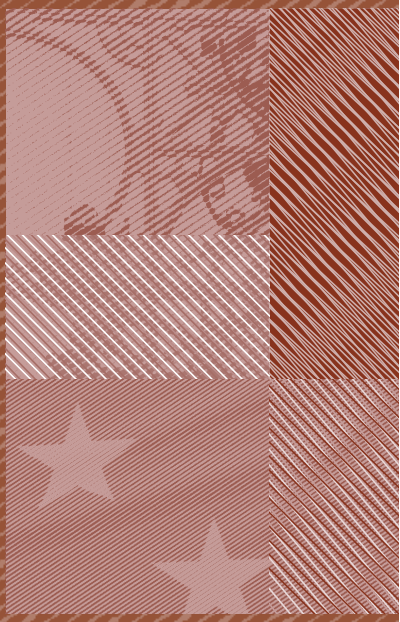
FINANCIAL INNOVATION FOR A SUSTAINABLE ECONOMY

2019

Andrés Alonso and José Manuel Marqués



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Abstract

Climate change and its management and mitigation are unquestionably among the main risks facing our society in the coming decades. The financial sector plays a key role in this challenge, firstly because of its exposure and the consequent capital shocks if this risk crystallises, and secondly because it has the task of financing the investments needed to transform our economy into a sustainable one. This article reviews various initiatives under way in the private financial sector to introduce the variable "sustainability" into its decision-making process in order to achieve a balance sheet with a smaller carbon footprint *(transformation* of stock) and to develop a business strategy aligned with responsible investment principles and international standards *(transformation* of flow). We analyse the innovations emerging along the path to *sustainable finance,* looking particularly at: 1) *new suppliers and services* in the market, 2) the creation of *sustainability-linked financial instruments,* 3) the adaptation of financial risk management policies, and 4) the interaction of *technological progress* with climate change.

Keywords: *fintech,* sustainable development goals, climate change, sustainability, green bonds, innovation, artificial intelligence.

JEL classification: Q54, Q55, Q56.

Resumen

El cambio climático, su gestión y mitigación, constituye sin duda uno de los elementos de riesgo más importantes que afrontará nuestra sociedad en las próximas décadas. El sector financiero desempeña un papel fundamental en este reto, tanto por su exposición y las consiguientes implicaciones patrimoniales que pueden derivarse de la materialización de este riesgo como por su labor canalizando las inversiones necesarias para transformar nuestra economía en un modelo sostenible. En este artículo se revisan distintas iniciativas que están teniendo lugar en el sector financiero privado en el proceso de introducción de la variable «sostenibilidad» en la toma de decisiones, con el objetivo tanto de lograr un balance con una menor huella de carbono *(transformación del* stock) como de desarrollar una estrategia de negocio alineada con unos principios responsables acordes con los compromisos internacionales *(transformación del* flujo). Se analizan las innovaciones que están surgiendo en el camino hacia unas *finanzas sostenibles* en relación con 1) la aparición de *nuevos proveedores y servicios* en los mercados, 2) la creación de *nuevos productos* financieros con criterios de sostenibilidad, 3) la adaptación de la *política de gestión de riesgos* financieros, y 4) las interacciones entre los *avances tecnológicos* y el cambio climático.

Palabras claves: *fintech,* principios de desarrollo sostenible, cambio climático, sostenibilidad, bonos verdes, innovación, inteligencia artificial.

Códigos JEL: Q54, Q55, Q56.

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Introduction

The management of *climate change* risk is being paid increasing attention by government authorities, economic agents and the academic world. This attention is not surprising in view of the impact of the transformations required to comply with the Sustainable Development Goals (SDGs) described in the Paris Agreement [UNFCCC (2015)], along with the short time period for implementing these transformations and the serious consequences, in economic and social terms, of failing to mitigate climate change. It is thus not surprising that the European Commission has given great importance to this matter and has entrusted the climate action portfolio (European Green Deal) to one of its three vice presidents.

Some studies, such as that of Climate Action Tracker, estimate that if the current rate of carbon dioxide emissions continues, the *temperature will rise* by an average of *nearly 3.3°C* by the end of the century. Examination of the current policy commitments (National Determined Contributions, hereafter NDCs) indicates that they would only manage to trim this rise to 3°C in 2100 with respect to pre-industrial levels [CAT (2018)]. In this respect, there is still much to do and we have to be more ambitious. Indeed, scientific studies [Rafteri *et al.* (2017)] put at 1% the probability of achieving the target rate of 1.5°C set in Paris. Economically, if the current policies do not change, *the global temperature rise would end up having significant effects on world GDP,* by as much as 10% in 2050 according to the International Renewable Energy Agency [IRENA (2019)], or, expressed in per capita terms, 7.22%, according to a recent academic study [Kahn *et al.* (2019)]. In addition, it is estimated that in 2100 the volume of stranded assets (e.g. those relating to fossil fuel mining activities incompatible with the current commitment to sustainability) would be up to 3% of the current capital stock [OECD (2016)]. This shows the need to push ahead with the transformations needed to safeguard economic growth [Lafakis *et al.* (2019)] and the prosperity of future generations [Stern *et al.* (2019)].

The public authorities have already recognised the importance of this challenge.[1] Among other initiatives, this year has seen the signature of the so-called Coalition of *Finance Ministers for Climate Action* [CAPE (2019)], whereby nearly 20 countries undertake to adopt the Helsinki Principles, a statement of best practices for sustainability in macroeconomic and fiscal policy and public financial management. All this lays the foundations for a new economic reality, through an adaptation of the *regulatory and supervisory framework* so as to integrate explicitly the various physical and transition risks associated with climate change [Marqués and Romo (2018) and González and Núñez (2019)].

