The energy transition and the financial system

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Abstract

After briefly setting out the scientific evidence on climate change (CC), particular emphasis is placed on characterising the problem from an economic standpoint. Then the strategies the different lobbies have used to hamper the energy transition are reviewed and as is confirmed have been successful since, as will be argued, this transition has not yet begun. Afterwards the attempts within international coalitions to arrive at agreements to define a carbon price that takes into account its social costs and provides for the transition to another decarbonised energy system are analysed. The causes for the meagre results obtained are set out, these arise from the fact that none of these agreements met the three basic requirements needed: to be effective, to be fair and to be credible.

The second part of the article refers to the risks and opportunities that the energy transition poses for the financial system. The potential problems that delayed decision-making can cause for financial stability are particularly underscored, both on the publication of financial information by CC-related agents and on the consideration of the risks derived from the energy transition. It is noted that most financial institutions, regulators and regulated alike, have accepted the account of the seriousness of the CC problem. Also evident, however, is the little progress achieved in practice to resolutely and rigorously address this critical problem. Finally, it is concluded that, in the current circumstances, it does not seem reasonable to expect the financial system to play a significant role in channelling the considerable economic resources needed to finance a new energy infrastructure.

1 Introduction

The average temperature of the Earth's surface is today 1 ºC higher than it was before the industrialisation of our economies, taking as a reference the average value over the 1850-1900 period. Our growth model needs deep-seated changes if we are to succeed in keeping this rise below 2 ºC. Once this limit is surpassed, science warns us of the high likelihood of our natural environment undergoing drastic and irreversible changes, endangering the well-being of future generations. Worse, the latest studies and empirical findings signal that the reality of climate change exceeds the most pessimistic forecasts and that the threshold would need to be set at 1.5 ºC. Tackling this problem unavoidably requires breaking, or drastically weakening, the strong link between economic activity and the emission of a series of gases behind the so-called "greenhouse effect".

The "greenhouse effect" is the natural phenomenon caused by several gases present in the atmosphere. These condition the Earth's temperature which, without such gases, would be approximately 21 °C colder, making it uninhabitable. Along with steam, the main greenhouse gases (GHGs) are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs). Admittedly, the atmospheric concentration and characteristics of each of these gases differ, particularly their capacity to absorb terrestrial radiation; but their overall effect can be converted into CO_2 equivalents. In any event the main GHG is, it should be stressed, CO_2. And in the past two centuries it has contributed around 80% of the greenhouse effect.

The greenhouse effect process can basically be described as follows: the Earth receives energy from the sun in the form of high-frequency waves that pass easily through the atmosphere and are reflected on the Earth's surface, which sends them back towards space, but at an appreciably lower frequency, owing to the fact their temperature is lower. However, not all this radiation returns to space. The GHGs absorb a substantial portion, insofar as such radiation has a lower penetrative capacity than that coming directly from the sun. Thermal equilibrium is achieved when the energy from the sun is offset by that irradiated out to space.

Evidently, this thermal equilibrium may be seriously affected if, for whatever reason, the concentration of GHGs in the atmosphere increases. That would bring about a greater absorption of the radiation reflected on the Earth's surface and a reduction in the heat expelled to space. The upshot would be a greater heating up of the planet, what we know as the "greenhouse effect". Such global warming is at the source of CC, understood as a significant and lasting change in global and local climate standards. This is manifest in the atmosphere and oceans warming, in the changes in the water cycle, in ice and snow loss, in rising sea levels and in the emergence of new, extreme climate phenomena. The stock of GHGs built up in the atmosphere will largely influence the dynamics of increased global warming. This effect will be durable and last for centuries, even if GHG flows were to drop drastically from a certain point in time.

2 Evidence of climate change

It was in the 1820s that the French physicist Jean-Baptiste Fourier analysed GHG properties, and it was the Swedish chemist Svante Arrhenius, the 1903 Nobel prize-winner, who asserted for the first time in 1896 that the levels of CO_2 affect the Earth's thermal balance. Science, then, has been abreast of this grave problem for over 120 years.

The latest Nobel prize-winner for Economics, William D. Nordhaus (2018a), stressed this fact in his Nobel Banquet speech on 10 December last year, noting that “The science of climate change was founded in 1896, the very year that Alfred Nobel died and established these prizes. In that year, the Swedish chemist Svante Arrhenius provided the first numerical prediction of the impact of doubling atmospheric carbon dioxide. His estimate of 5.1 °C is remarkably close to the figures produced by the highest-resolution models today”.

