2.1}$$

, where GVA stands for the Gross Value Added of a given constituent 'i' for the year 2015. S_i and P_i stand respectively for total *Sales* and total *purchases* of the corresponding constituent for the same year. Data on sales and purchases are collected from the 2015 annual income statements for all the constituents included in our sample.

It is worth noting, however, that not all MSCI Europe's constituents have the same accounting methodology. Hence, for those companies that do not report their intermediate consumption or purchases in their annual income statement, we considered the half of their annual sales as a proxy for their gross value added of the year. For financial institutions such as banks and insurance companies, we considered their net interest income and net earned premiums respectively, as proxies for their gross value added.

Since constituents' annual income statements are expressed in different currencies, we converted all the values expressed in other currencies into one single currency base (Euro), while using end-year exchange rates.

The annual CO_2 emissions of each constituent is obtained using the following formula:

$$CO_2 i = GVA_i \times CI_{Europe/sector} \tag{2.2}$$

, where $CI_{Europe/sector}$ stands for carbon intensity by sector at the European level, and is available through Eurostat, a database of the European Union, which provides statistics and promotes harmonization of statistical methods across members.

2.3.3 Techniques for estimating the transition risk

Let TR_i denote the transition risk's impacts on the market price of constituent 'i', and let us assume that the government decides to put a price on carbon emissions in order to phase out or discourage carbon-intensive activities. Intuitively, the transition risk (TR_i) for a given constituent is a function of its carbon emissions CO_2i. TR_i = f(CO_2i; t).

If t denotes an exogenous carbon price set by the government to evict carbon-intensive activities, the cost associated with such a decision for each constituent is given by T_i. The implementation of carbon pricing would directly affect the market price of the underlying companies, as they would have to incur the cost of their carbon emissions.

$$T_i = t \times CO_2i \tag{2.3}$$

The transition risk TR_i (i.e., the estimated market price drop) for each company, in a given period, is thus given by the ratio between the cost of its carbon emissions and its operating profit, multiplied by its corresponding index weight.

$$TR_i = \frac{T_i}{OP_i} \times w_i \tag{2.4}$$

where OP_i and w_i stand respectively for the operating profit and weight of constituent i. From the equations (2) and (3), it follows that:

$$TR_i = \frac{t \times CI_{Europe/sector} \times GVA_i}{OP_i} \times w_i \tag{2.5}$$

We used a lower carbon price (EUR 21) for the fragmentation scenario, a medium carbon price (EUR 56) for the coordination scenario, and a relatively higher carbon price (EUR 86) for the transformation scenario. Those carbon prices are drawn from Stern and Stiglitz's 2017 report. However, it is also possible to consider higher carbon prices. For instance, Moore and Diaz

(2015) propose a carbon price of EUR 202/tCO_2.

2.4 Main results and discussion

Estimation results show that sectors, such as electricity and gas, transportation, and manufacturing are the major carbon-emitting sectors in Europe. For instance, the electricity & gas sector is the most carbon-intensive sector in Europe, with an estimated carbon intensity of 4540 tCO2/GVA in 2015. However, its contribution in terms of gross value added remains marginal (EUR 246 billion) compared to other sectors such as real estate (EUR 1.5 trillion), transportation (EUR 662 billion), and manufacturing (EUR 2 trillion). Figure 2.2 displays carbon emissions and gross value added by sector in the European Union for the year 2015.

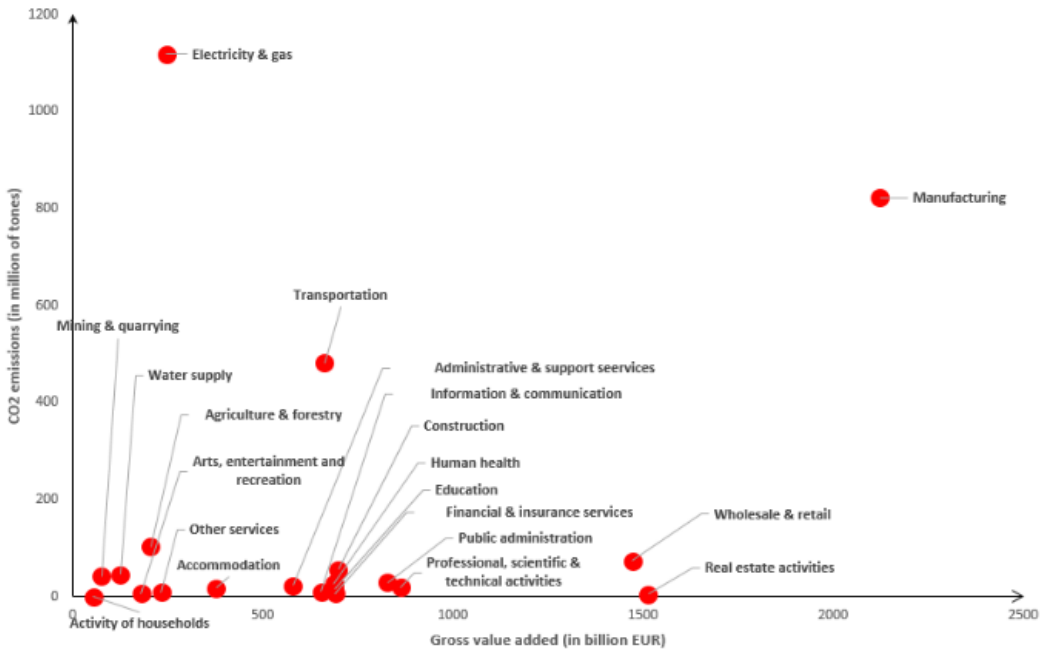


FIGURE 2.2: Carbon emissions and value-added by sector of European countries in 2015.

The results of our investigation suggest that if the carbon cost information were released to the market, the transition risk of climate change would have

a significant yet differentiated impact on the market price of MSCI Europe's constituents. This result is consistent with the literature on how Stock price reacts to market noise, and policy announcements (Beatty and Shimshack, 2010, Pastor and Veronesi 2011).

In terms of the overall portfolio impact, the transition risk would cost around 0.35% of the MSCI Europe's market capitalization under the fragmentation scenario, 0.86% under the coordination scenario, and 1.4% if the transformation scenario plays out (see Figure 2.3).

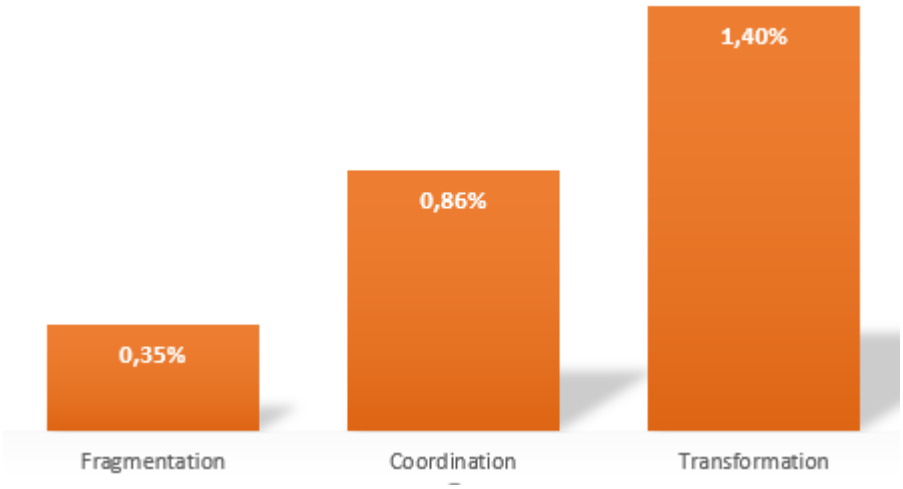


FIGURE 2.3: Overall portfolio losses due to the transition risk of climate change

Table 2.3 below summarizes the potential impacts of the transition risk by sector and by scenario. If the transformation scenario plays out, the transition risk would be significantly harmful to sectors such as electricity, utilities, transportation, and agriculture. The market price of transportation and agriculture-dependent companies would drop by at least 30%, while companies in sectors such as electricity and utilities would be delisted from the Stock, since their portfolios would become totally stranded (100% market-price drop). By contrast, financial service constituents are likely to be less affected by the transition risk, at least based on their estimated carbon emissions (less than 0.30% of market-price drop). However, those companies are

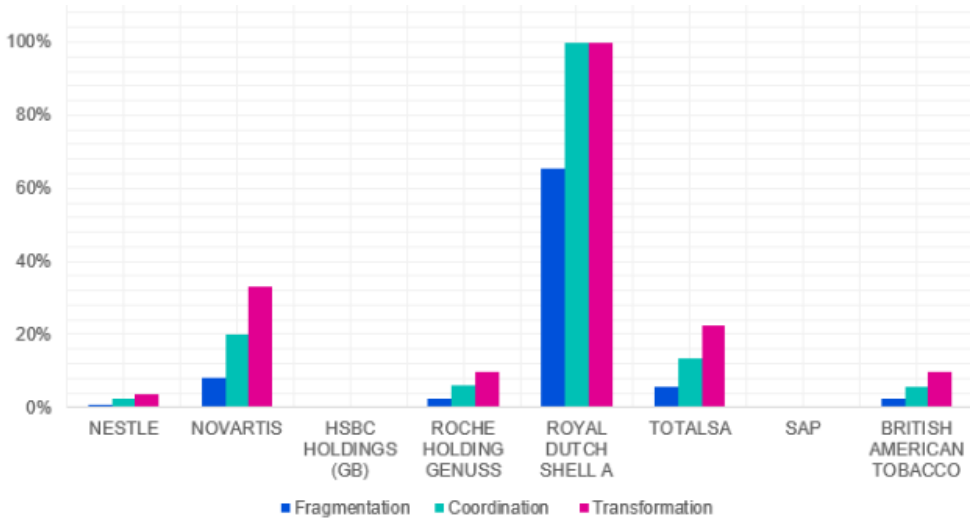
likely to suffer more from their indirect carbon emissions included in their loans to and purchases from carbon-intensive clients.

TABLE 2.3: Estimates of the transition risk by sector and by scenario

The transition risk by scenario and by sector (%)			
Economic sectors	Fragmentation	Coordination	Transformation
Agriculture & forestry	8.90	22.05	36.46
Manufacturing	4.25	10.51	17.38
Transportation	7.72	19.11	31.60
Arts, entertainment & recreation	0.08	0.20	0.33
Construction	1.45	3.58	5.92
Electricity	39.51	97.85	100
Utilities	47.04	100	100
Accommodation & food services	0.37	0.91	1.51
Wholesale & retails	0.66	1.64	2.71
Financial services	0.07	0.17	0.27
Water supply	1.64	4.05	6.70
Mining	4.72	11.70	19.34

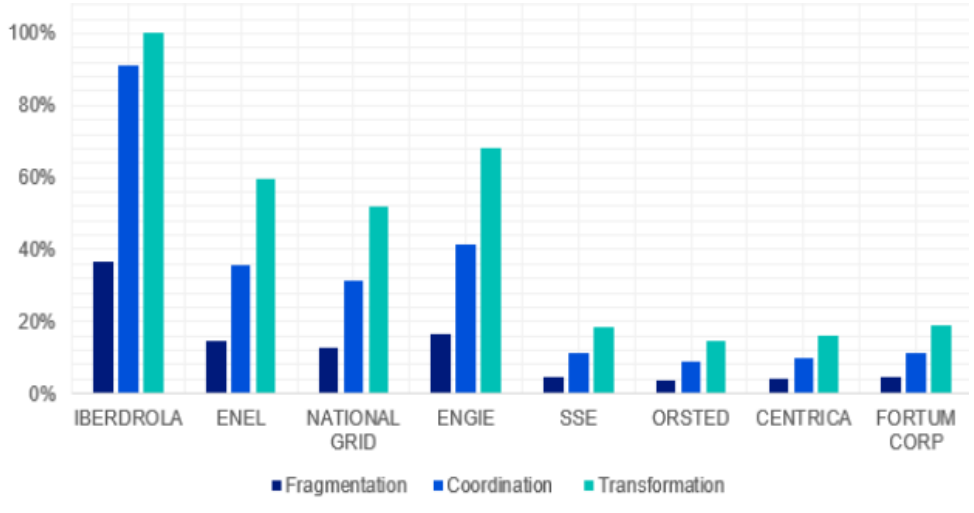
According to our estimates, among the top ten constituents of the MSCI Europe index, Royal Dutch Shell is likely to suffer the most from the transition risk if the transformation and coordination scenarios play out (100% market price drop in both cases). For the top utilities constituents, Iberdrola and Engie, Enel as well as National Grid would be the most affected by the transition risk of climate change under the transformation and coordination scenarios. The automobile industry would also suffer from the transition risk of climate change whatever scenario plays out. Companies such as Fiat, Michelin, Daimler, Renault, Peugeot SA., and Volkswagen would see their market price drop by at least 5% if the transformation scenario plays out.

Figures 2.4 to 2.7 below show the potential impacts of the transition risk by scenario for some of the top constituents of MSCI Europe index by sector.



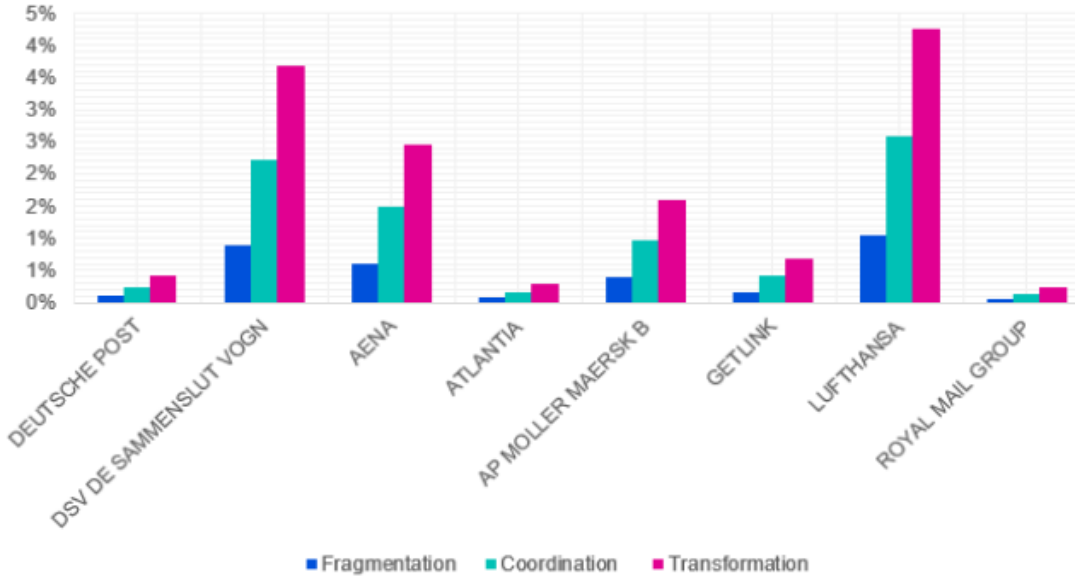
Source: Author's construction. Among the top constituents of this index, the Royal Dutch Shell is the most exposed to the transition risk of climate change. If both the transformation and coordination scenarios play out, all the assets of the Royal Dutch Shell would become stranded (100% of market share drop).

FIGURE 2.4: Impact of the transition risk on the market price of the MSCI Europe index's top constituents.



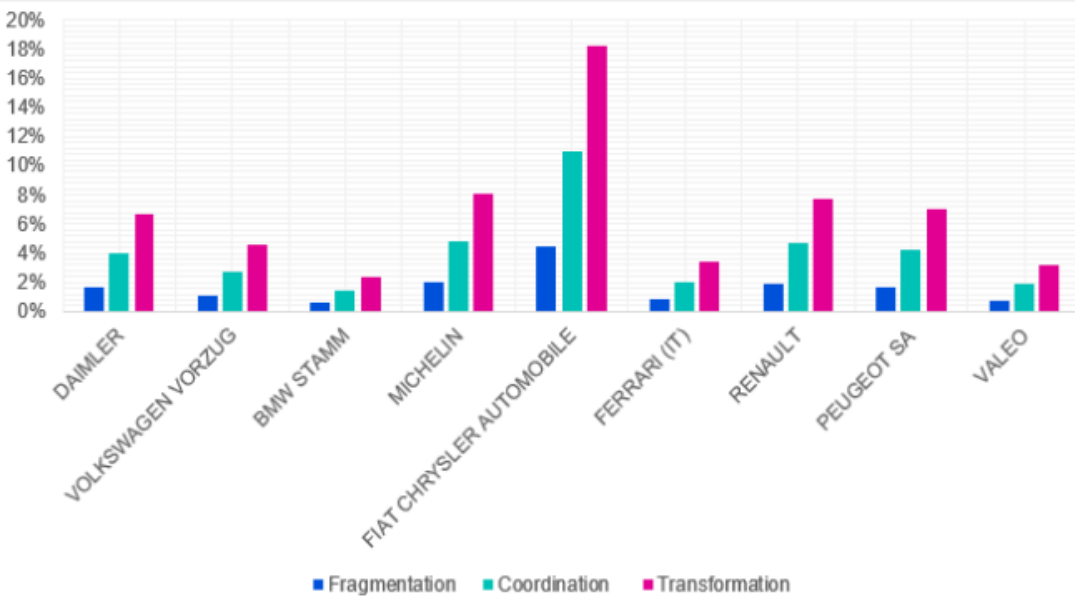
Source: Source: Author's construction. If the transformation scenario plays out the market price of those constituents would drop by 10% at least. Constituents such as Iberdrola, Enel, National Grid, and Engie will see their market price drop by at least 50%, and up to 100% for Iberdrola.

FIGURE 2.5: Impact of the transition risk on the top utility constituents of the MSCI Europe index.



Source: Author's estimates. Top transportation service constituents are likely to be less affected by the transition risk than would the utility constituents. The highest market price drop (4.5%) comes from Lufthansa.

FIGURE 2.6: The impact of the transition risk on the top transportation service constituents of the MSCI Europe index.



Source: Author's construction. The automobile industry will also experience losses from a sudden transition towards a low-carbon society. Under the transformation scenario, companies such as Daimler, Michelin, Fiat Chrysler Automobile, Renault, and Peugeot would see their market price drop by at least 5% (up to 18% for Fiat).

FIGURE 2.7: The impact of the transition risk on the top automobile constituents of the MSCI Europe index.

The findings in this essay confirm what previous studies have found about the exposure of the European financial system to climate risks (Battiston et al. 2017; Cahen-Fourot et al. 2019). In their study of the impacts of climate risks on the financial sector, Battiston et al.(2017) argue that the timing of climate policies matters, as they can lead to potential winners and losers. The results of their study suggest that the European banking sector is directly and indirectly exposed to climate-policy-relevant sectors, such as utilities, fossil fuel extraction, transportation, and housing. Our results show that whatever scenario plays out, the MSCI Europe index, which includes some of the biggest European financial institutions, would suffer losses from the transition risk of climate change.

While investigating the exposure of some economic sectors to the risk of physical capital stranding in ten European countries, Cahen-Fourot et al. (2019) found that the mining sector is the most vulnerable sector to the physical impacts of climate change. Furthermore, their results suggest that sectors such as electricity and gas, manufacturing, and mining are at risk of the transition-related stranding. Our findings confirm that risk by showing that electricity, utilities, transportation, and manufacturing, are at higher risk of capital stranding, whatever scenario plays out.