However, *completing these changes requires a certain amount of time,* since they are of a markedly global nature and require a high degree of coordination at international level.[2] Additionally, it should not be overlooked that the action that can be taken by institutions such

1 See, for example, FSR (2019) for a review of activity relating to the sustainability of the Central Bank of France, and DNB (2018) for an explanation of stress test preparations for the energy transition in the Netherlands.

2 As demonstrated, for example, in the case of the Task Force on Climate-related Financial Disclosures [TCFD (2017 and 2019)], coordinated within the framework of the Financial Stability Board (FSB).

as central banks *is limited by the mandates assigned* to them to fulfil their main objectives, such as controlling inflation, financial stability and the exchange rate [Villeroy (2019) and Lagarde (2019)].

In any event, the progress of the measures taken by regulators and supervisors should not be allowed to delay or prevent *the response of private financial institutions* when it comes to embracing climate change as one more factor of financial risk. Hence, although its measurement may be complex due to the absence of detailed information, this risk must be managed, as is the case with, for example, operational risk. Unlike other transformations in the financial markets (such as, for example, the lessons of the 2008 financial crisis), now the l*ength of time available for acting is limited* and barely negotiable, and it is not realistic to consider extending the time horizon for implementing the regulatory measures.

This article analyses the transformation being undergone by the financial sector as it introduces the variable "sustainability" into risk management in order to achieve a balance sheet with a smaller carbon footprint *(transformation* of stock) and to develop a business strategy aligned with responsible investment principles and international standards *(transformation* of flow). We analyse the innovations emerging along the path to *sustainable finance,* looking particularly at: 1) *new suppliers and services* in the market, 2) the creation of *sustainability-linked financial instruments,* 3) the adaptation of financial risk management policies, and 4) the interaction of *technological progress* with climate change.

1 New suppliers and services

The adoption by the financial world of sustainability as one of its objectives has led to the appearance of new service providers or agents in the markets. The starting point of this process of transformation is the quest for higher transparency, in which the main objective is to improve the access of market participants to information on the impact of climate change [TCFD (2017)].

Looking first at changes in the primary market,[3] an additional agent called a "verifier" is responsible for ensuring that the issuer meets its environmental commitments. This "verifier" role is now well established, since, according to CBI (2018c), 98% of the green bonds issued in Europe up to June 2018 had at least one external verifier, and recently the European Commission [TEG (2019b)] confirmed that, to obtain the EU Green Bond label, it will be compulsory to have at least one external verifier in order to validate the credibility of the issuer, both ex ante (for example, assuring compliance with certain standards or sustainable principles)[4] and ex post (to document the use of the funds raised in green investments or the climate impact of the new investments made by the green issuer).[5]

Several types of verification providers are thus distinguished [ICMA (2018a)], including most notably the comprehensive service known as "Second Party Opinion", which consists of a review of the issuer's sustainability commitment, or the individual external verification, which

TYPES OF VERFICIATION SERVICE

TABLE 1

Type of service	Description	Examples of providers
Second Party Opinion (SPO)	Normally involves an assessment of the adequacy of the framework according to external principles or standards. Account is taken of the firm's strategic policy, objectives and processes relating to the projects to be financed (use of proceeds).	Vigeo-Eiris, Sustainalytics, ISS-oekom, Imug, CICERO, Robecoo, MSCI, Dow Jones.
External verification	Usually focuses more on details, reviewing compliance with internal and external standards (e.g. an official certification), and the sustainability of the assets to be financed. Sometimes includes monitoring of the use of funds and of reporting quality.	Deloitte, KPMG, PwC, EY.
Rating	May assess how closely the issuer's framework is aligned with certain criteria set out in an in-house scoring methodology. The result is independent of the traditional rating.	Moodys, S&P, Fitch, Beyond Ratings.
Certification	Commitment to official principles or general standards determined by an independent third party. Normally verified externally.	ISO, ICMA, DNV-GL, Bureau Veritas, TÜV, CBI.

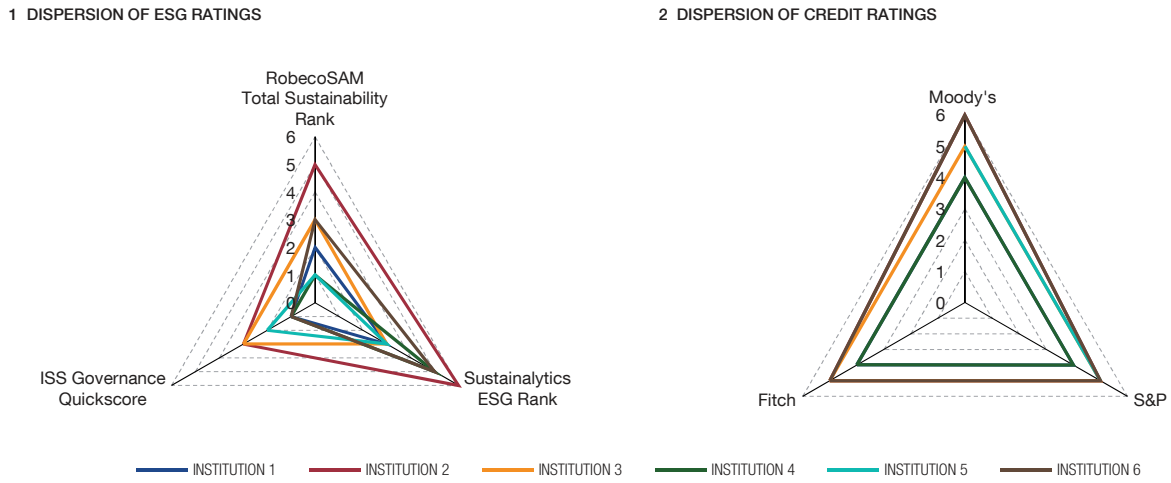
SOURCE: Devised by the authors using ICMA and CBI data.