The analysis of economic activity over recent centuries highlights the clear causal relationship between economic growth and GHG emissions, whereby their atmospheric concentration has gradually and uninterruptedly increased in step with emission flows. These flows have varied in accordance with the related economic cycles, with the transformation of the electricity generation industry and with the changes in land use. Undeniable technological developments have, over time, meant that each unit of GDP requires fewer GHG emissions, i.e. what we call the “carbon intensity in the economy” has slightly decreased. However, there is no improvement whatsoever in the indicator we know as “carbon intensity in energy supply” (CO_2 emissions/total primary energy supply), which has held virtually constant. Clearly, there is much room for improvement in this indicator, or expressed otherwise, it is necessary to supply primary energy that generates fewer CO_2 emissions.

The NOAA (US National Oceanic and Atmospheric Administration) website [see NOAA (2019a)] states that the average GHG concentration in the atmosphere, in terms of CO_2 equivalents, was 496 parts per million (ppm – the units in which these types of concentrations are expressed) in 2018, whereas in 2000 it was 441 ppm. In terms of the annual average concentration exclusively for CO_2, the attendant figure was 408.5 ppm for 2018, and 369.5 ppm for 2000.

It is particularly disappointing to see that, in the years in which we are discussing how we should be reducing CO_2 emissions, the amount we are sending up into the atmosphere is clearly accelerating. Indeed, three of the last four increases in CO_2 have been the highest directly recorded since 1959 at the Hawaii Mauna Loa observatory [see NOAA (2019b)]. This concentration has increased by 46% from the pre-industrial era level of 280 ppm.

As reflected in the recent September 2019 report, “State of the Climate in 2018” [see NOAA (2019c)], GHG levels are the highest recorded in the last 800,000 years. The records are direct measurements from the last 60 years and correspond to the values calculated drawing on samples in the air bubbles trapped in successive layers, at different depths, in the Antarctic and Greenland ice platforms, which can be dated at up to 800,000 years. This is an annual report that has been drafted for the last 29 years, under the leadership of NOAA scientists, and published in the Bulletin of the American Meteorological Society. More than 500 scientists from 65 different countries contribute to its content.

As a result of the progress in recent decades, CC science enables a distinction to be drawn between which part of global warming is due to human activity and which to a process of natural evolution. There are of course other natural factors that also affect changes in temperature, such as the relative position of the Earth's orbit around the sun, and changes in volcanic activity and in solar activity. But what is true is that scientific results state, for example, that in the last 50 years these natural effects taken as a whole have contributed, albeit very weakly, to global cooling and not to warming [see the Global Warming Index, GWI (2019), jointly published by the Universities of Oxford and Leeds].

Since the analysis of CC requires the use of complex and calibrated models including numerous and diverse natural sciences-related aspects, a certain lack of transparency is usually attributed to it. And this is frequently used in the public debate domain to question its results. Consequently, and for those economists interested in this problem, the papers by Stock (2019a and b) may be of interest. By means of a rigorous and readable econometric analysis, the papers validate the findings of these types of more complex models. Indeed, James H. Stock also reaches the conclusion that, essentially, all of the temperature increase since the pre-industrial era is anthropic and that two-thirds of it has been after 1975.

Recall that in the absence of GHGs the average temperature of the Earth would be –6 °C, whereas with these gases present today in the atmosphere it is 15 °C, i.e. 21 °C higher. Evidently, then, temperature is enormously sensitive to GHG concentration levels. This is why the increases in GHG concentration since before industrialisation are so worrying. The problem is not simply one of an increase in temperature, but also of a drastic change in the conditions in which humanity and ecosystems have evolved over time. However, the expressions "climate change" and "global warming" are usually used interchangeably to describe this phenomenon.

At present it is now impossible to include in an article such as this the vast amount of published and substantiated scientific information, as is also the case with the analyses by institutions and organisations that confirm that the CC taking place has an anthropic origin. Indeed, this is not the place to refer in detail to such solid scientific evidence. The reports by the Intergovernmental Panel on Climate Change [IPCC; see IPCC (2014)] do so with the utmost rigour. Specifically, their synthesis reports include and summarise the activities of Working Group I, which is responsible for updating the CC scientific base, and of Working Groups II and III, which are responsible for assessing the impact of CC on human and natural systems, and the means with which to tackle the challenge posed.