It is worth noting, however, that the main findings in this essay have major implications for the deployment of the low-carbon economy. While the transformation scenario is the best long-term solution for building a sustained and low-carbon economy, it also appears as the worse scenarios in the short term for the financial sector, suggesting that not all transformation is positive and welcome as pointed out by Nalau and Handmer (2015). As a result, the financial industry could be lobbying against a rapid low-carbon transition, should the government decide to charge carbon emissions through an effective carbon pricing scheme. Such behaviors have already been reported by Ferns et al. (2019), who highlighted a mythmaking strategy

in the discourse of the European oil and gas supermajors' CEOs to avoid the tensions between climate change and fossil fuels.

This implies that there may not be an effective carbon pricing at the global scale if governments fail to reach an agreement under the United Nations Framework Convention on Climate Change. In other words, carbon pricing alone, although essential, is unlikely to create enough incentives for rapid deep decarbonization (Criqui and Mathy, 2017; Heine et al., 2019). Instead, carbon pricing measures should be backed by flexible emission regulations (Jaccard and Criqui, 2017), and other innovative financial instruments, such as green bonds (see Essay 3 and 4). Without such a climate policy-mix, only the growing harmful impacts of climate-related physical events could lead to an effective climate-awareness among investors. A case in point is the devastating impacts of the violent Dorian hurricane in the Northwestern Bahamas.

Although this essay brings new insights on the literature on climate risks, it may have some limitations. The first limitation relates to the lack of a complete and accurate database on individual carbon emissions at different scope levels (scope 1 to scope 3). This led us to derive individual carbon emissions by using top-down approach. However, this can lead to underestimate or overestimate the carbon emissions of some constituents. The second limitation concerns the choice of lower carbon prices for our three specified scenarios and the focus on one year's carbon emissions. Future studies should consider actual carbon emission data, as robust data becomes available. Finally, the use of scenario analysis, which do not accurately represent the reality can be another limitation of this study. Nevertheless, the essay has the advantage of providing investors with figures about the potential impacts of carbon pricing on the Stock prices of their companies, while laying the ground for future empirical research on the transition risk.

2.5 Conclusion

Climate change is a social, environmental and economic risk, which is expected to have its greatest impacts in the future as global surface temperature and sea-level rise. Failure to mitigate and adapt to climate change is among the top global risks over the next decades. A sudden transition to a low carbon economy might be harmful to growth and would affect financial stability.

Climate mitigation policies, such as carbon pricing, are likely to have a significant impact on the stock market if investors continue to delay the incorporation of climate risk assessment into their investment decision-making. As climate impacts worsen, investors may need to revisit their approach to investment decision-making by incorporating climate risk assessment.

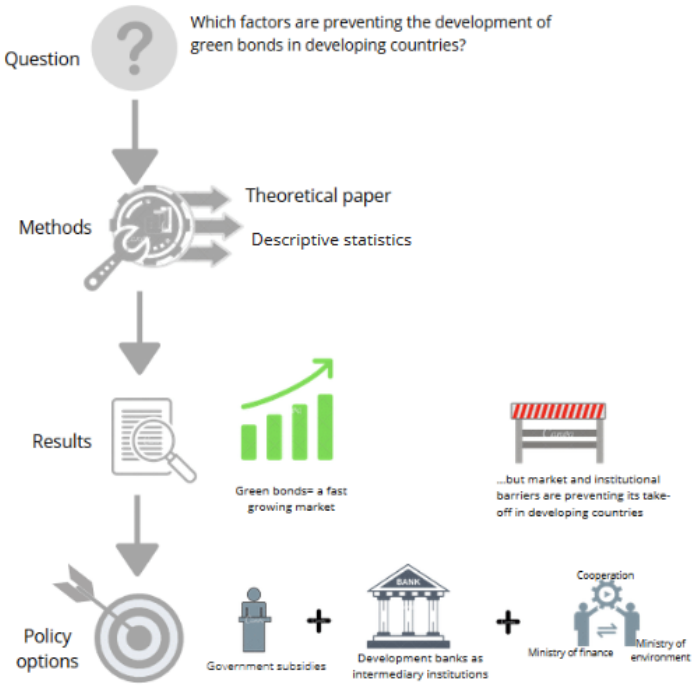
In this essay, we estimated the potential impacts of the transition risk of climate change on the market price of MSCI Europe' constituents, using scenarios analysis. Our findings suggest that, without significant reduction of their carbon footprints, companies in the MSCI Europe index would suffer significant yet differentiated losses from the transition risk of climate change. However, investors could face even more losses due to the interrelated nature of the transition risk, the physical, and the liability risk. By integrating climate risk assessment into their investment decision-making, investors could not only protect their portfolios against climate-induced losses, but also enable the development of innovative market-based instruments, such as green bonds.

Chapter 3

The green bond market: a potential source of climate finance for developing countries

"Issuing green helps a financial corporate understand its climate risks and prepare for what is coming".

- Armin Hermann, Head of Treasury, DKB.



3.1 Introduction

[1]

The transition to a resilient and lower-carbon economy requires significant investment from both public and private sectors. Recent climate summits have revealed that finance is critical for the implementation of Intended Nationally Determined Contributions (INDCs), in which nearly 200 countries have publicly outlined their intentions in terms of greenhouse gas reduction. For many developing countries, these intentions are highly dependent on the pledges of developed countries to provide them with USD 100 billion annually for their adaptation and mitigation projects (UNFCCC, 2009). However, the current economic turmoil that prevails in most developed countries (King, 2017) and the lack of common understanding about the balancing between adaptation and mitigation finance (Pickering et al., 2015) suggest that developing countries are unlikely to achieve their emission reduction targets by solely relying on those pledges. Rather, developing countries must also explore new financing mechanisms, such as green bonds if their commitments ought to be respected. As innovative financial instruments, green bonds provide an opportunity to tap into new pools of private capital to finance green projects (EY, 2018).

The term 'green bonds' refers to bonds whose proceeds are used to finance environmentally-friendly projects (Mercer, 2015), such as renewables, water and energy efficiency, bioenergy, and low carbon transports (Campiglio, 2016). So far, there is no universal definition of green bonds, though a growing consensus has emerged on what they are intended to do (OECD, 2017; German Development Institute, 2016). For the purpose of this essay, a green bond should be defined as a fixed-income financial instrument for raising

[1] This essay is an updated version of an article that I published in the *Journal of Sustainable Finance and Investment*, vol.9, 2019, Issue 1. DOI: https://doi.org/10.1080/20430795.2018.1498617.

capital to finance or refinance eligible green projects (OECD, 2017; ICMA, 2017). As such, green bonds are of significant importance to both investors and policy makers. On one hand, governments need access to affordable and reliable financial resources in order to fulfill their commitment under the 2015 Paris Agreement, which aims to hold the increase in the global average temperature to well below 2 degrees above pre-industrial levels (United Nations, 2015). In the other hand, investors are increasingly encouraged to adapt their business models to create a not only financial value but also social and environmental values (Schoenmaker, 2017).

During the 2008 financial crisis, green bonds were a concept of limited interest to investors (United Nations Secretary-General, 2015; German Development Institute, 2016), since environmental projects were deemed risky and non-profitable by traditional investors (Wharthon, 2015). Surprisingly, there has been an exponential growth in green bond issuance since then, attributable to an increased awareness from traditional investors about the benefits of green investments (Shishlov, Morel, & Cochran, 2016) and the potential impacts of climate change on financial assets (Carney, 2016; Mercer, 2015; Schoenmaker, 2017; Caldecott, 2017). Investors' appetite for green bonds has therefore grown rapidly (Pham, 2016), as they realize that climate change is a new investment return variable, which deserves significant attention (Mercer, 2015). Many investors, especially those in the carbon-intensive sectors of the economy, have now become very reactive to climate-related technologies, such as carbon capture and sequestration (CCS). More importantly, an increasing number of investors began to incorporate climate change risk assessments into their investment strategies (Byrd and Cooperman, 2018).

The European Investment Bank (EIB) was the first multilateral development institution to issue a climate-awareness bond, worth USD 1 billion, in 2007. A year later, the World Bank issued a second green bond to finance climate mitigation and adaptation projects in its countries of operations. Since

then, municipalities, commercial banks and some of the world's largest companies followed in the same direction. For instance, green bond issuance has grown drastically from USD 1 billion in 2007 to USD 895 billion in 2017, of which USD 674 billion were self-labeled green bonds, and USD 221 billion of certified labeled green bonds, according to the Climate Bonds Initiative. Certified green bonds refer to bonds that completed a certification process to receive the green label, which means that all their proceeds must be used to finance the green projects for which they have been issued. In contrast, self-labeled green bonds are bonds labeled as green by the issuer but not attested by an independent reviewer, as is the case for certified green bonds. Since 2014, there have been significant efforts aimed at making green bond standards more popular to investors (Ceres, 2014). Yet the size and scope of the green bond market remain negligible compared to the global fixed-income market (Franklin, 2016; Moody's, 2017). Furthermore, the development of the green bond market is only perceptible in some developed and emerging countries[2] . In many developing countries, however, the market remains incipient, and its full potential seems to be underappreciated. According to the Climate Bonds Initiative, only USD 2.2 billion of total flows in the green bond market, have been directed towards cities in developing countries compared with USD 17 billion in developed countries (Climate Bonds Initiative, 2016).

The objective of this analytical essay is to study the rise of the green bond market over the last few years, by putting an emphasis on its key drivers and the barriers that prevent developing countries from exploiting this new yet growing source of climate finance. Beyond its analytical contribution, this essay aims to push forward the literature on green bonds. The remaining of the essay is structured as follows. Section 2 shows recent trends in the

[2]Emerging countries are defined here as countries with high levels of economic development and potential for rapid industrialization. They include but are not limited to the top 20 emerging markets ranked by Bloomberg Market Magazine in 2013. Available here: https://www. bloomberg.com/news/photo-essays/2013-01-31/the-top-20-emerging-markets.

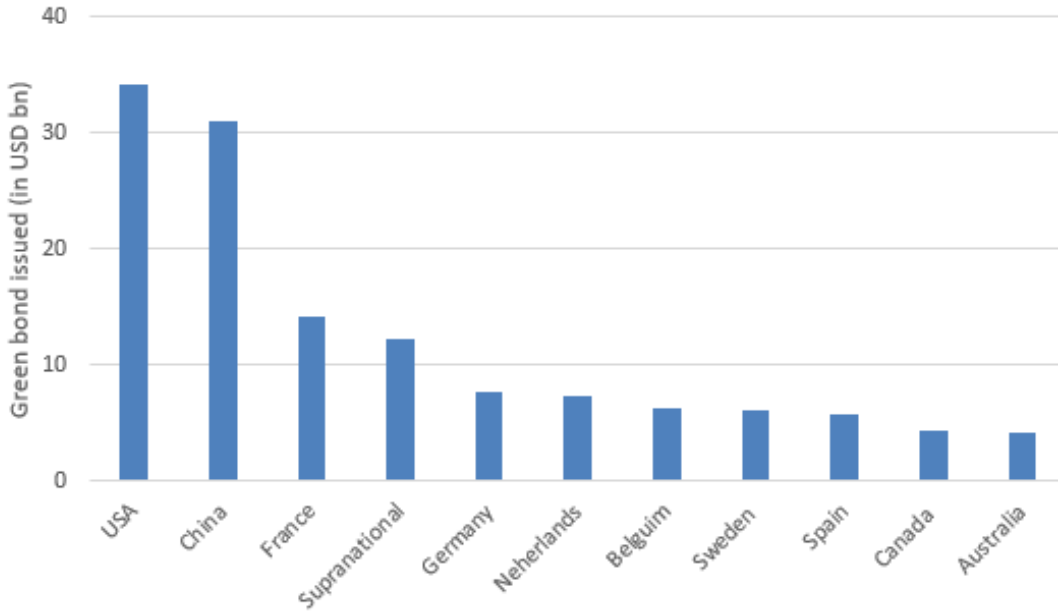
green bond market. Section 3 identifies relevant barriers that prevent developing countries from taking advantage of that market. Section 4 discusses the findings and provides a set of policy recommendations aimed at helping developing countries overcome these barriers. Section 5 concludes.

3.2 Recent trends in the green bond market

Green bonds provide an opportunity for long-term and sustainable infrastructure financing. Previously carried out by multilateral development banks (MDBs), namely the World Bank and the European Investment Bank, green bond issuance has promptly spread to other traditional investors, such as institutional investors, commercial banks, municipalities, and some of the world's largest companies. Investments in this new and growing segment of fixed-income markets have increased more than ten-fold over the past five years and is expected to reach USD 1 trillion by 2020, as the demand for green bonds continues to rise (CBI and HSBC, 2017). The launching of the Green Bond Principles (GBPs)[3] in 2014, which now involve a consortium of more than 200 financial and non-financial institutions, has only strengthened the emergence of green bonds. According to Climate Bonds Initiative's database[4], the total number of green bonds issued has increased from one in 2007 to more than 2000 issued green bonds in 2017, a spectacular annual growth of more than 113% during the same period. In 2018, the United States, China, and France stood as the world's top three green bond issuers, and are expected to continue to be the green bond market leaders over the next few years (see Figure 3.1).

[3]According to the International Capital Market Association, GBPs are voluntary process guidelines that recommend transparency and disclosure and promote integrity in the green bond market. They aid investors by ensuring availability of information necessary to evaluate the environmental impact of their green bond investment.

[4]The Climate Bonds Initiative is a London-based not-for-profit international organization, which has been tracking the green labeled market since 2009. It annually produces a report highlighting the state of the green bond market across the world.



Source: Climate Bonds Initiative (2018).
FIGURE 3.1: Top green bond issuers, as of mid-2018.

Developing countries, however, are excluded from this growing source of climate finance they need to implement their adaptation and mitigation projects. A thorough analysis of the Climate Bonds Initiative's database shows that only a small handful of investors and governments from those countries have issued green bonds so far. Nevertheless, a growing number of them are progressively looking after the market[5].

3.2.1 The key drivers of the green bond market

Without claiming to be exhaustive, this subsection identifies several forces that have been decisive for the development of the green bond market in developed and emerging countries over the last few years.

First, with few exceptions, green bonds are inherently similar to conventional bonds in terms of structure. Their deals carry the same risk/return profile like any conventional bond issued in the fixed-income market. The

[5]There are more and more of developing country Sovereigns issuing green bonds, including Argentina, Chile, Indenosia, Kenya, Malaysia, Nigeria, Morrocco, Seychelles, etc.

pricing and yield to maturity of green bonds are indeed akin to that of conventional bonds. Recent empirical studies showed that there is a strong correlation between the yield to maturity (YTM)[6] of green bonds and that of conventional bonds (Wanke, 2017). Figure 3.2 depicts this correlation for green bonds and conventional bonds issued by the German Development Bank (KFW) and Apple. The fact that green bonds are ranked pari passu with conventional bonds in terms of yield to maturity, is to some extent a key element that boosts investor's appetite for green bonds. Furthermore, investors have realized that investing in environment-related projects, does not necessarily jeopardize return on investment. The main difference between green bonds and conventional bonds is that unlike the latter the proceeds of the former must be entirely allocated for environmentally-friendly projects (CBI and HSBC, 2017). Moreover, green bonds often require a more complex-issuance process, since their deal typically involves at least three market players, whose roles are discussed in the next subsection.

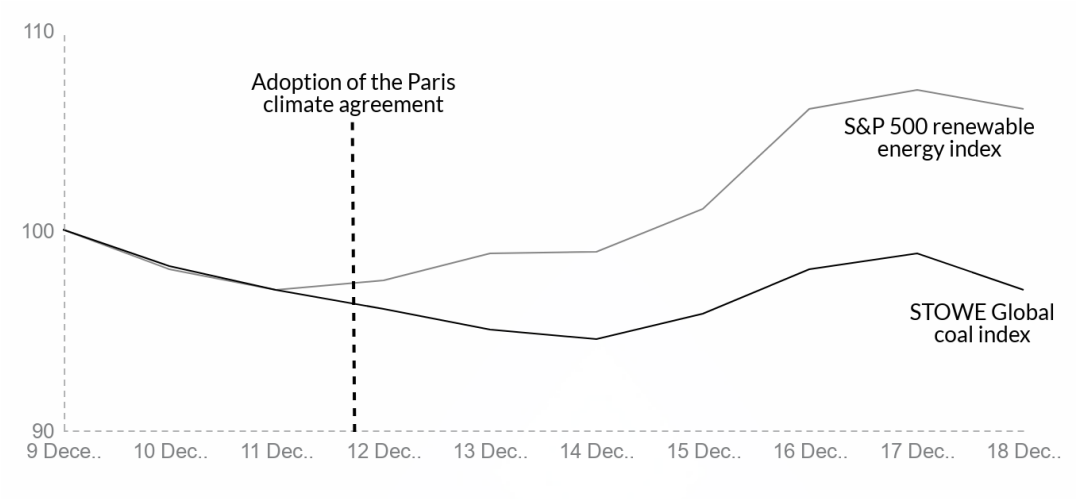
Source: Bloomberg as of 1/31/ 2017.
FIGURE 3.2: Yield to maturity: green bond vs. conventional bond.

[6]The Yield to Maturity is the internal rate of return of an investment in a bond if that bond is held until the end of its lifetime.

The recent rise of the green bond market also stems from two mutually re-enforcing arguments. The first is due to an increased understanding about the potential links between climate change and financial stability. Investors and policy makers have indeed become increasingly aware of the potential risks climate change poses to businesses and the financial sector as a whole (Carney, 2016; TCFD, 2017). This climate-awareness has led to the implementation of preventive measures, such as climate risk stress tests aimed at assessing the exposure of financial institutions to climate change risks (Battiston et al., 2017; Mercer, 2015). The ultimate goal of these tests is to ensure that the whole financial system is resilient to climate change impacts. This is why some authors urge investors to move from the shareholder model which focuses on profit maximization only, to the stakeholder model which not only create financial, societal, and environmental values (Schoenmaker, 2017), but also protects the managing teams in place from hostile takeover bids (Jeffers, 2005).

Such a corporate governance structure, by taking into account the interests of all stakeholders, is conducive to climate settings incorporation into investment decision-making. As Weber (2018) suggests, the adoption of voluntary sustainability codes of conduct could help create a more sustainable financial system, in which environmental risks are well recognized and well managed by the business community. By doing so, investors could sensibly reduce their exposure to climate change risks, thereby limiting their potential capital loss due to stranded assets, as a result of climate change impacts. Stranded assets are "assets that have suffered from unanticipated or premature write-downs, devaluations or conversions to liabilities" (Caldecott et al., 2013). It is therefore important that investors include environmental-social-governance (ESG) criteria into their investment decision-making. The incorporation of such criteria within financial markets' structures is becoming increasingly obvious as rating agencies such as Moody's, Standard & Spoor,

and Barclay's MSCI have started to establish green bond standards and indexes aimed at assessing the environmental impacts of their clients' portfolios.