3 This article focuses on the debt markets as the key mechanism for raising the funds needed to comply with the Sustainable Development Goals [UNCTAD (2014)].

4 There are various standards for documentarily evidencing the commitment of issuers, such as the Green Bond Principles (GBPs) of ICMA, the Climate Bond Standard (CBS) of CBI, or the EU Green Bond Standards of the EC. The ISO international standards refer to this service as "validation".

5 The provision of verification services entails an additional cost in the process of debt issuance. To prevent this from hindering the development of the green bond market, various types of aid have been proposed to finance the extra cost borne by issuers. The European Commission [TEG (2019a)] estimates this cost at around €40,000. The current proposals to subsidise this cost include most notably temporary measures in jurisdictions such as China, Hong Kong or Singapore. On the other hand, studies such as Bachelet *et al.* (2018) find that external verifiers – particularly those using certification – reduce the financing cost for green issuers.

DIFFERENCES BETWEEN CREDIT AND ESG RATINGS (a) CHART 1



SOURCE: Devised by the authors from data of Bloomberg (August 2019).

a Ratings normalised using deciles (best rating = 100).

is performed issue-by-issue, or the new Environmental, Social and Governance (ESG) ratings, which include an assessment of matters relating to climate change, corporate governance and social commitments. In the latter, one of the main challenges of this new rating process is to achieve simple, uniform metrics that facilitate the assessment of risks that are difficult to quantify or are not even directly observable. In this respect, it is not surprising that, unlike in credit ratings, these indicators enjoy less consensus among the various sources (see Box 1).

DISPERSION OF ESG RATINGS BOX 1

The complexity of the problem facing ESG rating agencies is reflected in the current wide dispersion of the environmental and social ratings available for each issuer. Comparison of the ratings provided by 3 ESG rating companies (RobecoSAM, Sustainalytics and ISS) for six Spanish financial institutions shows significant differences in their sustainability assessments. This contrasts with the homogeneity of the credit ratings provided by the three main credit rating agencies for these same financial institutions (see Chart 1).[1]

1 For this analysis it was decided to normalise all the ESG ratings by the use of deciles, the lower levels denoting a better rating (first decile or best rated 10% of the sample). For example, in the case of RobecoSAM and Sustainalytics, the gross ranking has a base of 100, with higher values denoting lower ESG risk. Thus a RobecoSAM rating of 86 for BBVA corresponds to decile 2 (i.e. it lies in the upper 20% of the best firms). By contrast, ISS expresses the rating directly on a relative scale from 1-10, so these ratings are rescaled following the same process. In the case of credit ratings, the scales of S&P/Fitch and Moody's were expressed on a uniform basis using their equivalences, and subsequently the ratings were normalised on the basis of deciles using a total scale of 20 notches.

Moving on to changes in the secondary market, a new feature is the emergence of sustainable benchmarks for the securities of low carbon emitting companies which enable the performance of their shares and debt to be monitored from the standpoint of sustainability.[6] These benchmarks are essential, mainly to foster passive management strategies among investors, facilitating the proliferation of trading portfolios based on principles of responsible investment.

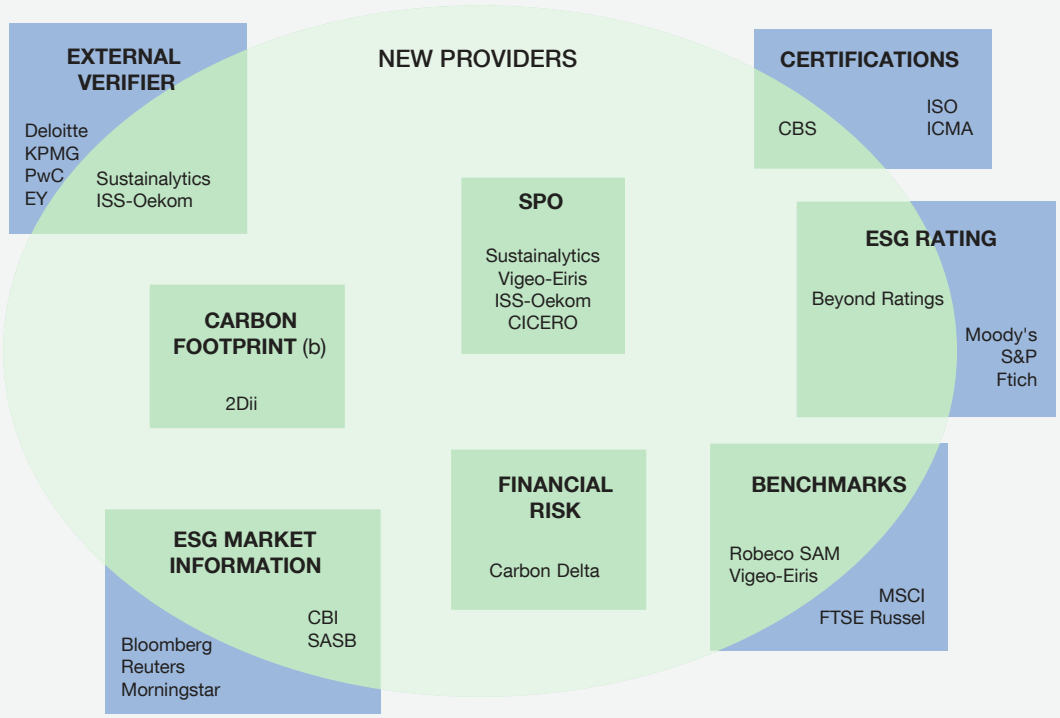
The new financial services relating to the sustainability sector are provided by a mix of traditional suppliers and new agents with a certain fintech profile [CBI (2018c)]. This *new business ecosystem* (see Box 2) is populated by large audit firms acting as external verifiers, while new specialised participants are emerging (e.g. ISS-Oekom or Sustainalytics), and by the main credit rating agencies, which participate in the area of ESG assessments. Also to be found are traditional financial market providers offering new indices, such as, for example, the MSCI ACWI Sustainable Impact Index, from MSCI, or the FTSE4GOOD, from FTSE Russell, which compete with new participants such as RobecoSAM or Vigeo-Eiris. In the same line, financial information platforms such as Bloomberg or Reuters have included ESG data in the analytical profile of companies, and firms such as Morningstar have included sustainability criteria in their classification of investment funds.