The IPCC was created in 1988 by the United Nations Environment Programme and by the World Meteorological Organisation. It does not conduct its own research but rather uses in its reports material from the most accredited and reviewed scientific literature. That same year, the United Nations General Assembly endorsed the decision to create the IPCC. The first Working Group report was published in 1990, followed by those in 1995, 2001, 2007 and 2013-2014. In 2007 the Group received the Nobel Peace Prize. Currently, 195 countries are IPCC members. The Panel meets at least once a year in plenary sessions.

3 The economics of energy transition

At the above-mentioned Nobel award ceremony, Professor Nordhaus stressed that "Over the last half-century, the full implications of climate change and its impacts have been illuminated by the intensive research of scientists in different fields. These studies depict an increasingly dire picture of our future under uncontrolled climate change. The signal contribution of economics is to recognize that climate change is a harmful unintended side-effect of economic growth, known in economics as an external effect or externality".

In fact, externalities may arise when not all the costs or benefits of an activity can be assigned exclusively to the economic agents undertaking such activity and, therefore, they may not take them into account when taking decisions on the allocation of their resources. Generally, the presence of externalities gives rise to the attainment of equilibrium under a competitive system not being optimal. Hence, inefficiencies arise since, as it considers exclusively its own costs, the producer of the good giving rise to the externality produces a smaller/greater amount of this good in the case of positive/negative externalities than an optimal situation would warrant. Clearly, in the case of CO_2 emissions, those responsible generate external negativities, since they inflict harm on other economic parties. The cause of this harm lies in the fact that the prices assigned to these types of goods do not reflect the costs of having emitted GHGs.

This externality has four basic characteristics. First, its global nature, i.e. GHG emissions arising in China have the same effect as those generated in Spain. Second, its long-lasting impact; once in the atmosphere these types of gases stay there for a very long time, for centuries even, meaning that the climate in 50 years' time is already influenced by today's emissions and levels of GHG concentration. Third, uncertainty; i.e. the problems of CC cannot be tackled in a determinist environment, since there is no certainty as to what the final effects are. In any event, scientific progress in recent years enables a set of predictions within reasonable confidence intervals to be formulated. And fourth, its potential to cause radical and irreversible changes and harm. As stated over ten years back in April 2008, in the first paragraph of the International Monetary Fund World Economic Outlook's chapter on CC [IMF (2008)], "climate change is a potentially catastrophic global externality and one of the world's greatest collective action problems".

Insofar as the negative externalities that fossil fuel use generates – especially GHG emissions – are not taken into account, this energy is in fact doubly subsidised. First, because environmental costs are not reflected. And further, on the figures provided by the International Energy Agency (IEA) [see IEA (2019a)], because fossil fuels directly received more than $400 billion in subsidies to the end-consumer and as inputs to electricity generation in 2018. Of this latter figure, around 30% still relates to the G20 countries. The changes that can be seen in these figures from one year to the next are, essentially, associated with the decline in international energy prices and not with a change in subsidy policy. And this despite the reiterated calls at G20 meetings, since 2010, to “rationalize and phase out over the medium term inefficient fossil fuel subsidies that encourage wasteful consumption” [see IEA (2010a and b)].

The economic policy instruments designed to address the problems of CC have different theoretical fundamentals and different levels of sophistication. Their complexity stems from the fact they have to take into account many economic sectors and countries with very different levels of development, and, ultimately, they have to accommodate the so-called stakeholders (the various authorities and pressure groups represented by agents with interests in this process).

Three criteria should underpin the assessment of CC policies. Firstly, effectiveness, i.e. they must result in levels of GHG emission that maintain the risks derived from CC at acceptable levels. Secondly, efficiency, i.e. they should minimise the costs associated with the ongoing reduction of emissions. Thirdly, equity, which in this case is no minor requirement since the developed countries are responsible for most past emissions and the under-developed countries are those which will suffer the consequences of CC to a greater extent.

Economic measures may be grouped into two broad categories: first, the mandate and control instruments; and second, market instruments.