Source: Adapted from DNB (2017). This figure shows how the rates of green (S&P 500 renewable energy index) and brown (STOWE Global Coal Index) companies responded to the ratification of the Paris climate agreement.
FIGURE 3.3: Response of financial markets to the Paris climate agreement announcement.

The second argument is political in nature and derives from the 2015 Paris agreement, signed in December 2015. At the Paris climate conference (COP 21), nearly 200 countries have adopted a binding climate deal aimed at cutting down greenhouse gas emissions in order to limit global warming 2 degrees above pre-industrial levels, with 66% of probability by the end of this century. Furthermore, during the 2016 G20 summit held in Hangzhou, the world's political leaders have agreed to "support the development of local green bond markets and promote international collaboration to facilitate cross-border investments in green bonds" (G20, 2017). This historic political support for climate action has sent positive signals to investors, thereby strengthening the green bond market development, especially in advanced and emerging countries. Figure 3.3, for instance, highlights the positive response of financial markets to the ratification of the Paris climate agreement.

This figure shows that the S&P 500 renewable energy index over-performed the STOWE global coal index shortly after the ratification of the Paris agreement, thereby highlighting the importance of policy support in scaling up the green bond market.

Last but not least, the development of the green bond market arguably stems from the consequences of "unconventional monetary policies" implemented by the world's major central banks in the aftermath of the 2008 financial crisis. The failure of monetary authorities to achieve economic recovery through accommodative monetary policies has resulted in low-interest rates and hungry for yield, especially in advanced economies (King, 2017). Consequently, institutional investors, "such as pension funds and insurance companies are coming under pressure to find ways of making their savings products more attractive and reduce the rising costs of pension provision in the face of falling real interest rates" (King, 2017, p.32). Such a pressure has led many institutional investors - who hold nearly USD 100 trillion in assets (Arezki et al., 2016) - to look for new investment opportunities such as those of the low-carbon transition, which also match their investment horizons. As one of the major market players in the fixed-income markets, institutional investors have realized that sustainable investing can preserve wealth and provide reliable streams of revenue, while reducing volatility in the equity markets. This increased climate-awareness and the low-interest rate environment prevailing in most developed countries have led institutional investors to recognize green bonds as a portfolio diversification instrument.

3.2.2 Typology and the functioning of green bonds

Depending on the use of proceeds, it is possible to currently distinguish between four specific types of green bonds, all of which are consistent with the Green Bond Principles: standard green use of proceeds bonds, green revenue

bonds, green project bonds, and green securitized bonds (ICMA, 2017).

A standard green use of proceeds bond is a debt obligation with recourse to the issuer in the case of default on interest payment or return of principal. The proceeds of such a bond should be tracked with a specific sub-account or by the issuer following an internal process that links the issuer's lending and green investments. While purchasing such a bond, it is recommended that the issuer makes known to investors the intended types of eligible investments for the balance of unallocated proceeds (Ceres, 2014). Green revenue bonds are non-recourse-to-the-issuer debt obligations, for which the credit exposure in the bond is to the pledged cash flows of the revenue streams, fees, and taxes (ICMA, 2017). The proceeds of that bond could go to related or unrelated green projects. Next, a green project bond is a bond issued for a single or pooled green project(s) for which risks are entirely bore by the underwriter, with or without potential recourse to the issuer (Ceres, 2014; ICMA, 2017). Finally, green securitized bonds are collateralized by one or more specific green projects. They include but are not limited to covered bond and asset-backed securities (ICMA, 2017). In the event of default of payment, green securitized bonds could provide recourse to the issuer only to the underlying assets. The repayment of such bonds usually depends upon the cash flows generated by these assets. It could be, for instance, the charge paid by consumers to use the infrastructures that have been set up thanks to the proceeds of the green bond (Kaminker and Stewart, 2012).

Given the lack of universal standards and definition for green bonds, it is likely that their characteristics (i.e., coupon and maturity) may differ from one issuer to another (Flaherty et al., 2016). Nevertheless, the goal remains the same, which is to finance green projects.

The process of issuing a certified green bond involves at least three major market players, including the issuer, an independent reviewer, and the underwriters as highlighted in Figure 3.4 below. The process then begins when

an issuer or a project developer sets up a green project. In the project document, the issuer should itemize, as much as possible, the expected positive impacts of its project on the environment. In order to avoid overestimating or underestimating those impacts, an independent reviewer who is a specialist of environmental impact assessment, is required to confirm whether the project is actually environmentally-friendly. The role of the independent reviewer is to carry out a quantitative and qualitative assessment of the project, based on the following criteria suggested by ICMA (2017).

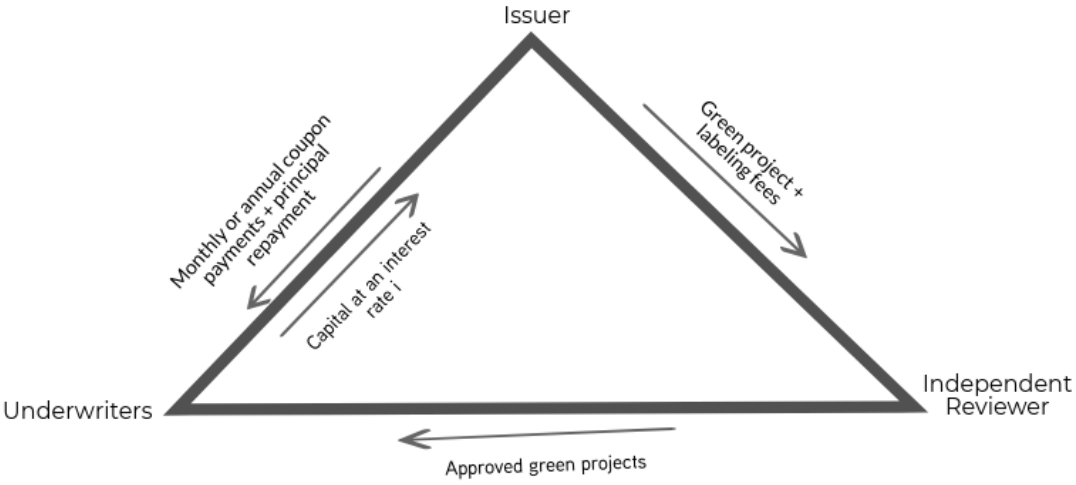
(1) The use of proceeds: prior to issuance, a legal document must specify how the proceeds of the bond will be used.

(2) A technical assessment of specific risks and opportunities tied to the project and the creditworthiness of the green bond issuer.

(3) The monitoring, reporting, and traceability requirements: several reports are regularly produced to monitor both the project and the use of the proceeds in order to make sure that the green bond proceeds are being allocated in accordance with the Green Bonds Principles.

Failures in complying with these requirements could result in the exclusion of the issuer from the green bond market. Once the second opinion attests the green nature of the project to be financed, the issuer is allowed to issue a certified labeled green bond in order to raise funds in the debt capital market. Green bond underwriters then provide capital to the issuer for a certain period of time at a fixed or variable interest rate (German Development Institute, 2016). This tripartite process of green bond issuance could entail some significant transaction costs, as argued in the next section. It is worth noting that Figure 3.4 below has been made simplistic for illustration purposes. In practice, however, this process may be more complex depending on the issuer and the market of distribution.

Although the green bond market is quickly growing, its size still remains small compared to the global fixed-income market (Franklin, 2016; Moody's,



Source: Author's construction.
FIGURE 3.4: The process for issuing a certified green bond

2017). According to S&P Global, green bonds represent only 1.4% of the total fixed-income market (S& P Global, 2017). Furthermore, the market is mainly polarized in developed and emerging economies. According to the Climate Bond Initiative data, China represented over 40% of the global green bond issuance in 2016, while regions such as Asia (excluding China) and Africa accounted for less than 6.5% of global green bond issuance in 2007-2016. These figures suggest that the green bond market faces many challenges that jeopardize its development in developing countries.

3.3 Barriers to the green bond market in developing countries

Although green bonds have the potential to attract significant private climate finance for developing countries, their adoption is still plagued with several barriers. These obstacles range from institutional to market barriers and are deemed to be the most challenging for the development of the market. This section elaborate on these barriers, while recognizing that their importance may vary across countries.

3.3.1 Institutional barriers

Green bonds foremost require technical skills for monitoring and assessing of their use of proceeds throughout the project's life cycle. Many developing countries, however, lack such technical skills which are essential to ensuring that projects are implemented in accordance with the Green Bond Principles. In other words, it is likely that developing countries are facing a green bond learning curve, in the sense that they do not have the basic knowledge for green bond management when they go to the market for the first time.

A recent survey by the G20 Green Finance Study Group revealed that the lack of knowledge of existing international practices in green bond transactions was reported by respondents (up to 74%) as an important barrier for the development of the green bond market (GFSG, 2016). This is particularly true in many developing countries, where this knowledge gap could also be exacerbated by the fact that the benefits of green bonds have not yet caught policy-makers' attention, as well as bond issuers and investors. The lack of commonly agreed standards for green bonds (OECD, 2017) and their relative newness could justify this gap of knowledge. Next, inappropriate institutional arrangements in some developing countries do not enable the emergence of green bonds. Often, different ministry departments with different mandates and skills are pursuing different, if not conflicting goals in the implementation of the government's policy. As a result, environmentally-friendly projects in countries where voters do not show strong support for climate policies (Obradovich and Zimmerman, 2016), are likely to become less of a priority. Pickering et al. (2015)'s argument that there is often a disagreement among ministries in developed countries about the balance between adaptation and mitigation finance for recipient countries, also holds for developing countries regarding the country's development priorities and

the mandates of different ministry departments. These divergences of priorities and mandates may result in diminished policy influence of Environment Ministries, meaning that an effective coordination between the Ministry of Finance and that of Environment, is essential for the development of government-backed green bond issuance and the emergence of local green bond markets. However, institutional barriers are compounded by market barriers that hinder the development of green bond in developing countries.

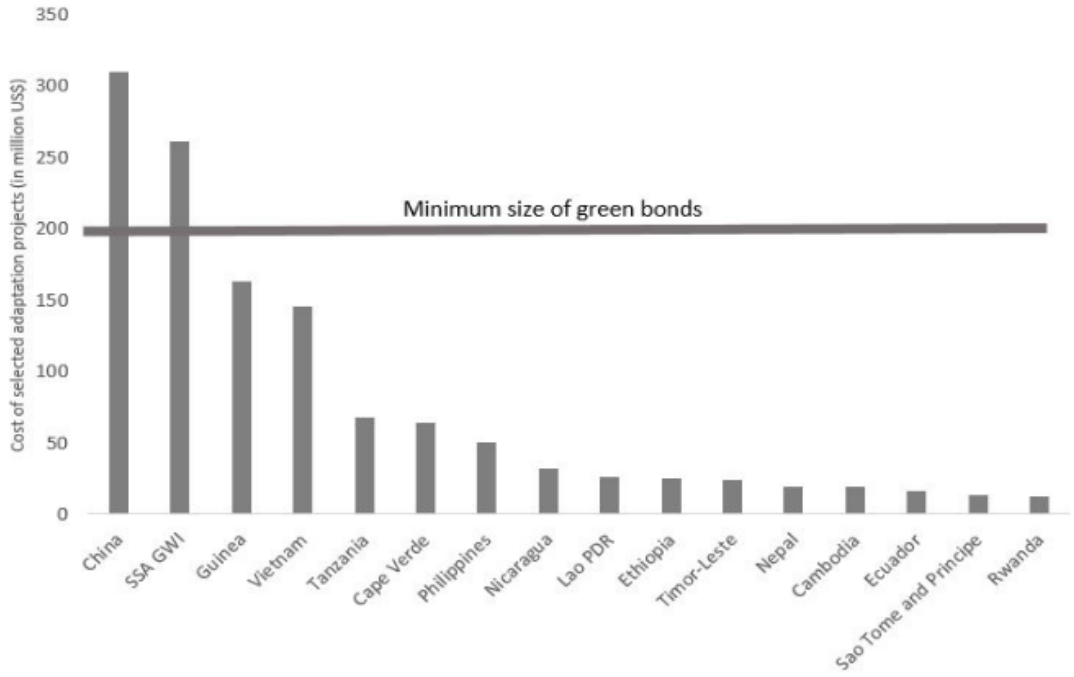
3.3.2 Market barriers

There are three important market barriers, which dampen the development of the green bond market in developing countries: the issue of minimum size, the currency of issuance, and high transaction costs associated with green bond issuance. The issue of minimum size refers to the minimum value that a green bond should bear to be appealing to green bond underwriters. If green bonds offer an opportunity to tap into private capital for sustainable infrastructure financing, one of their major constraints, is that their size must be large enough to be appealing to green bond purchasers, such as those of the Green Bond Underwriters League Table (GBULT). The GBULT includes some of the world's largest banks such as Citi, HSBC, JP Morgan or Bank of America Merrill Lynch, as well as some institutional investors who are managing trillions of dollars in assets. For these investors, the size, tenure, and liquidity of green bonds are key elements that they consider before lending their money (EY, 2018; Chiang, 2017; Duru and Nyong, 2016). According to Franklin (2016), bond investors like to see at least USD 200 million equivalent in liquidity before lending their money, while for the world's major rating agencies such as Moody's, green bonds must have a minimum value of USD 250 million to be eligible for index inclusion (Chiang, 2017).

It is worth noting, however, that many green projects implemented in

developing countries, are of small size and do not comply with the minimum size required by investors for a green bond transaction. In many of those countries, the low population density, coupled with high poverty rates usually makes standalone small projects more cost-effective than large-scale projects, especially in rural areas (UNCTAD, 2017). However, the size of the vast majority of these small scale projects barely exceeds USD 10 billion on average, suggesting that the minimum size required by investors could ultimately stand as an important barrier to market entry for developing countries. Figure 3.5, for instance, displays both the costs of different green projects implemented in selected developing countries and the minimum size required by investors. The underlying projects are coordinated and implemented by the World Bank and the United Nations Development Programme (UNDP) under the Least Developed Countries Fund (LDCF). For comparison purposes, Figure 3.5 has been adjusted to display the annual cost of China's pollution abatement projects (USD 310 billion) as well as the cost of the Green Wall Initiative (GWI), which is a regional green projects of Sub-Saharan African countries. It can be easily observed that the cost of individual projects is well below the minimum size that GBULT members require for green bond transactions.

Next, transaction costs refer to costs incurred by the issuer to get a green label certification from the independent reviewer and to produce regular documents showing the allocation of the green bond proceeds throughout the project's life cycle. Such transaction costs could prove to be significant (EY, 2018), especially when a creditworthiness survey of the issuer is required alongside the technical assessment of the potential impact of its project. According to Kaminker et al. (2016), the relatively high cost of obtaining a second opinion or third-party assurance could range from USD 10 to 100 thousand dollars. These transaction costs from pre-issuance to post-issuance could ultimately stand as an important barrier for small green bond issuers.



Source: Author's construction based on data from the Least Developed Countries Fund. Green projects in developing countries do not match the minimum size required by green bond underwriters in the green bond market.
FIGURE 3.5: The issue of minimum size

Finally, a non-negligible barrier to the spread of green bonds in developing countries is likely the currency of issuance. A review of the Climate Bonds Initiative's database shows that, between 2005 and 2017, investors have mainly use the Renminbi (32%), the US dollar (26%), and the Euro (20%) to issue green bonds. These figures suggest that developing countries -the majority of which have inconvertible currencies- must issue their green bonds in international currencies, should they desire to raise large amounts of capital in international financial markets. This financing mechanism, however, presents both the lenders and the borrowers with a currency risk, as the revenue flows of the project to be financed typically relate to local currencies (Edwards, 1983). It must be recalled that the currency risk is not new to developing countries, nor is it specific to the green bond market. Eichengreen

and Hausman (1999) neatly termed this issue the 'original sin' to characterize the fragile structure of developing countries' financial markets that undermines their ability to borrow abroad due to the inconvertibility of their currency or to borrow long-term domestically due to the dearth of domestic long-term credit instruments (UNCTAD, 2007). Nevertheless, it suggests that the implementation of local currency-based green bond issuance could be beneficial for developing countries.

3.4 Scaling up green bond issuance in developing countries

The green bond market is experiencing many challenges in developing countries that hinder its development. However, recent trends suggest that appropriate policy measures could help address these challenges and enable the market to take root. Some market analysts have suggested a "green stripping" system to cope with the issue of minimum size (Franklin, 2016). Under such a framework, an issuer could issue a bond aimed at financing both green and brown projects rather than issuing a hundred percent green bond. In that case, only a fraction of the proceeds of that bond- the green stripe - should be used to finance the green project. Although the green stripping system is a possible remedy to the issue of minimum size, this essay argues that it is only suitable for investors who are familiar with the market and have a good creditworthiness. However, the high debt service ratios of developing countries reduce their creditworthiness, thereby increasing their perceived probability of default (Edwards, 1986). Since issuers' creditworthiness is one of the key elements that investors consider before lending their money, it is likely that the green stripping system may not fit as the best solution for developing countries. Moreover, the green stripping strategy could give rise

to greenwashing behaviors. Greenwashing occurs when an issuer promotes green-based projects in order to raise funds in the green bond market, but actually operates in a way that damages the environment. Greenwashing "sins" could have, therefore, profound negative effects on investors' confidence on green bonds, thereby hampering the market development. Lax and uncertain regulations (Delmas and Burbano, 2011), as well as monitoring failures throughout the project's lifespan, are the key drivers of greenwashing behaviors.

Given the unsuitability of the green stripping strategy as a solution for developing countries and the problems it may give rise to, this essay calls for the implementation of local green bond markets based on a top-down approach, in which local governments play a central role. Such a role should consist of promoting local green investments and providing guarantees for local green bond issuance. For instance, the government could cover all the transaction costs associated with green bond issuance, so that the cost of issuing a green bond is on par with that of issuing a conventional bond.

The issue of minimum size is, however, just the tip of the iceberg. The core issue is that developing countries have a very limited access to national and international capital markets. According to the World Bank, less than 20% of the largest cities in developing countries have access to local capital markets, and only 4% have access to international capital markets (World Bank, 2013). Furthermore, projected population growth (UN-DESA, 2017)[7] suggests that most of climate change adaptation and mitigation projects in developing countries will be the responsibility of cities. This means that local governments need access to reliable and affordable green finance to implement their clean projects of the future.

Beyond the importance of an effective coordination between Ministries

[7]UN DESA. 2017. World Population Prospects: The 2017 Revision. United Nations Publications.

of finance and environment, it is important that multilateral and national developments banks act as intermediaries for green bond issuance and management in developing countries. Development banks are indeed able to borrow from financial markets on favorable terms due to their excellent credit ratings (UNFCCC Standing Committee on Finance, 2016). This fundraising capacity makes them able to lend funds to their developing country clients on more favorable terms than they would get from other lenders (Campiglio, 2016). However, as argued in previous sections most green projects implemented in developing countries are of small sizes, meaning that development banks would need to adopt a pooling strategy to cope with the market minimum requirements for green bond transactions. By pooling small size projects or focusing on regional-scale projects, such as the Green Wall Initiative, multilateral development banks could raise funding in more favorable terms and fund green project sponsors, who otherwise would not have access to capital at an efficient cost (RCB, 2017).