6 Emulating private initiatives, recently the European Commission [TEG (2019c)] proposed methodologies for two low-carbon benchmarks: a general one known as the EU Climate Transition Benchmark (CTB), and another which is more ambitious regarding the reduction of greenhouse gases (GHGs), known as the EU Paris-Aligned Benchmark (PAB).

The path to *sustainable finance* has brought a far-reaching transformation in the agencies which provide ratings or certifications. This process has given rise to new specialised firms such as Carbon Delta[1] or 2Dii, and traditional providers have incorporated sustainability-related factors into their traditional risk analyses.

1 In September 2019 the company MSCI announced it had acquired Carbon Delta.

Figure 1
SUSTAINABLE FINANCIAL SERVICE PROVIDERS (a)



SOURCE: Devised by the authors.

a Non-exhaustive list of providers.
b There are various methodologies for measuring the carbon footprint, including most notably PACTA (developed by 2Dii in collaboration with ING) and PCAF (consortium of international banks, such as Triodos Bank, to standardise carbon accounting).

2 New financial products

Probably the best-known innovation in sustainable finance is the green bond as a new financial instrument allowing the identification of an issuer's commitment to mitigating the risk of climate change. However, green bonds are not the only product which firms can use to establish their climate commitment credentials and offer investment assets with lower exposure to climate-change risk. In addition to green bonds, this section reviews briefly other wholesale and retail products or instruments for the financing of a sustainable economy.

2.1 Wholesale funding

Bonds and loans

The instrument most commonly used in the financing of sustainable investments is the so-called "green bond". Essentially, this fixed-income asset signifies a commitment by the issuer to inform of the sustainable use of the funds raised and the impact on climate change.

Nowadays different types of certifications or principles define the criteria for green bond issuance, including those developed by the Climate Bond Initiative (CBI) or the International Capital Market Association (ICMA). It should be noted in this respect that the fragmentation of these market criteria which has prevailed to date may soon be reduced by the recent publication of the standards just formulated by the European Commission [TEG (2019b)].[7] The conditions imposed for obtaining the new European Green Bond label reflect the decision to opt for *transparency* as the central pillar of the architecture of sustainable finance, seeking to validate in the eyes of investors the credibility and integrity of the issuers. The common taxonomy also standardises [TEG (2019d)] the *definitions* of activities considered sustainable, thus facilitating subsequent classification of what is deemed a green project or asset and what is not.[8] Additionally, issuers set out their sustainability strategy in a new document denoted "framework", which will accompany the traditional debt issuance programme. This "framework" increases the disclosure requirements for informing customers and investors through, inter alia, reporting on the use of funds and the impact of projects. All this must be compulsorily validated by the aforementioned new verifier.[9]

As a rapidly expanding market (see Chart 2),[10] most green issues are plain-vanilla structures (although, curiously, the first green bond issued was a structured instrument, as noted in Box 3), i.e. they consist of a fixed- or floating-interest rate coupon and a single repayment at maturity, in which the issuer's commitment to pay is the main support given to the investor.[11] However, financial innovation has led to the emergence of new, more exotic structures having

7 No further review of this proposal (call for feedback) is planned, so the June 2019 report may be considered final.
8 Also clarified are the options for the use of funds, including fixed assets, capital investments and R&D investment, as well as operating expenses dedicated to extend the residual life of certain green assets.
9 This is one of the key differences from private initiatives such as that of the ICMA, in which verification, albeit common practice, is voluntary.
10 Update of a chart published in BloombergNEF using data up to 2018.
11 Technically these are known as unsecured senior bonds (not backed by collateral).

to do with sustainability, such as, for example, Sukuk issues,[12] which comply with the Islamic principles of Shari law,[13] or perpetual bonds, hybrid instruments with features between equity and fixed income, such as the absence of a defined maturity and the establishment of optional early repayment calls for the issuer, normally in year five or seven of the life of the instrument [for further details, see CBI (2018a)].

THE FIRST GREEN BOND **BOX 3**

What is considered the *first green bond* was issued in 2007 by the European Investment Bank (EIB) under the name of Climate Awareness Bond (CAB). Curiously, this first bond was a structured note. Its yield was linked to the performance of an equity index, the recently created FTSE4GooD. In addition, the funds raised were committed for project finance in the field of renewable energy and energy efficiency. As a new feature, it included an option at maturity whereby the amount invested could be received in cash or used to withdraw from circulation an equivalent amount of carbon emission rights in the European emissions market (EU Emission Trading Scheme, ETS).