The mandate and control regulations require specific behaviour on the part of economic agents that normally translates into setting maximum gas emission ceilings and penalising non-compliance. Initially, the certainty provided by such methods is an advantage since, by making compliance with regulations obligatory, the proposed emission targets are met. However, in terms of economic efficiency, they only ensure static efficiency and, moreover, they do so only under the assumption – one that is unreal in practice – that all agents affected by the regulations have the same marginal costs curve in respect of emission reductions. In theory, these types of regulations treat all agents equally. In practice, however, certain exemptions usually break the principle of equity. The lack of efficiency and the few incentives generated for innovation are sufficient arguments for them not to be used. These regulations may be warranted when the optimum level of emissions is zero or very low, or when agents operate in non-competitive environments and, therefore, are not sensitive to price changes.

The market instruments are those that generate incentives for economic agents to reduce their emissions or develop less polluting technologies. GHG emissions have been seen to give rise to negative externalities, generating a divergence between the private costs and the social costs of emissions that leads to economic inefficiency.

Elementary economic principles indicate that the sole means of mitigating GHG emissions involves equalling both types of costs (private and social), which is equivalent to passing the related cost on to the user. The same principles also state that it is rather unrealistic to expect substantial reductions by appealing only to a sense of responsibility on the part of citizens that lead to changes in their consumption habits towards less carbon-intensive products.

Against this background, two theoretical approaches are used to address negative externalities: the setting of taxes, following the pioneering work by Pigou (1920), and creating markets for transferable emission permits along “cap and trade” lines, with the support of Coase’s theorem (1960). See Terceiro (2009) for a more detailed outline. In any event, adopting either of these solutions is a secondary issue here, which does not question the basic principle of having the private costs of emitting GHGs equal the social costs.

The highly superficial criticism usually levelled at subsidies for renewable energies often lack any economic fundament. Unlike fossil fuels, renewable energies generate positive externalities. This is because the developments by one specific firm can be swiftly emulated by others, which do not even belong to the same sector, and therefore this firm does not appropriate all the benefits from its investment. This process is known as “technological spillover”, which is no more than the external benefit arising when the knowledge derived from the initial investment spreads to other firms and individuals. This possibility of appropriation by third parties leads to a lower than socially desirable level of investment. Just like the use of taxes in the case of negative externalities, the related subsidies are warranted, usually taking the form of legal regulations that encourage specific technologies and that set the appropriate institutional frameworks.

The solution to the problem of CC necessarily involves simultaneously correcting the two types of market failings in this situation: the negative externalities generated by GHG emissions and the positive externalities generated in the development and roll-out of renewable energies.

Evidently, although this theoretical approach is impeccable, practical difficulties arise when it comes to assessing the positive externalities. Compounding this are the problems that arise on setting the complementarity or substitutability of public and private investment. It should therefore come as no surprise that there are as many successes as there are failures in this area. However, let us focus on the proposal to pave the way for an appropriate energy transition. The fact that the problem to be tackled is chiefly characterised by its above-mentioned globality, long-term nature, uncertainty and irreversibility, coupled with the fact climate stability is a public good, means that public policies should play a more relevant role than in other situations of negative externalities. It should be considered as a circumstance akin to that which arises with the positive externalities generated by education, which justifies the public funding education receives, even when they are also very difficult to evaluate.

Once again, the interests of fossil fuels have been better represented here not only in governments, but also in the media. This is because public opinion has an overinflated idea about the subsidies for renewable energies, when the truth is they do not total half of what fossil fuel energies receive. And this without bearing in mind, as earlier indicated, that the price of solid fuels is implicitly subsidised, on a far greater scale than cited here, since the cost of the negative externalities they generate is not included.

4 Lobbies and merchants of doubt

It is a well-known fact in today's world that there has been an exponential increase in the circulation of myths, illusory promises and unsubstantiated scientific facts, and the denial of proven facts. In some cases it is a question of simple lies, which are spread in numerous areas and at many different levels. Naturally, this is not only happening in the case of CC; it is also affecting many other aspects of social and natural sciences.

For example, in June 2017 the United States pulled out of the 2015 Paris Agreement on CC, with the following statement by its president: "In order to fulfil my solemn duty to protect America and its citizens, the United States will withdraw from the Paris Climate Accord". And he did so in a speech giving 18 reasons justifying this decision. It is worth analysing the document released, two months later, by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, refuting each and every one of these 18 reasons. In light of the texts approved at the Paris Conference, 12 of these alleged reasons are false and the other six are, simply, equivocal statements.