Another possible way to fill the green investment gap in developing countries could be, for instance, the establishment of green investment banks. According to OECD (2014), a green bank is a public or quasi-public entity established to facilitate private investment into domestic low-carbon, climate-resilient infrastructures. A well-designed green banking model could indeed be an effective tool for channeling private investments towards adaptation and mitigation projects. However, given the high costs of setting up a new bank, the dearth of capital, and the shortfall of skilled human resources in developing countries, making efficient use of existing multilateral and national development banks as well as existing climate funds, is undoubtedly the best solution. In the short to medium term, it is important to not only further the research on the technical implementation of the green banking model but also to improve data collection for future empirical-based research on the green bond market in developing countries.

Although the essay has reached its aim, which is to examine the rise of the green bond market over the last few years and the key barriers that undermine its rise in developing countries, one should not overlook its major limitations. First, by treating developing countries as a homogenous whole, the essay neglects their diversities in terms of green bond intake, institutional arrangements, and economic features. Second, the essay does not capture all the barriers to the green bond market development in developing countries. As the market grows, new barriers may unfold, while the barriers highlighted in this essay may become less important. Finally, the relative dearth of academic literature on green bonds was challenging for the author in embedding the essay within a theoretical framework. Nevertheless, it has the benefit of drawing at least the attention of policy makers and investors in developing countries, as well as rolling the red carpet out for future research.

3.5 Conclusion

Green bonds are growing quickly and are expected to reach record levels over the next few years. Factors such as similarity in terms of yield to maturity between green bonds and conventional bonds, increased climate-awareness from investors, the commitment of policy makers to counter climate change, and the current macroeconomic environment in most developed countries have underpinned the development of green bonds over the last few years. As innovative financial instruments, green bonds provide a historic opportunity to direct private finance towards low-carbon investments. While companies and local governments in developed and emerging countries are increasingly issuing green bonds to finance their adaptation and mitigation projects, a set of institutional and market barriers are preventing developing countries from appropriating the full benefits of green bonds. The lack of knowledge about how green bonds work, inappropriate institutional arrangement

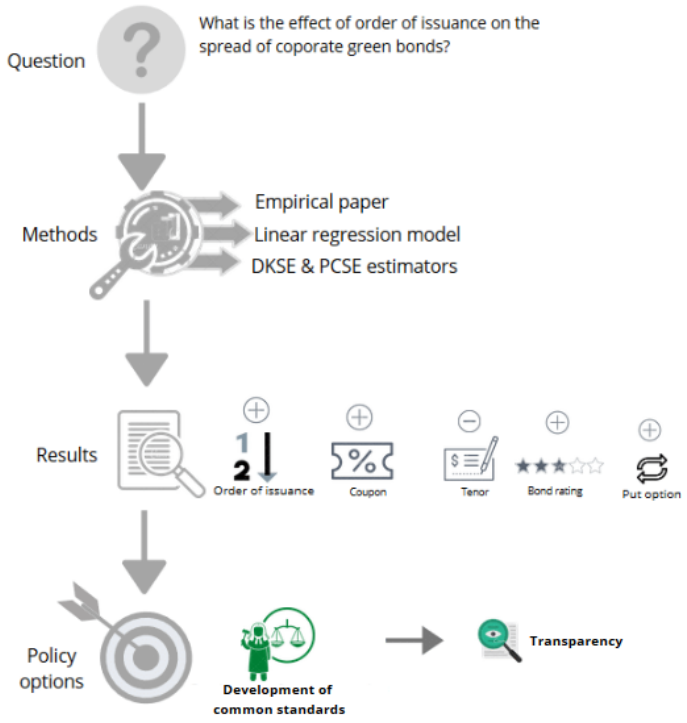
for green bond management, the issue of minimum size, the currency of issuance, and high transaction costs associated with green bond issuance are the key barriers that hamper the development of green bonds in developing countries. The results suggest, however, that with the right measures developing countries could take full advantage of green bonds to finance their adaptation and mitigation projects, as part of the Paris climate agreement. Potential measures include an effective coordination between ministries of finance and environment, an efficient use of multilateral and national development banks as intermediary institutions for green bond management, the provision of guarantees by local governments for green bond issuance, as well as the promotion of local green bond markets, in which domestic investors could issue local currency-based green bonds. By doing so, developing countries could enhance the development of green bonds and hasten the achievement of sustainable development goals.

Chapter 4

The determinants of Green Bond spread and the influence of issuance order

"The next big success story is green finance".

- William Russell, the Lord mayor of the city of London, in Bloomberg (2020).



4.1 Introduction

[1]

Fuelled by a growing appetite for environmental and social benefits on the part of investors, green bonds have enjoyed strong investor demand. Green bonds are debt finance instruments used to raise long-term capital for environmentally friendly projects, while offering returns that are similar to those of conventional bonds (BNP Paribas 2017; Ehlers and Packer 2017; Weber and Saravade 2018, 2019). As innovative financial instruments, they enable issuers to diversify their investor base by attracting a new type of responsible investors, namely institutional investors (Banga 2019; Breen and Campbell 2017; Buttin 2016; Martín 2019). One of the main characteristics of green bonds is that, in contrast to conventional bonds, there is transparency about the use of their proceeds, which are earmarked for green projects or products, thus generating a win–win outcome for both issuers and investors. This transparency however comes with a cost as it requires the set up of specific sustainability committees and expensive certifications and third party reviews (Martín 2019). For this reasons, many issuer may issue green bond without an official label making it harder for investors to defend the sustainability investment preposition.

Although the annual issuance of green bonds has increased extensively over the last few years from about USD 3 billion in 2011 to USD 167.3 billion in 2018 (CBI 2018), the green bond market to date represents only 2 per cent of the global fixed-income market (Reuters 2018). This limited market size has been the focus of many recent discussions as the growth of North American corporate green bond issuances has been slow (S&P Global, 2019); despite

[1] This essay was co-written with Micol A. CHIESA from the University of Oxfrod, who collected the data, and Barua SUBORNA from Federation University Australia, who ran the regressions. My task was to write the introduction, the literature review and thee conclusion. The specification of the theoretical model and the interpretation of the results were done collaboratively.

the willingness of most issuers to consider sustainable financing in the capital mix (Clark, 2017). As number of corporate sectors have had reasonable success issuing green debt, this essay focuses on identifying the major determinants of green bonds spread to facilitate the understanding of why, despite many companies would like to issue or re-issue them, they still feel unsure about market acceptance (S&P Global, 2019). Particularly, this essay focuses on observing the influence of order of issuance, that is to say the bond issued by the same company at different time series to see whether it has an effect on spread that could justify the slowness of the market. In fact, if issuers find cost of debt to become higher over issuances, they may not be incentivized to re-issue green bonds. On the other side, if potential issuers see interest rates growing over time, they may be discouraged to issue their first green bond, given the high initial cost of issuance and added complexity (for example, need to set up a corporate sustainability commission, need for a business plan with specific environmental features and need for certification). On the other side, it may be difficult for first-time green bond investors to evaluate properly all the risks associated with green investments (Buttin 2016) and therefore the overall perceived risk may increase as the market increases by including issuers coming from many different sectors and geographies (Lin et al, 2019).

Finding an increase of spread over issuances, would suggest that cost of finance may rise for the new issuances. It could also mean that market demand for subsequent issuances slows down, meaning less investors are interested in buying the bonds, prices therefore plunge and yields rise. Factors that could discourage further investments in green bonds are associated to risk-return potential, environmental commitments, and the request of funding for project with an unclear association to environmental positive change (Tolliver et al. 2019; Zerbib, 2019).

In fact, as the company proves the proceeds are having a positive environmental impact while being able to generate a profit or savings to return the debt, the perceived risk associated with green bond issuances should decrease over time translating into lower interest rates and helping the world moving towards a greener economy. If investors feel confident on this type of investments, their perceived risk on subsequent issuances should decrease as well reducing the cost of financing for later environmental issuances compared with the first. As a result, the higher the number of issuances, the lower likely the cost of financing and the higher the environmental performance of a company in the long term.

As the green bond market continues its growth, and the market supply tends to exceed demand primarily due to increased corporate and institutional environmental commitment (Morel and Bordier 2012), it becomes relevant to investigate the determinants of green bond pricing, including the experience curve effect.

One important aspect of evaluating the market-based cost of bond financing is its reference to the market interest rates, in particular, Treasury yields. (Durbin and Ng 2005; Cavallo and Valenzuela 2010; Garay et al. 2019).

In general, the difference between yields offered on corporate bonds and those offered on government bonds with the same maturity is often defined as yield spread, and can be influenced by the market, issuer and project characteristics (Choudhry and Lizzio, 2015; Elton et al. 2001). Bonds trading at larger spread could reflect investor's scepticism about this new security as the market is still establishing international standards and giving the first signing of positive use of proceeds and capacity of repayment. Lower spread on the other side, would reflect that issuances have enough demand in the market for them, that the project is considered more valid and less riskier, at least compared with other issuances.

The aim of this essay is to examine empirically the effect of order of issuance on the spread of green bonds compared with government bonds. This investigation also includes other bond and market characteristics that could ultimately affect the cost of financing green bond.

The empirical examination involves the application of two different panel data estimation techniques on a dataset of more than 600 bonds issued in Dollar, Euro, Swedish Krona, Chinese Yuan and Japanese Yen. The analysis covers monthly spread data for the last five years, considering a set of control variables in addition to the order of issuance. Estimates are produced for the whole set of determinants for all bonds, and across currencies and maturities.

This study is original and differs from previous ones in at least three respects. First, to the best of one's knowledge, it is the first to investigate what effect issuance order has on green bond yield spread, which drives the pricing of green bond issuances. Second, while most studies define and analyze spread by matching green bond yields to those of conventional bonds issued by the same issuer, this study rather considers the difference between green bond yields and the Treasury bond of the issuer's home country. Lastly, it makes it easier to understand how investors consider credit risk for green bonds and how they price green bonds in relation to risk-free Treasury bonds; being the Treasury yield curve a benchmark for pricing bonds and setting yields in other areas of the debt market.

The remainder of this essay proceeds as follows. In section 4.2 there is a review of the literature on the experience curve and the determinants of corporate bond spreads. Section 4.3 contains a description of the methods and data used in the study. Section 4.4 consists of a presentation of and a discussion about the key findings. Section 4.5 concludes while exploring possible areas of future research.

4.2 Literature review

This section reviews the literature on green bond pricing and the determinants of the yield spreads on corporate bonds. Green bonds have become a mainstream investment tool of growing interest for investors, especially for the so-called socially responsible investors (Pham 2016; CBI and HSBC, 2017). Unlike conventional bonds, green bonds have unique features, and their issuance follows a special process (Li et al., 2019). Moreover, a growing number of studies show that investment in green bonds is beneficial to shareholders (Tang and Zhang, 2018), and reduces investors' exposure to environmental risks (Ehlers and Packer, 2017).

There is a consensus that the proceeds of green bonds are earmarked for green infrastructure projects (OECD, 2017; ICMA, 2017; Baker et al., 2018; CBI, 2018) that contribute to achieving the low-carbon transition (Kidney and Boulle, 2015). However, the literature on the determinants of green bond pricing is barely nascent, and has been mixed so far (Horsch and Richter, 2017). Over the last few years, several studies have attempted to investigate various dimensions of the green bond market, including the market's volatility (Pham 2016), its portfolio diversification benefits (CBI 2016; Reborodo, 2018; Banga, 2019), as well as the determinants of the issue size (Chiesa and ch 2019; Barua and Chiesa, 2019). Siswantoro (2018) argues that certification by a second opinion has an effect on green bond prices. Patridge and Medda (2019) investigate the US green municipal bonds and conclude that indexes comprised of green municipal bonds outperform their conventional counterparts.

In their investigation of the pricing and ownership patterns of the US corporate and municipal bonds, Baker et al. (2018) found that municipal green bonds are traded at a premium to otherwise conventional bonds, while the pricing and ownership effects are stronger for bonds certified as green by an

independent reviewer. While analysing the effect of non-pecuniary motives of investment in green bonds, Zerbib (2019) used a matching method to estimate the spread of green bonds over comparable conventional bonds. The results of this study suggest a negative green premium, meaning that the yields of green bonds are lower than that of conventional bonds, especially for low-rated green bonds. Similar results were documented by Kapraun and Cheins (2019), who found a significantly negative premium of 20-30 bps for green bonds across currencies and issuer types. Furthermore, Bloomberg (2015) found that green bonds are traded at lower yields compared with their non-green peers, due to the shortage of supply. Likewise, GRESB (2015) found that investors require higher coupons for green bonds compared with conventional bonds from the same issuer, and price green bonds with respect to their buy and hold strategies. However, a study from Barclays (2015) suggests that some green bond investors are ready to pay a 20 basis point premium over conventional bonds in the secondary market to in order to decarbonize their portfolios.

Meanwhile, other studies document that there is no pricing differences between green and conventional bonds (Tang and Zhang, 2018; BNP Paribas 2017; Hachenberg and Schiereck 2018; BMO Global Asset Management 2017). A study on thirty-four green bonds, of which eight are from repeat issuers, shows that, on average, EUR green bonds achieve larger book cover, and slightly lower spread compression than their vanilla equivalents, while USD green bonds on average achieve a slightly lower book cover, and the same spread compression as their vanilla equivalents (CBI 2018). The same study shows that seven days after pricing, green bonds had tightened more than vanilla benchmarks, while twenty-height days after pricing, green bonds had, on average, tightened by more than matched indices. In some cases where corporate green bond spread is higher, this may be due to imbalances between supply and demand (CBI 2016).

While investigating the relationship between the initial public offering (IPO) price of green bonds and the probability of issuer defaults, Weber et al. (2018) find that investors learn to price green bonds well after a few repetitions, suggesting an experience curve effect on green bond pricing. By analysing the determinants of sovereign bond issuances, Grigorian (2003) looked at the differences between first and subsequent issues and found that, in general, investors require a lower interest rate from repeated issuers (i.e., issuers with at least one outstanding bond) while interest rates on debut issuers' bonds are usually higher. Because of the debut issuers' new experience with the market, which does not allow for immediate incorporation of all information into the bond's price, investors display risk-averse behaviors (Loncarski and Szilagyi, 2012).

With respect to corporate bond spread in general, it is commonly agreed that the yield spread is a proxy for default risk (Andersen 2018; Chen et al. 2007). Since corporate bonds are riskier than government bonds, investors could ask for a higher yield spread over risk-free Treasury bonds, so as to compensate for the risks taken (Durbin and Ng 2005; Choudhry and Lizzio, 2015; Garay et al. 2019). In other words, the higher the spread over Treasury bonds, the riskier the bond for investors and the costlier the bond for the issuer (Cavallo and Valenzuela 2010). Such spread could again vary across maturity, sectors, or market of issuances. For example, Garay et al. (2019) explain that, provided that the economic conditions remain constant, the yield spreads of short-term bonds are significantly lower than those of long-term bonds.

In their study of the impacts of liquidity risks on green bond spread, Wulandari et al. (2018) - after controlling for bond-specific characteristics, macroeconomic conditions and credit risk- found that liquidity risk has a higher explanatory power for the yield spread of green over conventional

bonds. Corporate bond yield spreads generally depend on a variety of factors. These include issuer characteristics (Bachelet et al. 2019), the liquidity of the bond (Abudy and Raviv 2016; Chen et al. 2007; Huang 2016; Lin et al. 2019, 2011; Wulandari et al 2018), maturity (Huang and Huang 2012), credit risks (Duffee1998; Huang and Huang 2012), credit rating (Krylova 2016), the sophistication of the issuer (Roden and Bland 1986), as well as the environmental preferences of the investors (Zerbib 2019). Ge and Lui (2015) assert that firms with favorable corporate social performance in the US primary market enjoy lower bond spreads.

With particular reference to the spread of green bonds over government bonds, empirical evidence on the factors influencing the level of spread relative to Treasury bonds appears limited (Agliardi and Agliardi 2019). In particular, there is no study yet available on the effects of the order of issuance on the yield spread of corporate green bonds.

4.3 Methodology and data

4.3.1 Model and variables specification

To examine the learning curve effects on green bond spread, the following formula is used to calculate spreads of corporate green bond yields over Treasury yields.

$$Spread_{it} = Y_{it} - Y_{gt}, \tag{4.1}$$

where Y stands for Yield, i indicates a Green bond, g indicates a Government bond (Treasury bond), and t indicates a date in a particular year.

Since risk-free rates reflect government bonds with no credit risk, and are used as a benchmark for other risky assets (ECB 2014), the excess yield of a corporate green bond over a comparable government bond shows the

premium required by the investors for the risks associated with the issuer of the bond. Therefore, green bond spread was considered over government bonds rather than conventional corporate bonds because it can capture the risk factor involved with the green bonds issued.

Testing the experience curve effects begins with the following specification

$$Spread_{it} = \alpha_i + \beta_i order_{it} + \beta_i X_i + \beta_i Z_{it} + \epsilon_{it} \tag{4.2}$$

where α is constant, $order_{it}$ is the order of issuance of a bond from the same issuer, β_i indicates coefficients, X_i represents factors that are time-invariant but varies across bonds, and Z_{it} indicates factors that vary both across bonds and over time. A set of control variables was introduced in place of X_i and Z_{it}, that are based on the literature and that consider the bond, issuer and market characteristics. The variables chosen are listed and defined in Table 4.1.

TABLE 4.1: Variable description

Variable	Measurement
Spread	The difference of yields between Green bond and Treasury bond
Lag of spread (l_{spread})	One period lag of spread
Order of issuances (order)	Order of issuances
Coupon rates (cpn)	Original Coupon rates of the bonds
Tenor (maturity)	Original Total maturity of the bond in number of years
Call feature (call)	Dummy for call option availability with a bond (1 if available, 0 otherwise)
Put feature (put)	Dummy for put option availability (1 if available, 0 otherwise)
Bond rating (brat)	Credit rating assigned to the bond by S&P, Moody's, or Fitch (see Appendix A1)
Company type (cotype)	Dummies for Type of original issuer (1 for Parent or 0 for subsidiary)
Guarantee feature (grnte)	Dummies for the availability of guarantee feature (1 if Yes or 0 otherwise)
Instrument type (instr)	Dummies for EIKON classification of the instrument (1 for note, 2 for bonds, and 3 for debentures)
Coupon class (cpncls)	Dummies for five coupon class fixed effects: Discount/zero =1, Fixed =2, Floating=3, Range =4, Variable=5
Coupon frquency (cpnfrq)	Dummies for coupon frequency fixed effects: Annual=1, Monthly=2, Quarterly=3, Semi-annually=4
Currency	Dummies for fixed effects of five coupon currencies - USD, EURO, Chinese YUAN, Japanese YEN, Swedish KRONA
Issuer sector	Dummies for fixed effects of nine sectors: Financials (Banking, Leasing, Mortgage banking, Property and Casualty Insurance, and Other financials); Manufacturing (Automotive Manufacturer, Conglomerate/Diversified Mfg, Electronics); Real Estate (Home Builders, Building Products, Lodging, Real Estate Investment Trust); Utilities (Oil and Gas, Gas Utility - Local Distrib, Utility – Other); Transportation (Railroads, Transportation – Other); Industrials (Machinery, Metals/Mining, Industrials – Other); Food Processors; Health Care; and All Others (Publishing, Retail Stores – Other, Service – Other)
Market of distribution	Dummies for fixed effects of market of Distribution – Domestic; Global; Eurobond (including Masala and Uridashi); Group of Dimsum, Panda, Samurai, and Yankee; and Other foreign bonds

Using the variables chosen, we specify the following equation for estimation:

$$Spread_{it} = \alpha_i + \beta_1 l_{spread_{it}} + \beta_2 order_{it} + \beta_3 cpn_i + \beta_4 tenor_i + \beta_5 call_i + \beta_6 put_i + \beta_7 brat_i + \beta_8 cotype_i + \beta_9 grnte_i + \beta_{10} instr_i + \sum_{j=1}^{m} \beta_j cpncls_i + \sum_{j=1}^{n} \beta_j cpnfrq_i + \sum_{j=1}^{p} \beta_j C_i + \sum_{j=1}^{q} \beta_j S_i + \sum_{j=1}^{f} \beta_j M_i + \sum_{n=2014}^{2018} \beta_j Y_j + \epsilon_{it} \tag{4.3}$$

where $Spread$ is the Yield differences between Green bonds and Treasury bonds; l_spread, one period lag; $order$, order of issuance; cpn, coupon rate; $tenor$, total maturity of the bond; $call$, Dummy for call option feature availability; put, Dummy for put option feature availability; $brat$, Scores assigned for bond rating by different agencies (following Appendix Table A1); $grnte$, Dummy for availability of guarantee feature, $instr$, Classification of the instrument (note, bonds, or debentures); C, Coupon currency; S, issuer sector; M, Market of distribution; and Y, Year of issuance.