One of the latest market innovations, focused on the transformation of a current stock of non-green assets, is *transition bonds.*[14] This new asset class seeks to provide means of financing for the energy transition of firms not currently having a green classification under, for example, European taxonomy.

Paralleling the growth of green loans has been the expansion of the market for *green loans* as bilateral financing products subject to sustainability commitments. The same as bonds, green loans are guided by certain principles, such as the Green Loan Principles of the ICMA, which govern the definition of green commitment, the assessment of the projects financed, the management of funds and the reporting.

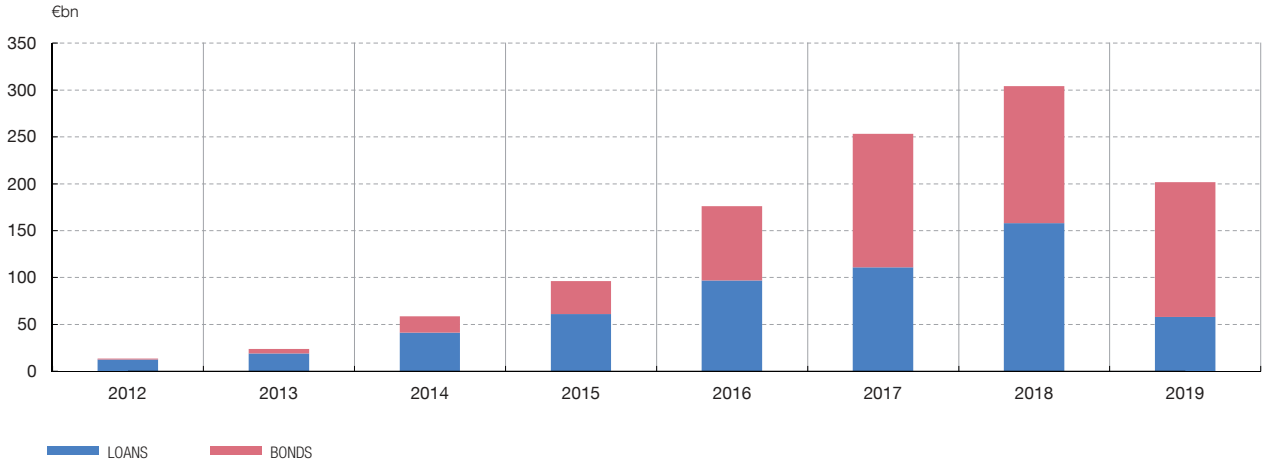
Separate mention should be made of sustainable loans issued under the German format known as Schuldschein, which consist of debt certificates whose terms and conditions are agreed between the parties entering into the loan. These certificates may subsequently be distributed to investors other than the original lender. Curiously, Spain is one of the main areas in which this sustainable product is issued, behind Germany and the Netherlands [according to data of CBI (2018a)].

12 Pioneer issues to finance solar projects in Malaysia [CBI (2018a)].

13 In this structure the issuer sells certificates to a group of investors, receives cash which he uses to purchase an asset partially owned by the group of investors, and distributes a portion of the profit obtained in the form of dividends to the investors. The assets obtained must comply with the ethical principles of Islamic law, which include green assets and projects.

14 The initiative originating at AXA (2019) focuses on creating in-house standards similar to those of green bonds, with emphasis on the eligibility of projects intended to undergo transition to sustainable economic activities, such as, for example, the capture of carbon emissions or the use of alternative fuels in air transport.

VOLUMES OF SUSTAINABLE BONDS AND LOANS ISSUED CHART 2



SOUCE: Devised by the authors from data of Bloomberg Finance LP.

PUBLIC-PRIVATE INITIATIVES BOX 4

The private financial sector plays a key part in financing the energy transition, but it also leverages its role when it shares the financing burden in certain public-private initiatives.[1]

One of the points addressed in the Paris Agreement (2015) was the commitment to mobilise, by various means, a total of $100,000 million each year from 2020 to help developing countries to mitigate and adapt to the effects of climate change. The governments agreed that a portion of this financing would be provided through the creation of a multilateral fund called the Global Climate Fund (GCF), devoted to working in cooperation with accredited financial institutions such as COFIDES in Spain to finance sustainable projects. To date nearly half of the $5,000 million committed in this fund to support more than 100 projects have been used to help avoid 1,500 million tonnes of CO_2 emissions.

Noteworthy in the real estate sector is the PACE (Property Assessed Clean Energy) programme of the USA, which features an innovative model (ENER 2019) by means of which the financial sector provides government-subsidised loans to cover the cost of renovation of residential and commercial properties in order to enhance energy efficiency, undertaking to pay back through the taxes levied on the housing. In Europe there is a pilot programme called EuroPace financed by the European Commission's Horizon 2020 programme.

1 For an exhaustive summary of public-private initiatives in sustainable finance, see the United Nations platform SDG Financing Solutions. Also, OECD (2019) reports an assessment of the impact of government climate programmes on the mobilisation of private capital.

Lastly, *project finance* is also notable as a key instrument in the transition to a sustainable economy,[15] since a considerable portion of the fixed assets needed to achieve a low-carbon economy are concentrated in areas such as transport, real estate or infrastructure [TEG (2019b)].[16] These are typically financed by project debt (at times with government participation or support, as explained in Box 4). One of the main innovations in this field is the so-called *impact bonds and loans,* in which the debt interest rate is linked to an assessment of the issuer's sustainability, such that when this assessment improves, the financial cost decreases.[17]

Covered bonds and securitisation

The issuers of so-called green covered bonds,[18] relying on their usual issuance programme, commit to use the funds raised in projects defined in their green framework. Thus investors, in addition to an ordinary claim on the firms' assets, has a priority claim on a set of assets pledged as collateral, which need not necessarily be made up of green assets. In some cases, certain issuers promise, for internal policy reasons, to maintain sufficient green assets to back the covered bonds, while others officially link the financing they obtain through green bonds to the collateral eligibility criteria of their green covered bonds. Most green bonds are governed by private contracts, although a notable exception is the Luxembourg initiative (see Box 5), which sets in place a law identifying the specific characteristics required of green bonds, specifying that it is compulsory to delimit green collateral.

The green *securitisation* market also merits growing interest. Firms use securitisation to take certain assets off their balance sheet, financing such disposal through the sale of an instrument known as an "asset-backed security", which only has these assets as collateral.

RENEWABLE ENERGY COVERED BONDS: LUXEMBOURG'S PIONEERING LAW **BOX 5**

Luxembourg is pioneering the conceptual change represented by sustainable covered bonds. A law of 22 June 2018 introduced a new class of covered bond in which the collateral is limited to renewable energies *(Lettres de Gage Énergies Renouvables*, LdG-ER). Specifically, these covered bonds must be backed by loans earmarked for non-fossil energy sources, such as wind, solar, aerothermal, geothermal, biogas, etc. power. The securities eligible to form part of the collateral backing the covered bond include, in addition to the aforementioned loans, the shares of firms in the renewable energy sector or securities purchased in asset securitisations of those sectors.

15 One of the first initiatives in the area of sustainable finance was the signature in 2013 of the Equator Principles, agreed in the financial sector for the determination, assessment and management of environmental and social risks in project finance.

16 For example, achieving sustainable infrastructure or constructing solar and wind plants is key for mitigating climate change; achieving greater water efficiency is crucial for protecting marine resources, as is similarly important the management of waste and recycling plans, etc.

17 Practical examples are the sustainable impact loans marketed by ING, or the recent revolving credit facility developed by Philips, which is linked to the sustainability of the firm (May 2019).

18 For more information, see ING (2018).

Unlike covered bonds, in this case the investor does not have a claim to the firm's assets as a whole and the collateral is not renewed dynamically. Noteworthy [CBI (2018b)] is the activity in securitisation of renewable energy loans (e.g. for construction of solar power plants) or residential and commercial green mortgage securitisation (e.g. securitisation of PACE loans).

Derivatives

The influence of derivatives for climate change risk hedging is somewhat limited, since this type of global warming risk is hard to diversify[19] and materialises over a long time horizon, so it is difficult to find counterparties that can guarantee payments derived from climate-related events [Andersson *et al.* (2016)]. Nevertheless, there are new academic proposals, such as those suggesting the construction of alternative indices based on text recognition techniques to quantify the impact of climate change news, which would enable the creation of a dynamic hedging strategy in which the payments on derivatives depend on the behaviour of this index as an underlying [Engle *et al.* (2019)].

In any event, there are partial solutions for hedging in local environments. For example, the field of natural catastrophes features climate derivatives, in which the underlying asset is a certain meteorological event, such as temperature, pressure or rainfall, allowing physical climate risk to be hedged.[20] Another common alternative in project finance is energy derivatives, instruments whose underlying is the price of a certain energy source, whether it be oil, coal or renewable energy. A specific example in this respect is proxy revenue swaps, used particularly in wind or solar projects, in which a current of certain or fixed flows is exchanged for a series of variable flows linked to deviations in project income caused by the volatility of electricity generation.

2.2 Retail funding

Deposits, mortgages and consumer credit

An increasingly important line is that relating to retail instruments. In this case the ultimate aim is to increase *customers' engagement* with sustainability in order to modify their behaviour and reduce their exposure to climate change risk.[21] This commitment is expressly included as one of the principles of responsible banking recently agreed in New York by 130 international financial institutions.

As mentioned at the beginning of this article, the transition to a sustainable economy involves modifying the stock of assets and redirecting the flow or new activity to a business model

19 That is to say, it cannot be eliminated by adding more assets to the portfolio, as occurs with systemic or market risk.

20 Notable at international level is the role of the World Bank as an issuer of catastrophe bonds, which include optionalities of this type.

21 Outside the financial arena, there are many initiatives in this respect, such as that of Rare.org, whose purpose is to design optimum mechanisms to change behaviour, such as, for example, the standardisation of diets compatible with the sustainability of the planet, optimum use of thermostats or the management of household waste [BIT (2019)].

compatible with a low-carbon economy. This allows customers to finance assets not exposed to climate change risk and, in addition, new services are emerging which allow the transformation of previous exposures which were usually not green. A typical example is the schemes to transform mortgages into a sustainable category by promoting investment in projects to improve home energy efficiency.[22] In this respect, some banks are already offering loans which improve or remunerate the interest-rate spreads in place depending on the energy efficiency of the house.[23]

In sectors other than real estate, banks have many instruments allowing customers to control the use of their funds. There are initiatives along these lines at the base of the pyramid of banking products, such as green deposits and fixed-term deposits in which the institution commits to use those resources in projects meeting sustainable standards, or green credit cards which measure (and inform the customer of) the carbon footprint of the expenses incurred with it and allow limits to be set in this respect.

22 Standardisation initiatives include house energy efficiency certification such as EeMAP (Energy efficient Mortgages Action Plan) and EeDaPP (Energy efficient Data and Portal Protocol).

23 Examples are the green loans of BBVA or the variable-rate mortgage of Triodos Bank. Similarly, in July 2018 Natixis announced the creation of a green supporting factor which it will apply in lending. This factor will discriminate positively in the allocation of capital to those transactions which comply with the Paris Agreement, and negatively where such compliance is lacking.