We further control for coupon Class fixed effects ($\sum_{j=1}^{m} \beta_j cpncls_i$), coupon Frequency fixed effects ($\sum_{j=1}^{n} \beta_j cpnfrq_i$), coupon Currency fixed-effects ($\sum_{j=1}^{p} C_j$), issuer Sector fixed effects ($\sum_{j=1}^{q} \beta_j S_j$), Market of distribution fixed-effects ($\sum_{j=1}^{f} \beta_j M_j$), and Time (year) fixed-effects ($\sum_{n=2014}^{2018} \beta_j Y_j$).

4.3.2 Data

Panel data from the Thomson Reuters Fixed Income Database were used to examine how corporate green bond yields vary with changes in the level of the Treasury term structure. This database contains the monthly price and other characteristics of corporate and government bonds. The initial bond dataset consisted of a total of 819 bonds issued over the five-year period from September 2013 to December 2018. Since there is still no universally

agreed definition of a 'green bond', the sample used here is compiled from the 'green bond' tag in the TR database. This excludes all so-called 'green bonds' that are not clearly aligned with the Climate Bonds Initiative Standards. A subset of the data in this database is used in this study. First, all bonds that were issued in minor currencies (that did not provide a significant sample for observation) were eliminated from the sample. This left us with five main currencies – US dollars, the Euro, the Swedish Krona, the Chinese Yuan and Japanese Yen. Next, we eliminated zero-coupon bonds, dual currency bonds, bond issued by corporations with headquarters in fiscal paradises and corporation that filed for bankruptcy. The data left after the elimination process pertained to nearly 614 bonds for the period from 01 January 2014 to 31 December 2018 (see Table 4.2 for summary statistics).

The monthly spread for each of the bonds is taken for the whole period, which results in a panel data set. To ensure consistency during spread calculation, comparable Treasury bonds are matched against each green bond by matching bond maturity, coupon currency, and market of issuance. To determine the order of issuance, we rank each issuance from the same issuer starting from 1 onward, which gives an overall order of issuance of all bonds ranging from 1 to 33 (see Table 4.3 for bond distributions).

Equation (2) is estimated in three steps – (i) all bonds combined; (ii) currency level and (iii) maturity bucket segregation (shorter, longer and medium maturity bonds) separately.

4.3.3 Estimation techniques

To choose the suitable panel data estimation technique for equation (2), it is necessary first to examine the diagnostics of the data across all five levels specified above. A modified Wald test and Breusch-Pagan/Cook-Weisberg test are used to check for heteroskedasticity, a Pesaran (2004) CD test to check

TABLE 4.2: Summary statistics

Variable	Obs.	Mean	Stand. Dev.	Min	Max
Spread	197,278	1.37	1.66	-0.19	9.16
Coupon	197,399	2.33	1.88	0	9.63
Tenor	197,399	6.82	4.28	2	31
Order of issuance	197,399	2.12	3.03	0	33
Call feature	197,399	1.22	0.41	1	2
Put feature	197,399	0.04	0.19	0	1
Rating code	197,399	7.81	5.73	0	16
Company type	197,399	1.59	0.49	1	2
Instrument type	197,399	1.56	0.50	1	3
Guarantee feature	197,362	1.15	0.36	1	2
Market type					
Domestic	197,399	0.48	0.50	0	1
Global	197,399	0.05	0.22	0	1
Eurobonds	197,399	0.41	0.49	0	1
Dim-sum-Samurai-Panda-Yankee	197,399	0.02	0.14	0	1
Other foreign	197,399	0.04	0.19	0	1
Coupon class					
Discount/Zero	197,399	0.01	0.10	0	1
Fixed	197,399	0.81	0.39	0	1
Floating	197,399	0.17	0.38	0	1
Range	197,399	0.00	0.00	0	0
Variable	197,399	0.01	0.10	0	1
Coupon frequency					
Annual	195,541	0.57	0.50	0	1
Monthly	195,541	0.00	0.00	0	0
Quarterly	195,541	0.18	0.38	0	1
Semi-annual	195,541	0.26	0.44	0	1
Sector					
Financial	197,399	0.54	0.50	0	1
Manufacturing	197,399	0.02	0.12	0	1
Real Estate	197,399	0.16	0.36	0	1
Utilities	197,399	0.17	0.38	0	1
Transportation	197,399	0.01	0.08	0	1
Industrial	197,399	0.01	0.10	0	1
Food processing	197,399	0.01	0.09	0	1
Healthcare	197,399	0.00	0.07	0	1
Other sectors	197,399	0.08	0.28	0	1
Year					
2014	197,399	0.02	0.13	0	1
2015	197,399	0.05	0.22	0	1
2016	197,399	0.13	0.33	0	1
2017	197,399	0.28	0.45	0	1
2018	197,399	0.52	0.50	0	1

TABLE 4.3: Bond distribution by currency, maturity and order

By currency	**Total**	**By maturity**	**Total**	**By order**	**Total**
YUAN	116	Shorter (<3 years)	16	1	349
Euro	192	Medium(3 - 10 years)	483	2	111
YEN	57	Longer (>10 years)	115	3	44
KRONA	119			4	23
USD	130			5	10
				>5	77
Total	614		614		614

cross-section dependence, a variance inflation factor (VIF) test to check for multicollinearity, a Wooldridge test to check for serial correlation (AR1), and a Cumby-Huizinga (1992) test to check for moving average (MA) autocorrelation. Table A2 in the Appendix presents the diagnostic checks showing that data at all levels contain significant heteroskedasticity, cross-section dependence, multicollinearity and serial correlation.

Furthermore, the test results show the existence of MA autocorrelation for most of the panels at different lag orders (see Table A3 in Appendix for autocorrelation matrixes). The persistence of serial correlation and MA autocorrelation is common in financial time series data such as yield. To deal with serial correlation, the one period lag of spread (l_spread) is initially included in the model; however, the diagnostic check indicates the persistence of serial correlation even after including the lag. Considering the diagnostic checks, two different panel data estimators are chosen to estimate equation (2), namely the Prais-Winsten Panel Corrected Standard Errors (PCSE) and the Driscoll-Kraay standard errors (DKSE). The PCSE regression can mitigate the biases of heteroskedasticity, Cross-section dependence, multicolinearity and serial correlation.

On the other hand, DKSE can mitigate the biases of heteroskedasticity, Cross-section dependence, multicollinearity and MA autocorrelation at different lag orders. The use of two different estimators helps us not only to mitigate the biases identified in the diagnostic checks but also to check the reliability of our estimates across estimation techniques. While implementing both the estimation techniques identified, the estimation process procedurally includes 521 out of 614 bonds to produce the final results. Since the actual number of bonds included in estimation differ with that of the initial dataset considered, we present the distribution of the total number of bonds by currency of coupon denomination, maturity, sector, and order of issuance in the results discussion section.

4.4 Results and discussion

Table 4.4 shows the effects of the actual order of issuance and other determinants on spread for all bonds. Table 4.5 presents the effects of the determinants by currency for and Table 4.6 represents the effect by maturity. The

discussion focuses first on the order of issuance effect before proceeding to shed light on the other determinants.

TABLE 4.4: Determinants of green bond spreads (all bonds)

Variable	All bonds	
	DKSE	PCSE
Coupon	0.003***	0.002***
	(0.001)	(0.000)
Tenor	−0.000**	−0.000*
	(0.000)	(0.000)
Order of issuance	0.000***	0.000**
	(0.000)	(0.000)
Call option	0.001	0.000
	(0.001)	(0.000)
Put option	0.003**	0.002*
	(0.001)	(0.001)
Bond rating	−0.000**	−0.000*
	(0.000)	(0.000)
Company type	−0.000	−0.000
	(0.000)	(0.000)
Guarantee feature	−0.001	−0.001
	(0.001)	(0.001)
Instrument type		
Bonds(1)	–	–
	–	–
Notes(2)	−0.001**	−0.001
	(0.001)	(0.001)
Debenture(3)	−0.003	−0.002
	(0.004)	(0.004)
Spread(*L*1)	0.997***	0.998***
	(0.001)	(0.000)
Constant	–	−0.006
	–	(0.002)
R squared	0.99	0.99
No. of Observations	188,738	188,738
No. of Bonds	521	521
Currency x Market x Coupon Class x Coupon Frequency x Sector x Year fixed-effects	Yes	Yes

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

TABLE 4.5: Determinants of green bond spreads (by currency)

Variable	YUAN		EURO		Japanese YEN		KRONA		USD	
	DKSE	PCSE	DKSE	PCSE	DKSE	PCSE	DKSE	PCSE	DKSE	PCSE
Coupon	0.006***	0.005***	0.001	0.001	0.005**	0.004**	0.002**	0.001	0.005***	0.004***
	(0.002)	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
Tenor	0.000	0.000	-0.000	.000	.000	0.000	0.001	0.001*	-0.000***	-0.000***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Order of issuance	0.001**	0.001**	0.000	.000	-0.000	0.000	0.001	0.000***	0.000*	0.000*
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Call option	–	–	0.001	0.001	–	–	0.070	0.042***	-0.001	-0.001
			(0.000)	(0.000)			(0.011)	(0.008)	(0.002)	(0.001)
Put option	0.001	0.000	–	–	–	–	–	–	–	–
	(0.001)	(0.001)								
Rating	-0.000		0.000	.000	0.001	0.001	0.002***	0.001***	0.000	0.000
	(0.000)		(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)
Company type	-0.001	-0.001	0.001	0.001	-0.010	-0.008**	-0.011***	-0.007***	-0.002	-0.002
	(0.001)	(0.002)	(0.001)	(0.000)	(0.004)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
Guarantee feature	-0.000	0.0000	0.000	0.000	0.006	0.004	0.006**	0.004	-0.000	-0.000
	(0.001)	(0.000)	(0.000)	(0.000)	(0.024)	(0.020)	(0.003)	(0.003)	(0.001)	(0.001)
Instrument type										
Bonds (1)	–	–	–	–	–	–				
Notes (2)	0.002	0.001	-0.001	-0.001	–	–	-0.006***	-0.004***	-0.004***	-0.003**
	(0.002)	(0.003)	(0.001)	(0.001)			(0.001)	(0.001)	(0.001)	(0.001)
Debenture (3)	–	–	–	–	–	–		–	-0.008**	-0.006
									(0.004)	(0.004)
Spread (L1)	0.991***	0.992***	0.997***	0.998***	0.997***	0.997***	0.978***	0.986***	0.996***	0.997
	(0.004)	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.003)	(0.002)	(0.002)	(0.001)
Constant	-0.011	-0.010	0.003	0.001	0.012***	0.010	-0.036***	-0.022	-0.013	-0.005
	(0.009)	(0.008)	(0.002)	(0.002)	(0.004)	(0.004)	(0.008)	(0.007)	(0.011)	(0.005)
R squared	0.994	0.995	0.999	0.999	1.00	1.00	0.986	0.991	0.998	0.999
No. of Observations	24,886	24,886	71,316	71,316	6,905	6,905	43,515	43,515	42,351	42,351
No. of Bonds	96	96	173	173	25	25	117	117	112	112
Currency x Market x Coupon Class x Coupon Frequency x Sector x Year fixed-effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

*Figures inside and outside parentheses indicate robust standard errors and coefficients, respectively. Significance levels: ***=1%, **=5% and *=10%*

TABLE 4.6: Determinants of green bond spreads by maturity

	Shorter Maturity		Medium Maturity		Longer Maturity	
	DKSE	PCSE	DKSE	PCSE	DKSE	PCSE
Coupon	0.081**	0.062***	0.002***	0.002***	0.003*	0.002**
	(0.039)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)
Tenor	–	–	−0.000*	−0.000	0.000	0.000
	–	−(0.000)	(0.000)	(0.000)	(0.000)	
Order of issuance	0.004**	0.003***	0.000***	0.000**	0.001**	0.001
	(0.002)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Call option	–	–	0.000	0.000	−0.000	−0.000
	–	–	(0.000)	(0.001)	(0.001)	(0.001)
Put option	–	–	0.002*	0.001	0.027	0.021
	–	–	(0.001)	(0.001)	(0.034)	(0.038)
Bond rating	−0.001***	−0.003***	0.000**	0.000**	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Company type	−0.043**	−0.033***	0.000	−0.000	−0.000	−0.000
	(0.020)	(0.003)	(0.000)	(0.000)	(0.001)	(0.001)
Guarantee feature	−0.269*	–	0.000	0.000	−0.001	−0.001
	(0.145)	–	(0.001)	(0.001)	(0.001)	(0.001)
Instrument type						
Bonds(1) -	–	–	–	–	–	–
-	–	–	–	–	–	–
Notes(2)	–	–	−0.001**	−0.001	−0.003***	−0.003***
	–	–	(0.001)	(0.000)	(0.001)	(0.001)
Debenture(3)	–	–	–	–	−0.004	−0.003
	–	–	–	–	(0.004)	(0.004)
Spread(L1)	0.904***	0.926***	0.998***	0.999***	0.995***	0.996***
	(0.046)	(0.005)	(0.001)	(0.000)	(0.002)	(0.001)
Constant	0.064**	0.057***	−0.016***	−0.006**	0.005	0.002
	(0.031)	(0.008)	(0.006)	(0.003)	(0.009)	(0.005)
R-squared	0.999	0.999	0.999	0.999	0.997	0.998
No. of Observations	2,402	2,402	142,714	142,714	43,622	43,622
No. of Bonds	14	14	149	149	96	96
Currency x Market x Coupon Class x Coupon Frequency x Sector x Year fixed-effects	Yes	Yes	Yes	*Yes*	*Yes*	*Yes*

Note: * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Data show that order of issuance is positive and significant for all bonds, YUAN, Swedish Krona and US dollars meaning that the higher the issuance ranking the higher the spread, confirming that order is an important factor determining green bond interest rates. As investors familiarize with green bonds in certain markets, the demand to buy these instruments decreases and therefore investors are willing to buy them only at a higher interest rate. This investor's attitude is not confirmed for the bonds issued in EU and YEN

but is consistent for all maturity levels. Despite investors moving towards a more responsibilities behavior with regard to long-term sustainable investment (Clark, 2016) with their appetite for environmental project exponentially increasing (Clark 2018), results shows that they are not willing to do it for a reduced price, notwithstanding the international capital market association (ICMA) massive work in strengthening the structure and definition of green bonds to increase investors' trust.

For China, where policymakers commitments to transforming the market into a full-fledged green finance system transformed the country in a leading players in the global green bond market, the proportion of green bond issuance aligned to international definitions is still low. This may explain why investors after the first issuance, may increase their risk perception on subsequent issuances offering higher interests that translates in higher spreads to Chinese treasury bonds. In the US and Swedish market, this phenomenon could also be explained by the type of companies able to issue green bonds and the way projects are monitored to ensure that they finance either new or ongoing projects for which the green bonds were issued. If corporations do not prove these systems reliable, it can increase investor scepticism and therefore lower their willingness to facilitate environmental project with lower interest rates. These findings complement the available literature on green bond supply and issuance (Chiesa and Barua 2019: 149; Demary and Neligan 2019; Glavas and Bancel 2018).

Among the other determinants considered, coupon rates have a significant and positive effect on spread when estimated for all bonds together, for all currencies but EURO and for all maturities. Coupons are often used to leverage on value of green bonds to investors; hence, higher coupons are likely to result in higher spreads. Although there is no direct literature on the effects of coupon rates on green bond spreads, studies on interest rates and personal taxes (Hachenberg and Schiereck 2018; Liu et al. 2009; Sarig and

Warga 1989: 1355), especially those regarding conventional and corporate bonds, support the findings (Duffee 1998: 2225; Helwege and Turner 1999: 1873). Results further shows that tenor, has a significant and negative effect for all bonds, driven by the bonds issued in US dollars and with medium maturity. The effects of tenor are insignificant for all other estimations. This is supported by literature on the question of tenor and green finance (Chang 2019; Madan and Schoutens 2012).

The effects of the option features embedded in green bonds are tested on their spread. The call option feature is found to have a positive effect only on Swedish krona bonds. This is an expected result because companies that can afford to put a call option on their bonds are already in the lower risk category. The results here are consistent with the literature on call options and option valuations (D'Halluin et al. 2001: 56; Edwards et al. 2007: 1433; Hachenberg and Schiereck 2018). By contrast, the results suggest that spreads in green bonds with put options are likely to be higher. This may be because bonds for which investors require a put option, namely the ability to sell the bond back to the issuer before maturity, may be considered riskier so have higher spreads.

Except for Swedish krona bonds, bond rating was also found to be significant with negative effects on green bond spread. This is completely consistent with market trends as the riskier the bond, the higher the spread. Risker green bond in fact, have lower liquidity and prices, leading to higher spreads compared with the ones less risky. This is likely to be driven by the higher demand from investors for higher rating securities because of their higher liquidity. This result is in line with the available literature on issuer characteristics associated with going green and with green bond volatility (Bachelet et al. 2019; Bethune et al. 2017: 15; Clapp and Pillay 2017; Pham 2016: 271).

Company type, the other determinant in this analysis, shows a significant and negative effect on green bond spreads for Japanese Yen, Swedish Krona

and shorter maturity bonds. These results indicate that yield spread of bonds issued by parent companies are likely to be lower compared to those issued by subsidiary companies. In other words, investors could earn higher yield relative to treasury bonds by investing in bonds issued by subsidiary companies rather than parent companies.