3 Management of financial risks

Sustainable finance will only be put on a firm footing once the impact of climate change is conceived as a new input in the financial risk function. We can regard climate change risk as a two-sided coin. This takes into account both how companies' businesses impact the climate and how climate change affects the expected profitability of companies.

This twofold nature of risk is reflected in the double materiality criterion described in the European Commission's proposal[24] to amend the non-financial reporting directive so as request firms to provide the following information [TEG (2019e)]:

— *Environmental and social materiality:* the impact of firms' activity on the process of climate change.

— *Financial materiality:* the impact which climate change (physical and transition risk) may have on firms' financial accounts.

This definition of materiality serves to understand the innovations relating to the *measurement of climate change* risk. Regarding environmental materiality, it is now possible to quantify what is known as the "carbon footprint" to measure the impact of greenhouse gas emissions in terms of carbon equivalent. Box 6 explains various methodologies to measure this carbon footprint (particularly in investment portfolios, which is especially important for understanding the impact of the business of financial institutions). In short, the carbon footprint will allow us to know how closely firms are aligned with a sustainable economy, as agreed in Paris (2015). A recent international agreement was entered into by 30 financial institutions to commit themselves to measuring climate change risk in their investment portfolios.

Once the carbon footprint of the credit or investment portfolio of financial institutions is known, this variable has to be expressed in economic terms to quantify the impact of climate change in terms of *financial materiality*. Doing so involves incorporating this factor into the measurement of *credit risk,* for which there are various methodologies,[25] such as climate stress tests[26] or adaptations of methodologies for simulating value at risk (VaR), as explained in Box 7.

24 The European proposal is, in this respect, more ambitious than TCFD, since this latter initiative refers only to financial materiality, as explained in the document by the group of experts of the European Commission [TEG (2019e)].

25 For more details, we recommend reviewing the documents of UNEP-FI on the various methodologies for measuring physical risk and transition risk.

26 For example, the central bank of the Netherlands conducted a stress test to measure energy transition risk [DNB (2018)], and the Bank of England, in cooperation with 2Dii, conducted a stress test in 2019 in the insurance sector on the basis of the exposure to climate change estimated by the PACTA methodology (this tool is available online).

The basis for accurate measurement of the carbon footprint comes from Kyoto, and, in particular, from the greenhouse gas (GHG) protocol, which defines seven types of polluting gases including carbon dioxide, methane, nitrous or fluorinated, all of which can be expressed as "carbon dioxide equivalents" (CO_2e).

The measurement of emissions must be based on three components. The first is *emissions actually released,* among which may be distinguished those that are *direct,* produced by offices and vehicles (scope 1), those that are *indirect,* originated by the consumption of utilities, such as electricity and heating (scope 2), and those known as scope 3, arising from the production chain (purchase of raw materials, goods transport, etc.) and from business activity (distribution of products, investment portfolio, etc.). The second component is *avoided emissions,* for example through investment in renewable energies, and the third is *sequestered emissions,* for example through investment in woodland.

According to this protocol, financial institutions have to report up to the level of scope 3, with particular importance being given to the measurement of the *investment portfolio's carbon footprint.* Diverse methodologies have been developed to measure it. A first group of metrics, including the PCAF methodology,[1] which takes a *backward-looking* approach to quantify the carbon footprint in its current state, is based on the construction of attribution factors within the asset portfolio and the weighting of companies' emissions according to the financial institution's share in the financing provided to each company. Another group of metrics, which includes the PACTA methodology,[2] aspires to measure the carbon footprint of investment portfolios by taking a *forward-looking* approach which simulates the behaviour of the current carbon footprint, measured in terms of temperature as a means of aligning it with a global warming path under future climate scenarios.

1 Supported by institutions such as Triodos Bank, ABN Amro or APG.
2 Entities such as WWF or ING (TERRA project) use this methodology, both in collaboration with the specialised firm 2Dii (Two Degrees Investing Initiative).

The Climate VaR (CVaR) project launched by Carbon Delta in a rapidly developing field consists of an initial calculation of companies' costs and profits over the next 15 years for each energy transition scenario simulated (e.g. 1.5ºC, 2ºC, 3ºC or 4ºC) and each risk factor (physical, transition, regulatory and technological opportunities) under various assumptions. The time series of climate net costs is discounted to its present value using the required internal rate of return to the company (WACC).[1]

DIn this way a company's CVaR is calculated as the present value of climate net costs divided by the market value of the company.

$$CVaR_{equity} = \frac{\text{Climate costs / profits}}{\text{Market value of equity}} \qquad CVaR_{debt} = \frac{\text{Climate costs / profits}}{\text{Market value of debt}}$$

The credit risk structural model of Merton (1970) can be used to break it down into the impact on equity and the impact on debt.

A methodology is thus obtained which allows the potential impact of climate change risk on the value of companies' liabilities to be measured, distinguishing between the effect on equity and the effect on debt under different scenarios.

1 Stern *et al.* (2019) criticise the fact that the scenarios do not include tail events (tipping points), which in the case of climate change may be particularly significant, or the impact of discounting future climate costs, which may be interpreted as discrimination against future generations.