The results show that the availability of a guarantee feature has a significant and negative effect only for short maturity bonds. Most investors are expected to opt for guaranteed but smaller gains rather than to take major risks for higher gains; hence, guarantee features mean lower spreads for risk-averse investors. This is backed by the relevant literature on government guaranteed bonds and the concept of risk acceptance (Chygryn et al. 2019: 1448; Levy and Zaghini 2010: 753; Pagano and Von Thadden 2004: 536; Ratha et al. 2018: 69; Sanchez et al. 2017).

Another factor is the type of instrument. The results suggest that issuing notes greatly negatively affects green bond spreads provided that they fall within the medium-longer maturity bucket. This is in line with the available literature on issuing financial instruments and the different characteristics of bonds, notes and debentures (Amihud and Mendelson 1991: 1412; Febi et al. 2018: 53).

A positive effect of the lag of spread variable across all estimations is consistently found, indicating that the previous day's level of spread positively affects the current day's spread.

The findings, however, are subject to some limitations encountered in this research. First, although this study is based on Thomson Reuters green bond labeling, it does not include all the bond issued with environmental use of proceeds as many companies prefer not to officially label their environmental related bond. Second, this dataset does not include other minor currencies and therefore does not study the growing markets that could be potentially

important issuers in the coming years. Finally, despite utilizing the best possible estimation methods to the best of the authors' knowledge, the five-year daily dataset used in this research could have a long autocorrelation structure, which could still be sources of some biases.

4.5 Conclusion

Green bonds are unique financial instruments because they are mainly issued with the aim of financing projects geared towards encouraging a green economy and a healthy environment through anti-climate change policies. The use of green bonds to finance projects has, given their tendency to attract investors from both local and foreign markets, been on the rise in recent years. Many investors now have a green investment mandate, which creates a market for green bonds and as a result they have received green bond with great enthusiasm. Accountability for such projects should be highly traceable and green investors should have full confidence in the projects to be undertaken.

The players of the markets in which a green bond is issued are expected to determine the risks associated with it, thus affecting the green bond spreads for that market. In addition, the market in which the green bond is issued is also expected greatly to affect the determination of the risk-free rates and the certainty of yields, further creating differences in spread.

In this essay, we conducted a linear regression analysis to determine the differences in the levels of significance and the reasons why some of the factors are highly significant while others are of less significance to the green bond spreads. Critical of the factors under analysis included; coupon, tenor, options, company type, guarantee feature and instrument type while controlling for coupon currency, coupon class, coupon frequency, market of distribution, issuer sector, and year fixed effects. Throughout the analysis, the findings were based on both the DKSE and the PCSE techniques for all five

currencies (US dollar, Euro, Swedish krona, Chinese Yuan and Japanese Yen) and the three bond categories (general, shorter, medium and longer maturity bonds). The study found that, beside the regular factors, order of issuance has an effect on the spread that is significant and positive for all bonds and across all maturities. This means that further issuances of the same issuers are perceived as riskier from the investors that therefore are willing to offer only higher interest rates. This results could be driven by three main reasons.

First, subsequent green bond issuances could reflect a reduction in green project quality and an increase in green project risk. As companies grow and seek access to additional debt liquidity, they may propose more controversial green projects over time, signalling greenwashing attitudes to investors. Investors, as part of the green bond investment analysis would likely see new projects as more risky and price them appropriately at a wider spread.

Second, the large increase in green bond issuance from 2011 – 2018 may have outstripped green bond demand. While investors have "poured" into the green bond market, the demand may still be lower than the overall supply of new issuances. As a result, investors presented with an abundance of green bond choice may be more discerning towards second, third, fourth and fifth issuances from existing companies. In addition, investors are likely to have a diversification bias, where they are only willing to hold one issuance from each issuer to avoid concentration which would increase sale and exit liquidity risk.

Third, green bonds may be showing higher spreads over subsequent issuances due to increased market risk. The period of our sample from 2014-2018 saw rises in economic and political as well as climate risks which could have had an effect on the perceived risk that investors anticipated in the market and in individual green bond issuances. These market risks could be driving wider spreads independent of individual green bond projects.

In order to the flatten spread faced by green bond issuers and guarantee

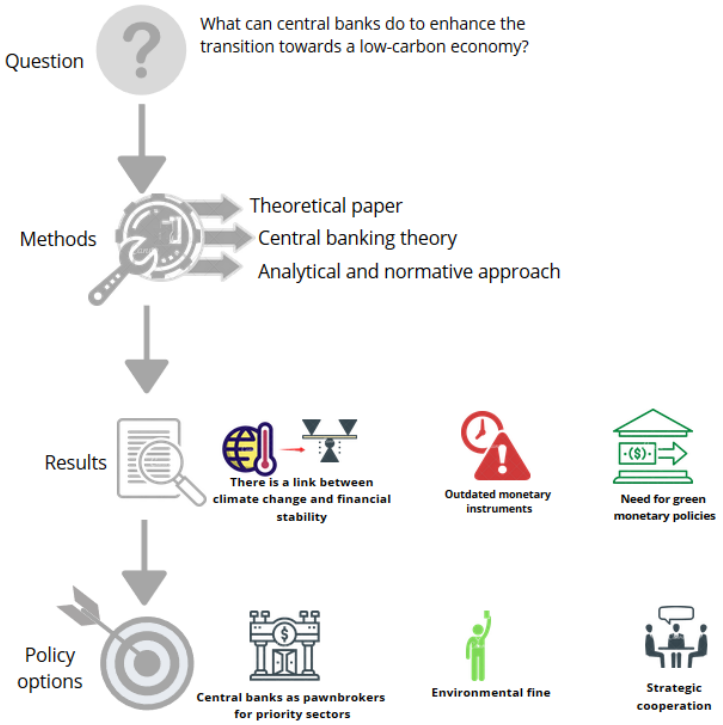
a good and stable market for them to re-issue, we suggest the setting of a common taxonomy for green bond certification. Such a taxonomy is likely to increase transparency, reduce the transactions costs associated with green bond issuance, and improve the overall funding strategy of the issuers, while attracting new types of investors, including small investors from developing countries. Furthermore, doing so could help not only to predict the future growth of the market, but also to counter greenwashing behaviors, where issuers spend considerable time claiming to be green rather than acting in accordance with their claims.

Chapter 5

The role of central banks in scaling up climate finance

"We must do everything we can to support and complement the action undertaken by states. It is a great challenge for us, as supervisors in the 21th century. I would even say that it is our «new frontier»"

- François Villeroy de Galhau (2018), The Banque de France.



5.1 Introduction

Climate change has opened up the debate about the role of central banks in enhancing the transition towards a low-carbon economy. For many decades, central banks have concentrated their efforts towards combating consumer price inflation. However, the recent climate crisis and the call for bold actions to phase out fossil fuels (IPCC, 2018) have made acute the question whether central banks should only care about inflation at the expense of societal and environmental challenges. Over the last few years, climate change has proven critical to firms' investments and their stakeholders across the world (Masahiko and Upmanu, 2015), and is threatening the effectiveness of monetary policies (Batten et al., 2016).

Similarly, the last few years have seen many central banks, in both developed and developing countries, make a stand against climate change (Carney, 2016, 2019; Campiglio et al., 2018). Yet many central banks' practices continue to stand as a headwind to the implementation of the sustainable development agenda. Even for those central banks that explicitly recognized climate change as a threat, little has changed in their day-to-day practices, notwithstanding the fact that there is a link between climate stability and financial stability, at least in the long-term (Carney, 2016; Aglietta and Espagne, 2016)..

In its three consecutive annual reports on the global risks, the World Economic Forum has identified climate change as one of the ten top global risks by likelihood and impacts (WEF, 2017; WEF, 2018; WEF, 2019). Furthermore, Stern (2006) argued that climate change is likely to have long-lasting impacts on economic growth. According to Stern's estimates, a business-as-usual scenario could cost between 5% and 20% of global GDP. It is now widely accepted that climate change is threatening foundations of the global economy if nothing is done to mitigate it (Zenghelis, 2016). An unchecked climate is

expected to reshape the world economy by reducing average global income 23% by 2100 and by exacerbating global income inequalities (Burke et al. 2015; Zenghelis, 2016).

From investment perspectives, climate change has become a real threat, hurting investment plans across the world. For instance, the insurance and reinsurance industry is already incurring a growing burden of financial losses due to climate change in both its liabilities and assets (Farid et al., 2016; Dietz et al., 2016). Moreover, some climate risks such as ecosystem losses or climate-induced poverty are not financially valued yet, implying that climate-induced financial losses might be underestimated globally (van Tilburg et al. 2016). Hence, climate change could be considered as the new variable central banks should henceforth consider while designing their monetary policy. Yet none of central bank models integrate climate change so far. This, however, calls into question the role of central banks in modern economies.

By revisiting the principles of central banking in the 21st century, Dow (2017) argues that central banks need a new framework that recognizes the linkages between the conditions for monetary stability, financial stability, and economic stability. This argument is also endorsed by Taouil (2015), who argues that monetary policy needs not be subjected to mechanical and stringent inflation control rules when the economy is growing sluggishly. Rather, it should be flexible and used wisely in time of crisis or weak growth. The same rationale should be applied to monetary policy design in a time of a changing climate, given the linkages between climate stability and financial stability.

The analysis of the role that central banks can play in tackling climate change should focus on three critical questions: First, what are the challenges posed by climate change to central banks' mandates? Second, what kind of innovative instruments should central banks develop to address those challenges? Third, what role could central banks play to ensure that financial

institutions set aside enough capital to deal with climate risks? Only by addressing these overarching questions could central banks effectively contribute to the deployment of a low carbon society.

The second essay of this dissertation is unequivocal about the first question: climate change is a real threat for financial stability. While delivering a seminal speech at the Arthur Burns Memorial Lecture, Mark Carney, the outgoing governor of the Bank of England, argued that climate change is posing three main risks to financial stability: the transition risk, the physical risk, and the liability risk (Carney, 2016). According to Batten et al. (2016), climate change will affect monetary and financial stability mainly through the physical and transition risks.

Regarding the second question, the third and fourth essays of this dissertation show that, as innovative financial instruments, green bonds can help investors to not only diversify their portfolios, but also contribute to addressing climate change.

So far, however, little is known about what central banks can do to enhance the development of a greener financial system, and encourage financial markets to allocate enough capital for the low-carbon economy. The fear of seeing central banks depart from their traditional role of maintaining price stability has been curtailing central banks' response to the climate crisis.

The aim of this essay is to address this shortcoming in the literature on central banking. By adopting a normative approach and undertaking a historical review of the evolution of central banks' objectives, I argues that a careful redesign of central banks' mandates to incorporate climate change settings can lead to a positive-sum game for both the global economy and the environment. Put in other words, I suggest that the implementation of smart green monetary policies to foster the transition towards a low-carbon economy does not call into question the independence of central banks. Instead, by creating and sustaining an environment which enables financial markets

to allocate enough resources to green infrastructure projects, central banks are logically extending what they have been doing since the 2007-09 financial crisis. The only difference being that such an extension of their mandate should target projects that can potentially generate positive environmental impacts while boosting growth.

The essay is built on King's concept of the end of alchemy. In his book, King(2017) argues that something is wrong with our current banking system and more broadly with monetary policy. While the use of traditional monetary instruments has led to huge benefits for society and fueled economic growth for the last two centuries, these instruments no longer operate efficiently in modern economies. Continually falling interest rates, rising inequalities, weak economic growth are, among others, evidence that central banks' models have become irrelevant to current problems. For King, it time to recognize the limits to monetary policy. Modern prosperity requires central banks to act as *pawnbroker for all seasons*, meaning that they should always do whatever it takes to prevent the collapse of the system.

This essay is therefore original for at least two reasons. First, it stands as a major contribution to the literature on central banking in a time of climate change. Second, it provides monetary authorities with new tools aimed at helping them in their efforts to steer financial markets towards sustainable investing.

The remaining of the essay is structured as follows. Section 2 reviews the literature on the evolution of central banks' objectives since their inception. Section 3 argues that, given the evolutive nature of central banks's mandates and the need to address climate change, incorporating climate targets into monetary policy design does not necessarily jeopardize the independence of central banks and their objective of price stability. Just like financial stability has become part of many central banks' mandates in the midst of or after financial crises, climate risk should also benefit from the same treatment, given

it relevance for financial stability. Section 4 identifies potential barriers to the development of a greener financial system. Section 5 provides a set of policy measures for embedding climate change into monetary policy design. Section 6 concludes.

5.2 The evolution of central banks' objectives

The world's oldest central banks were not designed with inflation targeting[1] frameworks nor were they granted independence in the first place. Only recently, has inflation targeting frameworks spread to many central banks' practices across the world, after their first adoption by Germany and Switzerland in the 1970s and New Zealand, Canada and the United States in the early 1990s (Neumann and Hagen, 2002). Many central banks today were initially private banks before becoming public institutions due to their dominant position in their home countries (Capie 1995; Epstein, 2006; King, 2017).

During economic booms and busts, governments have been unable to resist the desire to print paper money to finance their expenditure. Such government practices have been commonplace during war and crisis times. The Bank of England, for instance, was primarily established in 1694 to help the British government finance its military expenditure (King, 2017). The Second World War was another case in point. Indeed, many western governments have massively relied on central banks to finance their war expenditures (King, 2017). During the 2007-09 financial crisis, central banks have wisely reoriented their attention towards financial stability to prevent a meltdown of the global financial system (Nakaso, 2013). Moreover, the Eurozone crisis in 2010 showed that central bankers are not caught up in an 'ideological

[1]Inflation targeting (IT) is a monetary policy framework in which the central bank publicly announces a medium-term inflation target and adjusts its policy rates in order to meet this target (German Development Institute, 2015).

trap', as some might argue. Indeed, the European Central Bank did 'whatever it takes to preserve the Euro (ECB, 2012)[2]. Central banks' objectives have , therefore, always evolved according to the prevailing macroeconomic environment.

It was bad experiences of hyperinflation scenarios in Germany after World War I, in eastern European countries after World War II, and more recently in developing countries that led many governments across the world to adopt inflation targeting frameworks (Poole and Wheelock, 2008). In England, for instance, before the adoption of those schemes in 1992, inflation stood at over 750% (King, 2017). Furthermore, to ensure that monetary policies are implemented without any political pressure, many central bankers were granted independence. The idea underpinning such an independence was that, by delegating monetary policy to an independent central bank, free of any political pressure, it is possible to achieve a low and stable price level, which is critical to firms and households' investment decision making. As Issing (2002) put it: *'There is today a broad consensus that stable money is too important to be left to the day-to-day political process . . . it makes sense for society to create an independent institution that stands above the fray of day-to-day politics and can pursue this objective [price stability] with minimum distraction'. p.27.*

In fact, in market economies, households and firms usually base their consumption and investment decisions on their anticipations and expectations about the future (Coibion et al., 2018). A stable and predictable economic environment is thus the basis for long-term investment patterns. Firms and households need an environment with less uncertainty in order to plan their long-term investment and consumption decisions (Gaiotti and Generale, 2002). Put in other words, this argument means that price movements are to market economies what bad weather is to air traffic.

[2] Speech by Mario Draghi, President of the European Central Bank at the Global Investment Conference in London 26 July 2012

The idea behind inflation targeting frameworks is that by setting a clear inflation target, central banks could anchor the expectations of households and firms, so that in the short to medium terms price movements are transparent, predictable, and do not affect their consumption and investment patterns (Greenspan, 2002; King, 2017). Controlling the level of inflation within an economy is therefore as important as bailing out that economy when it is running dry of liquidity.

History provides good reasons why inflation should be paid due attention. In countries such as Germany, the United Kingdom, and Japan, the implementation of IT frameworks has proven successful in preventing economic busts (Bernanke et al. 2001).

Yet even after their very hard-won independence, governments in both developed and developing countries have continued to rely on central banks to deliver economic recovery or financial stability in bad times. A case in point is the bailout of the *too big to fail* banks, rescued in the midst of the 2007-09 financial crisis. In other words, central banks have always saved the world economy in bad times and should continue to do so, as long as the global economy walks into rocky roads.

Although IT frameworks have proven effective in maintaining low inflation rates during the 20^{th} century, they unfortunately led to a confusion between stability and sustainability (King, 2017). Most central banks' frameworks today do not enable them to play a proactive role in promoting the sustainable development goals.

However, given the growing complexity of modern economies, there is more to managing the economy than hitting a target on consumer price inflation (King, 2017). The sustainable development imperative and the climate crisis suggest that central banks may need to extend their current narrow mandates to incorporate sustainability into their policy design.

Such a paradigm shift requires central bankers to humbly recognize that

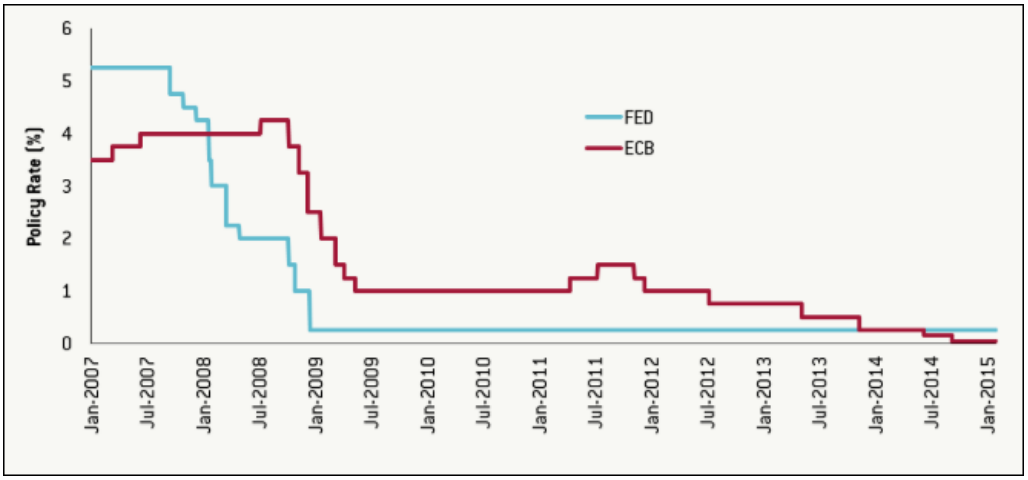
their traditional instruments have become powerless in understanding how inflation works in modern market economies, especially in the context of climate change. It also requires them to go beyond this simple diagnosis of the outdatedness of their instruments, and think about a new generation of monetary policies that could help address the pressing issues of our time.

5.3 Old instruments, New challenges

5.3.1 Outdated instruments

Over the last decade, monetary authorities have pushed their tool-kits to the extreme in the hope that it would help the world economy recover. Yet the global economy is still growing sluggishly and many central banks have failed to achieve their inflation targets, despite the clear rules-based approach of their IT frameworks (Stein, 2018; Volz, 2017). What is more, it is likely that central banks are facing a crisis of confidence since the latest financial crisis (Giles, 2017). This sentiment that central banks are facing a crisis of confidence is even shared by the former Governor of the Fed, Janet Yellen, who argued that in today's economy, '*the conventional framework for understanding inflation dynamics could be misspecified in some fundamental way*' (Yellen, 2017). The 2007-09 financial crisis has seriously put into question the idea that central banks should only focus on price stability at the expense of other critical goals, such as financial stability, growth, and employment (German Development Institute, 2015).

The context of many economies has evolved since the 20^{th} century, and financial markets have become more complex than ever before (Akerlof and Shiller, 2009). Today's global economy is far away different from that of the nineteenth or twentieth centuries. In many advanced economies, the main



Source: Bruguel (2016). The world's major central banks have reached their lower bound rates in 2015, thereby challenging the conventional wisdom about the relationship between monetary policy and inflation.
FIGURE 5.1: Policy rates: The US Federal Reserve vs the ECB.

challenge of central banks is no longer higher inflation rates, but an unprecedented environment of low (even negative) interest rates that has settled in since the 2007-09 financial crisis. Between 2009 and 2015, the policy rates of the Fed and the European Central Bank, have stagnated between 1.5 and zero percent, despite several accommodative monetary polices (see Figure 5.1). In light of this ineffectiveness of recent monetary policies, it becomes harder to avoid the question of how much do central bankers really know about inflation in the post-crisis era (Borio, 2017).

Its is likely that climate change can explain part of such ineffectiveness of recent monetary policies, as it has become not only a threat for financial institutions but also a determining factor in the price of goods and services. It is therefore worth recognizing that climate change poses unprecedented challenges for central banks and financial regulators (Campiglio et al., 2018). Thus, there are good reasons to question the reluctance of some central banks to engage with sustainability issues.

The discrepancy between central banks' models and the need for their

proactive role in addressing the complex challenges faced by the world economy could well be illustrated by what King (2017) called the flawed frameworks of central banks. As he puts it:

'Imagine that you called a plumber to deal with a problem in your kitchen. You would expect a professional plumber to arrive carrying a box of tools from which he would select the appropriate instrument once he had diagnosed the problem. Suppose, however, that he arrived with a single tool, confident that whatever was wrong could be resolved by the use of this single instrument.'

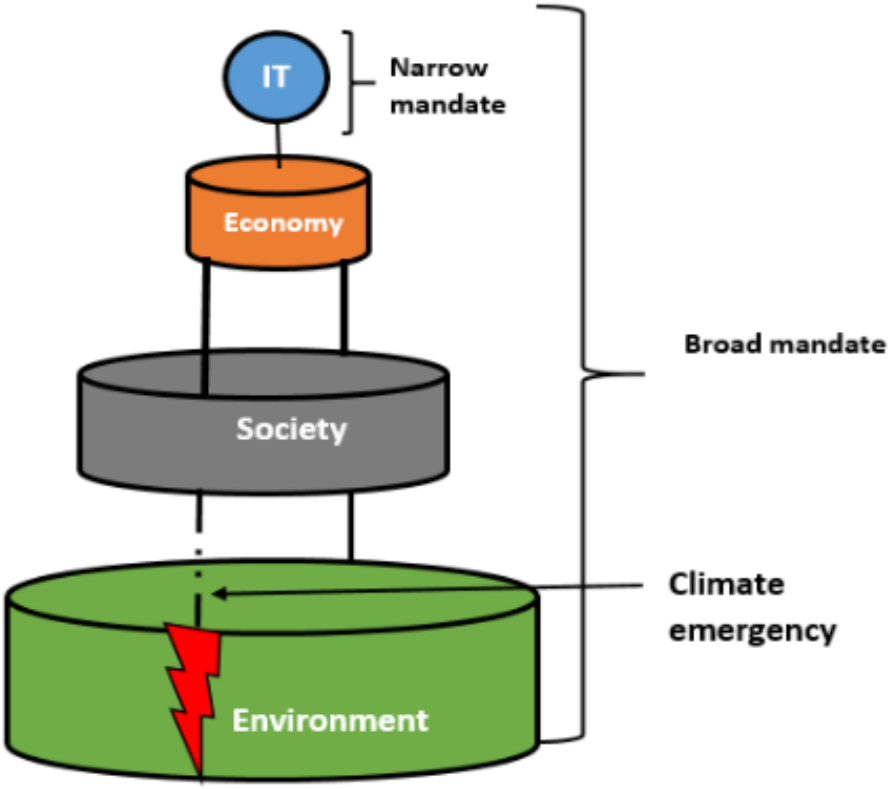
This enigma suggests that there is no a single rule or instrument that can long remain optimal without taking into account the dynamics that occur within the system for which that rule or instrument was designed. Since modern economies are not static systems, so should be the rules governing them, meaning that focusing only on inflation targeting frameworks- howsoever effective they are- is not enough to addressing all the complex and non-linear problems faced by modern market economies. What is expected from modern central banks, is more accountability and transparency in their practices rather than the application of stringent rules (King, 2017). Therefore, central banks should update and, if necessary, ditch some of their instruments to better capture the dynamics of modern economies.

In a volatile, uncertain, complex and ambiguous world (VUCA world), focusing on a single monetary instrument, hoping it will help stabilize the economy is nothing but an illusion. As King (2017) argues, modern central bankers should act like doctors who continuously need to be on top of the latest technical developments, implying that a good monetary policy is a continuing process of learning and updating as the structure of the economy changes. Central banks should, therefore, put the climate challenge on par with inflation control and financial stability.

This shift will certainly require a slight extension of their current narrow mandates. However, as this essay argues, such an extension is not contrary

to their objective of price stability and/or financial stability. Instead, by embracing this new paradigm central banks are ensuring that the financial system is resilient to climate risks and that sufficient financial resources flow to low-carbon projects. Moreover, such a shift is a logical continuation of what they have been doing since the crisis, except that this extension should target priority sectors.

5.3.2 Linkages between climate change and monetary policy



Source: Adapted from Schoenmaker (2017). There is a need to adopt a holistic approach to monetary policy. Many central banks focus on their narrow mandate of inflation targeting (IT), while there is a need to move towards the broader mandate which recognize the interdependencies between the economy, the society and the environment.
FIGURE 5.2: A broadened mandate for central banks

For central banks to diffuse sustainability into monetary policy design, they may need to see their decisions as being oriented towards an integrated

system composed of three intertwined elements: economy, environment, and society (see Figure 5.2). The equilibrium of this integrated system is dependent on the soundness of the poles between the economy and society units in one hand, and the environment's in the other. A sock on any of these components could reverberate on the whole system. For instance, a sock on the environment unit could mean fewer resources available for use in the society. This resource scarcity could lead to weak economic performance, and its corollaries in terms of violent conflicts and migrations across the world. If the bridge between the environment and the society crumbles, the whole system is at risk. However, by working hand in hand with the financial markets players, central banks could help avoid this 'tragedy of the horizon'.

Next, by destroying the productive sectors, climate-related physical events could create demand and supply shocks in the markets of goods and services (Mckibbin et al., 2017), which in turn could lead to a temporary '*climate-induced inflation*' that cannot be absorbed by a tightened monetary policy. As far as we know, there is a literature gap regarding this concept of climate-induced inflation. Within the traditional theory of central banking, inflation is a purely monetary phenomenon (Dow, 2017), which central banks should control by implementing a tightened monetary policy. There is usually a time lag between the moment an anti-inflationary policy is implemented and the time it produces the expected outcomes on price levels (Fabris, 2018). However, climate socks, as a result of temperature increase and sea level rise, are more likely to have direct and immediate impacts on short-term consumer price levels. Thus, by endorsing this idea of climate-induced inflation, it becomes easier to argue that central banks should no longer neglect climate change when designing their monetary policies.

A first step towards integrating climate change into monetary policy design could be, for instance, the extension of the so praised Taylor rule, so as to include a parameter for climate-induced inflation. The traditional Taylor

rule suggests that interest rates should rise if inflation is above its target and the output above its trend level (King, 2017). In other words, interest rates in the Taylor rule are a function of the differences between current and expected levels of inflation and output, as depicted in Equation 1.

$$i = r* + p_i + 0.5(p_i - p_i*) + 0.5(y - y*) \tag{5.1}$$

Where: i = nominal interest rate, $r*$ = real interest rate (usually 2%), p_i = rate of inflation, $p*$ = target inflation rate, Y = logarithm of the real output,

$y*$ = logarithm of potential output.

However, as Volz (2017) argues, climate change and environmental damages could have a direct impact on price stability through their effects on food and energy systems. The extended Taylor rule with climate-induced inflation implies that interest rates are also a function of the output gap caused by potential climate shocks. By denoting z* the logarithm of the real output, y_c the output loss following a climate shock, and pi_c the climate-induced inflation rate, the extended Taylor rule can take the following form:

$$i = r* + pi_c + 0.5(pi_c + pi*) + 0.5(y - z*) \tag{5.2}$$

, where $z* = (y* - y_c)$, $pi_c > pi$, y is the potential output without climate shocks.

Equation (5.2) above suggest that, climate shocks could cause interest rates to rise above their expected levels under the traditional Taylor rule. In light of this, it is likely that central banks are facing a '*climate dilemma*', which can be summed up in one question: should they continue arguing that climate change is out of their prerogatives while knowing that it could affect the efficiency of their monetary policy and create a ground for financial instability?

The recently established Network for Greening the Financial System (NGFS)

suggests that central bankers are not turning a deaf ear to the sustainability challenge faced by the global economy. However, for this network to become operational, and hopefully lure other central banks, there is a need to recognize that the current narrow mandates of central banks undermine their capacity to address climate-related risks.

As this essay claims, it is possible to integrate climate mitigation targets into monetary policy design without departing central banks from their traditional role of ensuring price stability. A clear narrow mandate focused on price stability was initially perceived as a means of avoiding power abuse by central bankers and governments (Issing, 2002). Yet the turmoil of the global economy suggests that flexibility in central banks' mandates should be the rule, not the exception. In modern market economies, the role of central banks should not be to eliminate consumer price fluctuations year by year but to reduce the degree of uncertainty over the price levels in the long-run (King, 2017). Consequently, there is room to deviate from stringent inflation targeting frameworks when circumstances demand.

However, such a call for flexible central bank mandates does not mean that central banks should replace the government in the fight against climate change. Instead, the rationale for such a paradigm shift is to recognize that central banks have become an important building block of the global economy and should therefore play the roles the new macroeconomic environment expects them to. One of those roles may consist of identifying and removing the barriers to climate finance.

5.4 Barriers to climate finance intake

Although green finance is growing fast, it still represents roughly 2% of total fixed-income markets (Thomson Reuters, 2018). Conversely, companies relying on fossil fuels continue to benefit from large amounts of public and

private investments. For instance, USD 87 billion was lent by the world's 37 top banks for fossil fuel extraction in 2016, with USD 437 billion invested by the oil and gas industry (Reuters, 2017). These figures suggest that the low-carbon transition will not take place overnight, as long as the world's energy system continues to rely so massively on fossil fuels.

There are several barriers to the development of a sustainable financial system. The truth is that the current structure of financial markets does not provide enough incentives for phasing out carbon-intensive investments. Widespread short-termism in investment decision-making, misaligned incentives, information asymmetries, financial mis-education, and lack of relevant data to guide policy makers are among others the barriers to green finance intake (Green Finance Taskforce, 2018; United Nations, Inter-agency Task Force on Financing for Development, 2019).

Short-term profit maximization and short-term executive payoff schemes have been mentioned by many authors as ones of the key barriers that prevent financial markets from delivering sustainable finance for low-carbon projects (Haldane, 2016; Schoenmaker, 2016). The widespread short-termism behavior within financial markets is altering the incentives of firms' executives to transfer the savings of today for long-term investment (Haldane, 2016). According to Haldane (2011), short-termism is the tendency of financial markets to weight too heavily short-term outcomes at the expense of long-term opportunities. Thus, the challenge for central banks is to daunt short-termism in firms' investment decision-making in order to scale up the development of a sustainable financial system (Schoenmaker and van Tilburg, 2016).

According to Schoenmaker (2017), there are three stages of sustainable finance (see Table 5.1). The first stage is Sustainable finance 1.0, which aims to maximize short-term profits for shareholders without any consideration for environmental and societal issues. The second stage- Sustainable finance

Source: Schoenmaker (2017). Note: F = financial value; S = social impact; E = environmental impact; T = total value. At Sustainable Finance 1.0, the maximisation of F is subject to minor S and E constraints.

TABLE 5.1: A framework for sustainable finance.

Sustainable finance typology	Value created	Ranking of factors	Horizon
Sustainable Finance 1.0	Shareholder value	F > S and E	Short term
Sustainable Finance 2.0	Stakeholder value	T = F + S + E	Medium term
Sustainable Finance 3.0	Common good value	S and E > F	Long term

2.0- takes into account the interests of all the stakeholders involved in the production process, and aims to create not only financial returns but also environmental and societal outcomes in the short to medium terms. The third stage is the Sustainable finance 3.0, which put common goods, such as the environment, ahead of financial returns. The objective of Sustainable finance 3.0 is to promote a sustainable society, where growth does not come at the expense of the environment.

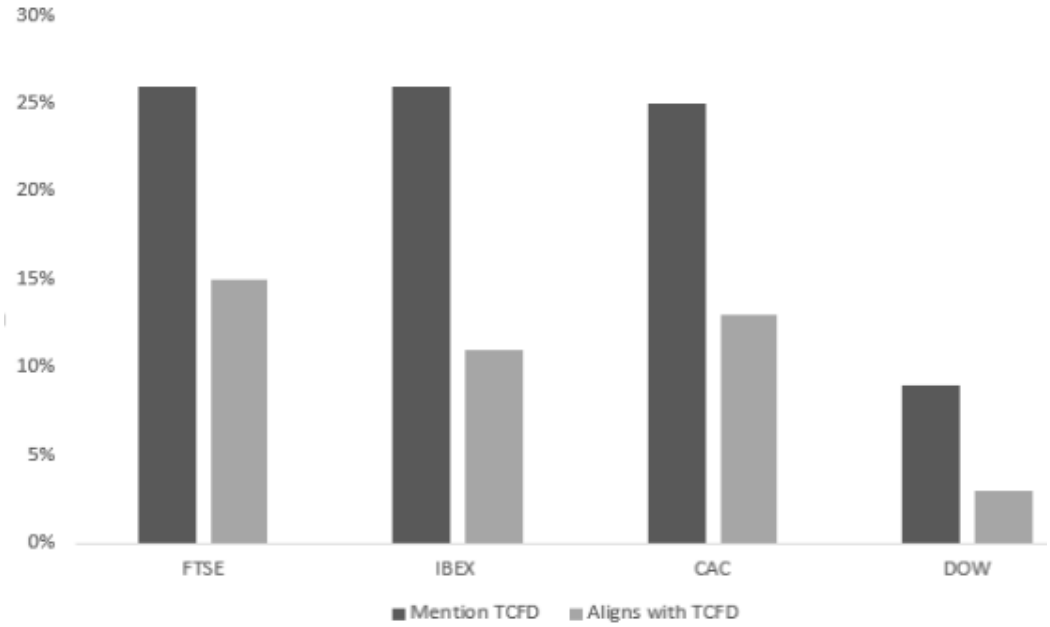
By comparing these three stages, Schoenmaker (2017) concludes that the majority of firms are still dragging their feet at the first stage (i.e., Sustainable finance 1.0), due essentially to entrenched and widespread short-termism practices and lack of collective support for green investments. Such a behavior may due to the fact that the protection of the environment, as part of corporate social responsibility, is not always measurable and profitable as much as the financial markets would expect (Amaeshi, 2010).

The second important barrier to the deployment of a greener financial system is likely the fear of path-dependency effects. The path dependency phenomenon refers to the fear of locking-in effects by historical events (Arthur, 1989). Some investors might be willing to invest in long-term green projects. However, those projects generally generate returns on investment only in

the long-run and requires new technologies that may become outdated only a few years later, given the pace of technology progress. Hence, risk-averse investors may hesitate to lock their capital into projects that will generate financial returns only in the long-term, and which success depend on the evolution of technology. This time inconsistency (i.e., the willingness to invest in long-term infrastructure projects and the fear of locking one's capital for a long period of time without a guarantee of an acceptable level of return) could ultimately prevent investors from draining out large amounts of capital for low-carbon infrastructures. In other words, it means that profit-seeking investors are expecting green investments to be not only ecological but also economical.

To this must be added the fact that, since the 2007-09 financial crisis, the implementation of macroprudential policies by central banks has put the banking sector in a position where it is no longer willing to take too much risks. Consequently, perceived risk remains higher for green investment, leading financial markets to continue privileging short-term returns over long-term opportunities. Nonetheless, there is growing evidence that a neutral-carbon economy can be both financially and economically viable (Rockström et al., 2017).

Finally, it is likely that the lack of common taxonomy for green finance and the limited awareness among investors regarding the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD) about climate risk reporting, are also undermining global efforts towards greening the financial system. According to HSBC (2018), only 8% of the world's biggest companies and 10% of investors are aware of the TCFD's recommendations. Although an increasing number of Stock-exchange-listed companies explicitly mention the TCFD's recommendations in their reports, merely 10% of them accordingly align their practices. For instance, 26% of the FTSE 100 constituents mention the TCFD's recommendations, while only 15% are aligned



Source: Ecoact (2018). The financial sector is timorously integrating the TCFD's recommendations on climate-related risk disclosures.
FIGURE 5.3: The level of integration of the TCFD recommendations by selected Stock Exchanges.

with them (Ecoact, 2018). For the Dow Jones' constituents, these figures fall to 10% and less than 5% respectively (see Figure 5.3). Central banks could play a proactive role in spurring the adoption of these recommendations by financial institutions.

5.5 Alternative monetary policies for the low carbon transition

In the previous sections I tried to demonstrate that climate change has become too important for monetary policy and the global economy to be neglected by central banks. The nexus between climate stability and financial stability in the long-run suggests that central banks could play a role in tackling climate change without overburdening their mandates nor giving up their independence (Volz, 2017).

It is possible to build on two recent developments in central banking to argue that central banks are best-positioned to lead the transition towards a low-carbon society. First, in bad and uncertain times such as those yielded by climate change, only governments and central banks can create an environment that reduces uncertainty for investors and enables markets to allocate resources to priority sectors. Second, one of the major forces of central banks is that financial markets always react to the decisions they take or are expected to take (King, 2017). This gives them a natural power to influence to the behavior of market players.

While there are several ways central banks could encourage the development of a green financial system (Volz, 2017), this essay focuses only on three instruments or policy measures: the green permanent lending facilities to priority sectors, the introduction of an '*environmental fine*', and strategic cooperation with non-banking financial institutions, such as institutional investors.

The green permanent lending facility scheme consists for central banks to act as '*pawnbrokers for all priority sectors*' (PFAPS). The PFAPS framework is a powerful tool since it represents a risk-free borrowing scheme for the banking sector. By allowing banks to always have access to central bank money for priority sectors at lower interest rates, central banks could create a green investment multiplier, since borrowing for green investments will become cheaper compared to borrowing for brown investments.

The aim of the green permanent lending facility scheme is to ensure that commercial banks- which controls between 85% and 97% of money supply (Mcleay et al., 2015) - will always have access to central bank money at a lower-interest rate to meet the demand for green investment in the priority sectors. Those sectors should be specified and designated as key for the low carbon transition by the central government, who can also provide guarantees for investors to ensure them that they could always get their money back

in case of default of payment.

Although priority sectors may differ from one country to another, there are some economic sectors that are particularly sensitive to climate risks. These include, but are not limited to, sectors such as electricity, transportation, agriculture, and manufacturing, which have been historically central to growth but now appeared highly vulnerable to climate policies.