4 Technological innovation

The development of new technologies vastly transformed the financial sector, and climate risk management formed part of this transformation [Allen *et al.* (2017)]. In this respect, new technologies are changing practically all the links of the financial sector value chain and, in all of them, opportunities arise in which sustainability criteria may play an important role.[27]

Some initiatives [UNEP (2016)] are enjoying increasing use, such as natural language processing (NLP) applications employing artificial intelligence techniques to monitor the sustainability metrics cited in firms' annual reports and financial statements. They are used, for example, by the Sustainability Accounting Standards Board (SASB) to measure the level of compliance with ESG corporate disclosure requirements. Another technique used to calculate the environmental reputation of firms is the measurement of user sentiment analysis by means of the interpretation of texts and articles, for which purpose the use of NPL techniques, advanced analytics and big data management is also required [Hawley (2017)].

A last example worth noting is the use of new technologies to measure physical climate change risk. In particular, institutions such as the World Bank use *image recognition techniques* in their catastrophe risk management strategy. In the Global Facility for Disaster Reduction and Recovery (GFDRR) project, satellite image identification, drones and 360º recordings from cars in the streets of Guatemala were used to locate vulnerabilities and prioritise investments. This technology was estimated to be 70% cheaper than the use of human capital and moreover reduced bias in data collection.[28] An algorithm identified buildings located on steep slopes, which are at higher risk from mudslides and defective rooftop material making for greater risk to human life in the event of flooding. The results showed that 85% of the buildings signalled by the algorithm were assessed by engineers as high risk, which helped to improve the strength of many modest dwellings.

However, it is important to note that the *technological progress derived from the use of artificial intelligence techniques has a cost in terms of climate impact.* As explained in Box 8, the increasingly complex calibration of certain algorithms has a high carbon footprint and this must be taken into account when analysing the optimum path to a low-carbon economy. This is particularly important for the financial sector, the activity of which (scope 2) has not had a significant carbon footprint up till now. However, the incremental use of cloud data storage services and of algorithm calibration by complex optimisation techniques may reverse this situation.

27 In this respect, UNEP (2016) analyses in detail all the initiatives in financial innovation which may have an effect on the achievement of sustainability objectives.

28 No prediction technique is free from bias, but there are techniques designed to monitor discrimination, algorithm or measurement bias.

Strubell *et al.* (2019) calculate the electricity carbon footprint of training deep neural network models for NLP. A decade ago NLP models could be trained on a laptop at home, but now they may require specialised hardware due to improvements in mass data storage. The training of models calls for high electricity consumption to run this hardware for weeks or months on end. Some of the parameter optimisation techniques (such as grid search) used in these models are computationally highly demanding. In this study the authors estimate that the energy consumption for training a complex model may be up to six times the amount consumed over the useful life of a car (626,155 lbs of CO_2 for the algorithm, compared with 126,000 for a car).

Table 1
ESTIMATED CO_2 EMISSIONS OF NLP MODEL TRAINING COMPARED WITH THOSE OF HOUSEHOLD CONSUMPTION

	CO_2 (lbs)
Consumption	
Aeroplane travel, flight from NY-SF	1,984
Human life, world average, one year	11,023
Human life, US average, one year	36,156
Car, average including fuel, one life cycle	126,000
Model training (GPU)	
NLP *pipeline (SRL parsing)*	39
Including calibration and experimentation	78,468
Transformer (large)	192
Including search in neuronal architecture	626,155

SOURCE: Devised by the authors on the basis of Strubell, Ganesh and McCalum (2019).

Conclusion

Climate change is unquestionably one of the main risk factors which our society will face in the coming decades. The financial sector plays a key role in this challenge, firstly because of its exposure and the consequent capital shocks if this risk crystallises, and secondly because it has the task of channelling the funds needed to transform our economy into a sustainable one. The financial authorities are fully conscious of this and are engaged in a lively discussion of measures recognising the *specific importance of climate change as a risk factor in the financial sector.* This regulatory discussion is beginning to give rise to specific initiatives, such as those deriving from the European Commission's action plan [TEG (2019a, b, c, d and e)], which will undoubtedly progressively shape the capital markets and the decisions of financial institutions in their intermediation activity. However, any new regulation requires time, and this interval should not serve as an excuse for the private sector to postpone positioning itself on such a vital challenge to its activity as is climate change. Those institutions which make most headway on initiatives and measures to internalise this risk in their decision-making will be the ones best prepared to compete when an appropriate regulatory framework is finally set in place [BCAM (2018)].

Climate change, along with new technologies, has unquestionably become a key driving factor of the transformation of the financial sector.[29] *This article has reviewed qualitatively some of the initiatives* under way at certain institutions or in the financial markets to address climate change risk. Clearly, this transformation is prompting the emergence of new products (e.g. green bonds and loans) and financial services (e.g. external verification and sustainable benchmarks), which are being furnished either by specialised new providers or through innovative initiatives by traditional players. This same *revolution* is occurring at higher levels, for example that of *risk management,* where work is under way in areas such as measuring the impact of business activity on the process of climate change (e.g. the carbon footprint) or assessing how firms' behaviour may be affected by the shift towards a sustainable economy (for this purpose, new adaptations of risk methodologies such as stress testing or VaR are under development). Lastly, it should be noted that the very transformation of the financial sector may significantly drive this change, although it is not free from *restrictions,* such as the potential impact on the carbon footprint of the use of cloud computing and big data and the calibration of complex artificial intelligence algorithms.

Although many of these initiatives are still at the early stages and in many cases limited use is made of them, the rate of development seen in segments such as green bonds and the momentum of regulatory change to explicitly incorporate climate change risk suggest that in the coming years we will witness a proliferation of such initiatives and that *sustainable finances will become mainstream* [UNEPFI (2018)]. This trend seems inevitable if there is really a will to address climate change and avoid the impact that an alternative scenario would have not only on the financial sector but on the welfare of society as a whole.

29 For more details, we recommend the United Nations platform Financial Innovation for the SDGs, the website of which is available here.

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