An aggressive transition to a low carbon society as suggested by Rockström et al. (2017) could lead to significant asset losses in those sectors. As global temperature increases, hard national or international climate policies aimed at limiting global warming will lead to many stranded assets in these strategic sectors, especially in western countries (Mercer, 2015, Caldecot et al. 2013, Schoenmaker and Tilburg, 2016, Battiston et al. 2017; Cahen-Fourot et al. 2019).

Paradoxically, however, around 62% of ECB conventional corporate bond purchases still take place in sectors such as manufacturing, electricity and gas production, which are responsible for 58.5% of the Euro zone greenhouse gas emissions (Matikainen et al. 2017). Since governments and central banks control only 10% of money supply in modern market economies (King, 2017), ensuring that credits flow to low-carbon projects, is nothing but laudable, especially when the short-term yield curve is flat as is actually the case in most advanced economies. Doing so does not necessarily cause central banks to depart from their role of ensuring price stability.

Next, central could also introduce an *environmental fine*, a punitive instrument aimed at deterring financial institutions, especially banks, from investing in carbon-intensive projects. The aim of the *environmental fine* is to ensure that banks set aside enough capital to deal with climate risks. However, the implementation of such an instrument requires central banks to conduct climate-stress testings in order to identify which banks are holding massive carbon-intensive assets in their portfolios (Battiston et al., 2017). Based on

the results of these stress tests, central banks could then levy an *environmental fine* on banks whose exposure to carbon risk is above 10% of the total of their portfolio. The rate of the fine should be set independently by the central bank, based on the IPCC's greenhouse gas reduction targets. The proceeds of that fine should be held in a particular fee-free and interest-free account at the central bank. The *environmental fine* could be a means of implementing the '*brown penalizing factor*' suggested by De Galhau (2018), in the sense that it encourages carbon divestment from financial institutions. More interestingly, the banks could ask central bank to use the proceeds of their fine to finance the priority sectors set by the government, instead of saving them in an interest-free account. A similar measure to the environmental fine is being tested in China, where about 9% of banks' total loans must be allocated to green projects. Since there is a lack of awareness about the TCFD recommendation, as previously argued, it seems also important that central banks act as «a watchdog» to ensure the mainstreaming of those recommendations into banks' investment decision-making.

Finally, central banks could scale up green finance supply by engaging not only with banks but also with institutional investors, which investment horizon matches the life cycles of most low-carbon projects. Over recent years, institutional investors have grown in size and became relevant for financial stability (Lescrauwaet, 2016). Due to the low-interest-rate environment that prevails in most advanced economies since the 2007-09 financial crisis, many institutional investors are increasingly looking for new investment opportunities in order to secure their revenue streams and reduce the volatility of their portfolios (Banga, 2019). For this triangular cooperation (central banks, banks, and institutional investors) to function , central banks may need to open the doors of their Network for Greening the Financial System to other financial institutions such as pension funds and insurances companies. Such a cooperation has the advantage of both boosting the green bond market and

aligning the whole financial industry with the Paris Agreement. Furthermore, this triangular cooperation allows central banks to avoid direct green bond purchase from the government. Banks and institutional investors could buy green bonds issued by the government and use these bonds as collateral when they borrow from central banks. Doing so enables the development of the green bond market and ensures that the financial sector is resilient to climate risks.

Since central banks across the world have different frameworks and different objectives, a major limitation of this essay is that its recommendations should not be taken as ready-to-wear instruments. Each central banks should adjust these recommendations according to its own reality.

5.6 Conclusion

Climate change has made extreme weather events more frequent and more relevant for financial stability. As guardians of financial stability, central banks are expected to play a proactive role in addressing the challenges posed by climate risks. This begins with the recognition that there is a need for a broader central bank mandate, compatible with the sustainable development agenda. The viability of our financial system requires that long-term opportunities be put over short-term profit maximization. More generally, climate change risk management should go beyond ideology and strive to transpose scientific climate risk modeling into financial models that enable the incorporation of sustainability into investment decision-making.

The barriers to a greener financial system range from large spread short-term practices and lack of green financial instruments to radical uncertainties surrounding the profitability of low-carbon investments. The fear of locking-in effects, and insufficient awareness about the TCFD recommendations are also dampening the development of green finance.

However, such barriers should not be a motive for inertia. Lessons learned from climate change suggest that, from investment perspectives, it would be a mistake to continue assuming that the '*future will continue to mirror the past*'. In the context of increased climate risks, past performance does not necessarily reflect what future performance will be. Central banks have three specific roles to play in disseminating this central message.

First, central banks could act as a pawnbroker for all priority sectors, so that banks could always have access to central bank money to meet the demand for low-carbon investments. Second, central banks could also impose an environmental fine on banks' portfolios so as to encourage carbon divestment. This measure ensures that banks set aside enough capital to deal with the unavoidable transition risk of climate change, should governments decide to speed up the transition towards a low-carbon economy. Finally, central banks should require financial institutions to integrate the TCFD recommendations into their investment decision-making.

By failing to address climate change, the financial system is preparing to fail from climate risks. It is worth noting, however, that the low-carbon economy cannot be achieved with private capital only. Far from being a market good for which the law of supply and demand suffices to close the loop, our environment is a common good and must be treated as such, both at the national and international levels. Governments should lead by example by showing an unprecedented strong political commitment towards achieving a neutral carbon society.

Chapter 6

Global conclusion

We may all have doubts about the timing of climate change. However, we can no longer afford to dismiss the idea that it is a reality. The growing economic, social, political, and environmental impacts attributable to climate change are evidence that it is time for us to scale up innovative climate solutions.

Arguably, a key component of such solutions is climate finance. Without a significant increase of finance for and beyond adaptation and mitigation purposes, climate change is likely to become a major threat to firms' investment decision-making and the structural transformation prospects of many developing nations.

The central objective of this thesis, which is structured in five essays, was to contribute to the scientific debates on the development and scale up of innovative financial solutions for addressing climate change, while contributing to achieving the 2030 Agenda.

Through theoretical and empirical analyzes, this thesis provides policy makers as well as investors with new insights about climate finance, climate risks, and innovative climate finance instruments, such as green bonds.

As an entry point into the analysis, the first essay took stock of the relationship between climate finance and the 2030 sustainable development agenda, and showed that climate finance can effectively contribute to achieving a sustainable structural transformation in developing countries. While there is a need to significantly increase adaptation and mitigation finance

for developing countries, it is also important to rethink climate finance as a possible driver of sustainable structural transformation through and beyond adaptation and mitigation projects.

The second essay is more than just a mere climate risk quantification exercise. It is a proof that our financial system is still heavily dependant on carbon-intensive activities, and therefore vulnerable to climate mitigation policies, such as carbon pricing. As climate impacts worsen, governments are expected to implement policies aimed at harnessing the transition towards a low-carbon economy. Such policies would create winners and losers. This essay therefore highlights a paradox: the risk of rising lobbying against climate mitigation policies in a time of relentless calls for urgent climate actions.

The third and fourth essays investigated the emerging green bond bond market and showed that green bonds are a window of opportunity for both policy makers and investors to mobilize additional investment for low-carbon infrastructures, while reducing exposure to climate risks.

The fifth and last essay in this dissertation provided new and provocative insights about the role of central banks in tackling climate change without giving up on their objective of price stability. This essay identified the barriers to greening the financial system and showed how central banks, which has become a building block of modern economies, can contribute to removing those barriers and steering the financial sector towards sustainable and responsible investing.

In light of these results, five major policy options can be put forward.

First, the climate finance- structural transformation nexus requires policy makers to develop a new political leadership that enable the development of a new climate mindset, and sustains the belief that sustainable development and structural transformation can go hand in hand. This, however, implies a radical shift from conventional beliefs that has for a long time opposed development process and environment protection. Harnessing such a new

climate mindset can only be done by identifying potential buoyant sectors in terms structural transformation, allocating enough financial resources to those sectors, and encouraging research and development on clean technological innovations.

Second, the heavily dependence of the current financial system on carbon-intensive assets suggests that climate risk awareness among investors is a prerequisite to any effort aimed at harnessing the transition towards a deep decarbonization. A simple way to increase climate risk awareness among investors is to encourage transparency in climate risk disclosure, use stress-testing methods to assess exposure of any investment plan to climate risks before implementation, and appoint corporate managers with long term vision and effective knowledge of the UN's sustainable development goals.

Third, although the green bond market appears as a window of opportunity to tapping into private capital for the low-carbon transition, it is still suffers from major barriers and weaknesses that need to be addressed. Fighting against greenwashing through transparency in the use of green bond proceeds is a necessary condition for the market to grow. In the same vein, the development of appropriate institutional frameworks for green bond issuance and the definition of common taxonomy for green bond issuance cannot but foster the deployment of a low-carbon society.

Finally, for central banks to remain credible, independent, and legitimate institutions in modern market economies, they would have to diffuse sustainability into their own activities. It is a paradigm shift, which requires central banks to be more flexible in their inflation targets. By incorporating climate change targets into monetary policy, central banks could not only increase the effectiveness of their monetary instruments, but also contribute to addressing the world's most pressing challenges. In a nutshell, climate change has become too important to be neglected by central banks.

If all those policy recommendations are properly addressed, we could still have the possibility to transform climate change into a climate chance.

Chapter 7

Appendices

Table A1: Rating Codes

Moody's	S&P	Fitch	Rating code assigned
Aaa	AAA	AAA	15
Aa1	AA+	AA+	14
Aa2	AA	AA	13
Aa3	AA−	AA−	12
A1	A+	A+	11
A2	A	A	10
A3	A−	A−	9
Baa1	BBB+	BBB+	8
Baa2	BBB	BBB	7
Baa3	BBB−	BBB−	6
Ba1	BB+	BB+	5
Ba2	BB	BB	4
Ba3	BB−	BB−	3
B1	B+	B+	2
B2	B	B	1

Table A2: Diagnostic tests

Panel	VIF test (mean value)	Heteroskedasticity		Cross-section dependence	Autocorrelation (AR1)	Moving average autocorrelation
		Modified Wald test	Breusch-Pagan/ Cook-Weisberg test	Pesaran (2004) test	Wooldridge test	Cumby and Huizinga (C-H, 1990, 1992)
All bonds	4.49	0.000	0.000	0.000	0.000	000 (lag 1)
Chinese yuan	2.29	0.000	0.000	0.000	0.000	0.045 (lag 1)
Euro	3.17	0.000	0.000	0.000	0.000	0.001 (lag 3)
Japanese yen	9.11	0.000	0.000	0.000	0.000	0.036 (lag 1)
Swedish krona	9.56	0.000	0.000	0.000	0.000	0.001 (lag 1)
US dollar	7.68	0.000	0.000	0.000	0.000	0.008 (lag 2)
Shorter maturity	4.31	0.000	0.000	0.000	0.016	0.177 (lag 1)
Medium maturity	4.87	0.000	0.000	0.000	0.000	0.000 (lag 1)
Longer maturity	5.42	0.000	0.000	0.000	0.000	0.024 (lag 2)

Table A3 Correlation matrix

	spread	coupon	tenor	order	call	put	exlist	cotype	grnte	*CNY*	*EURO*
spread	1.00										
coupon	0.54	1.00									
tenor	0.14	0.32	1.00								
order	0.41	0.33	0.18	1.00							
call	-0.06	0.06	0.26	-0.19	1.00						
put	-0.02	0.16	-0.07	-0.09	-0.08	1.00					
exlist	-0.45	-0.41	-0.31	-0.64	0.15	0.09	1.00				
cotype	0.20	0.19	0.09	0.32	-0.05	0.06	-0.30	1.00			
grnte	-0.01	0.15	0.00	-0.17	0.25	0.00	0.10	0.22	1.00		
CNY	-0.07	0.27	-0.24	-0.16	-0.16	0.52	0.18	-0.16	-0.06	1.00	
EURO	-0.25	-0.47	0.02	-0.29	0.21	-0.12	0.33	-0.21	0.00	-0.22	1.00
YEN	0.21	0.06	-0.05	0.05	-0.08	-0.03	-0.32	0.04	-0.07	-0.06	-0.12
KRONA	-0.21	-0.46	-0.31	-0.12	-0.21	-0.08	0.23	-0.09	-0.09	-0.16	-0.30
USD	0.37	0.61	0.39	0.46	0.09	-0.14	-0.49	0.36	0.13	-0.27	-0.51
Domestic	0.09	0.05	-0.07	0.33	-0.30	0.12	-0.24	0.04	-0.34	0.27	-0.32
Global	-0.06	0.07	0.11	-0.10	0.26	-0.04	0.11	0.02	0.14	-0.07	-0.13
Eurobond	-0.09	-0.14	-0.03	-0.26	0.15	-0.12	0.22	-0.03	0.26	-0.24	0.40
DimSum-Panda-Samurai	-0.03	-0.01	0.01	-0.05	-0.06	0.10	-0.07	0.04	-0.03	0.05	-0.08
Other foreign	0.06	0.16	0.14	-0.09	0.19	-0.03	0.01	-0.08	0.13	-0.06	0.02
Fixed	0.11	0.31	0.25	0.14	0.10	0.08	-0.13	0.04	0.02	0.14	0.20

Table A3 continued

	YEN	*KRONA*	*USD*	*Domestic*	*Global*	*Eurobond*	*DimSum-Panda-Samurai*	*Other Foreign*	*Fixed*	*Floating*
YEN	1.00									
KRONA	-0.09	1.00								
USD	-0.14	-0.37	1.00							
Domestic	-0.14	0.24	-0.01	1.00						
Global	-0.04	-0.10	0.26	-0.25	1.00					
Eurobond	0.13	-0.17	-0.14	-0.83	-0.14	1.00				
DimSum-Panda-Samurai	0.16	-0.06	0.03	-0.15	-0.03	-0.08	1.00			
Other foreign	-0.03	-0.07	0.09	-0.21	-0.04	-0.12	-0.02	1.00		
Fixed	0.01	-0.64	0.23	-0.11	0.07	0.06	0.05	0.04	1.00	
Floating	-0.06	0.68	-0.25	0.13	-0.06	-0.08	-0.05	-0.04	-0.96	1.00
Range	0.33	-0.03	-0.05	-0.07	-0.01	0.09	-0.01	-0.01	-0.15	-0.02
Variable	-0.02	-0.04	0.10	-0.01	-0.02	0.03	-0.01	-0.02	-0.21	-0.03
Annual	-0.16	-0.08	-0.70	-0.04	-0.19	0.18	-0.07	-0.12	0.38	-0.36
Quarterly	-0.07	0.67	-0.23	0.12	-0.06	-0.08	-0.05	0.00	-0.94	0.98
Semi-annually	0.22	-0.39	0.87	-0.04	0.23	-0.12	0.10	0.12	0.28	-0.33
Bonds	0.00	0.35	-0.50	0.45	-0.10	-0.40	0.02	-0.09	-0.21	0.23
Notes	0.00	-0.35	0.50	-0.45	0.10	0.40	-0.02	0.09	0.21	-0.23
Debenture	0.00	-0.01	0.02	0.01	0.00	-0.01	0.00	0.00	0.01	-0.01
Financial	0.10	-0.19	-0.16	-0.46	-0.05	0.45	0.07	0.10	0.05	-0.08
Manufacturing	-0.02	0.01	0.00	0.01	0.18	-0.08	-0.01	-0.02	-0.02	0.03
Real estate	-0.03	0.68	-0.27	0.30	-0.07	-0.25	-0.05	-0.07	-0.45	0.48
Utilities	-0.09	-0.30	0.44	0.36	0.00	-0.33	-0.02	-0.11	0.28	-0.26
Transport	0.07	0.03	-0.06	0.03	-0.02	-0.01	-0.01	-0.01	-0.02	0.02
Industrial	0.00	-0.05	-0.06	-0.02	-0.02	0.00	-0.01	0.10	0.04	-0.04
Food processing	-0.02	-0.04	-0.07	-0.10	-0.02	0.03	-0.01	0.23	0.04	-0.03
Healthcare	-0.01	-0.03	0.01	0.05	-0.01	-0.04	-0.01	-0.01	0.03	-0.02
Others	0.01	0.06	-0.10	-0.15	0.13	0.10	-0.02	0.01	-0.04	0.04

Table A3 continued

	spread	coupon	tenor	order	call	put	exlist	cotype	grnte	*CNY*	*EURO*
Floating	-0.18	-0.38	-0.26	-0.13	-0.15	-0.07	0.19	-0.06	-0.07	-0.14	-0.19
Range	0.33	0.14	-0.03	-0.02	-0.03	-0.01	-0.12	0.04	-0.02	-0.02	-0.04
Variable	0.04	0.16	0.05	-0.05	0.19	-0.02	-0.15	0.05	0.22	-0.03	-0.04
Quarterly	-0.17	-0.36	-0.22	-0.13	-0.15	-0.07	0.20	-0.08	-0.08	-0.14	-0.19
Semi-annually	0.48	0.62	0.35	0.46	0.12	-0.15	-0.61	0.37	0.13	-0.28	-0.49
Bonds	-0.27	-0.33	-0.22	-0.25	-0.09	0.23	0.30	-0.22	-0.18	0.40	-0.04
Notes	0.27	0.33	0.22	0.25	0.09	-0.23	-0.30	0.22	0.18	-0.40	0.04
Debenture	-0.01	0.01	0.01	-0.01	0.04	0.00	0.01	0.01	-0.01	-0.01	-0.01
Financial	-0.14	-0.08	-0.20	-0.34	0.11	-0.08	0.25	-0.06	0.29	0.14	0.20
Manufacturing	-0.05	0.02	-0.02	-0.05	0.06	0.18	0.06	-0.07	-0.04	0.11	-0.07
Real estate	-0.15	-0.34	-0.22	-0.06	-0.07	-0.06	0.18	-0.06	-0.09	-0.13	-0.19
Utilities	0.29	0.33	0.33	0.51	-0.05	0.06	-0.47	0.25	-0.25	-0.10	-0.12
Transport	-0.03	-0.05	-0.01	-0.04	-0.03	0.07	0.00	0.02	-0.02	0.03	-0.01
Industrial	0.11	0.14	-0.08	-0.05	0.06	0.01	0.04	-0.07	0.12	0.11	0.03
Food processing	0.02	0.00	-0.01	-0.05	-0.04	-0.02	0.04	-0.12	-0.03	-0.03	0.13
Healthcare	-0.01	0.04	0.00	-0.03	0.04	0.19	0.03	-0.03	0.06	0.09	-0.04
Others	-0.09	-0.08	0.11	-0.13	-0.06	-0.02	0.09	-0.19	-0.01	-0.05	0.08

Table A3 continued

	Real estate	*Utilities*	*Transport*	*Industrial*	*Food processing*	*Healthcare*	*Others*
Real Estate	1.00						
Utilities	-0.27	1.00					
Transport	-0.03	-0.05	1.00				
Industrial	-0.04	-0.07	-0.01	1.00			
Food processing	-0.03	-0.06	-0.01	-0.01	1.00		
Healthcare	-0.02	-0.04	0.00	-0.01	-0.01	1.00	
Others	-0.10	-0.19	-0.02	-0.03	-0.02	-0.02	1.00

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