As Pinker (2018) rightly states in his recent book Enlightenment Now, "Yet today the beauty and the power of science are not just unappreciated but bitterly resented. The disdain for science may be found in surprising quarters: not just among religious fundamentalists and know-nothing politicians, but among many of our most adored intellectuals and our most august institutions of higher learning".

It is then worth summarising the types of strategies behind these behaviours. For several decades now they have been setting back the possibility of addressing a true energy transition resolutely and rigorously. Such moves are placing us in a dangerous position, where much is at stake, and which Professor Nordhaus (2015) has called the “climate casino”.

It should first be said that most affirmations in CC science are made in terms of probability, and as such no statements on the results provided by CC science can be made with absolute certainty. In this situation marked by a lack of certainty, those who question scientific achievements are peddling doubt as a product to public opinion. This is the opinion put forward by Professor Oreskes and Professor Conway (2010) in their original book Merchants of Doubt. With numerous examples, they highlight how the strategy used and continuing to be used by the fossil fuel industry is almost identical to that employed earlier by the tobacco industry.

The response of the international community to this matter is set out in Article 3 of the United Nations Framework Convention on Climate Change [see UNFCCC (1992)], in force since 1994. Among other statements it maintains that “where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures [to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects]”.

This attitude of waiting for uncertainties to dispel and meanwhile addressing more pressing problems has two serious disadvantages. The first is the fact that, while waiting, the problem continues to worsen and the stock of GHGs carries on increasing at very significant rates, with the risk of specific and dangerous concentration thresholds being breached. The second is that, also in the meantime, fossil fuel infrastructure continues to be constructed and investment and capital committed in tremendously high amounts. This behaviour will exacerbate the problem of the overall fossil fuel energy-related assets, which form part of our growth model and which, necessarily, will not be usable in the process of energy transition. These types of assets, known as “stranded assets”, will be evaluated in the final section of this article.

When the argument used is the high costs that combating CC entails, one mistake should be avoided. This is, namely, considering the investment to mitigate CC as an exercise that involves subtracting a specific amount of resources from social welfare. Rather, it should be considered as the choice of a different path for technological and economic development, which will lead to the use of renewable energies with the aim of avoiding immense and eminently likely risks. In any event, the investment is relatively modest. For example, the cost for the United States of fulfilling the Paris Agreement (COP21) has recently been estimated by Heal (2017) as between 0.2% and 0.7% of annual GDP. This would be the cost of reducing 80% of 2005 emissions by 2050. It should be stressed that whatever the figure taken in respect of the cost of acting against CC, within the natural uncertainty a problem of this nature entails, the cost will always be several orders of magnitude below what, for example, the last financial crisis involved. Furthermore, this latter figure should not be confined simply to the assistance of financial system has received from governments. To characterise it as a whole, regard should be had to the negative externalities it has generated and that the other economic and social agents have undergone. Many of the consequences have not been simply static in nature; rather, they will run for years and some others will be permanent. Under this approach, many different papers have quantified the cost of the financial crisis. Annex 1 of the paper by the Bank for International Settlements [BIS (2010)] gives a summary of this literature to date. The numerous studies analysed provide an average cost of 106% of global GDP prior to the crisis, and the median stands at 63%. In particular, the work by Haldane (2010), the Chief Economist at the Bank of England, quantifies this cost at between 90% and 350% of global GDP in 2009. This significant interval of variation depends on the assumption made regarding which portion of the costs incurred in 2009 are permanent. As is well known, when the dynamic nature of this annual sequence of losses is considered, a fundamental variable in the final result is the rate of discount used, which in this case is 2.5%.

Another type of opposition to the energy transition is the fact that experience shows that seeking to correct market failings, through public intervention, has occasionally worsened the starting position. Examples of ill-executed public interventions are at the source of much of the reluctance to combat CC, given the belief that the regulator's mistakes always exceed the market's failings. This way of thinking tends to be against any type of public intervention and is wary of them, sometimes – no doubt – with good cause. Since there is awareness that accepting the free use of fossil fuels entails costly and global negative externalities and, consequently, that resolute public intervention is required that many are wary of, an attempt is made to avoid the issue by taking the easiest way out, which is calling into question what science has affirmed. Given that public intervention is not acceptable, the relevance of the scientific results is denied. From this standpoint, we could state that the opposition to the evidence of CC has more to do with ideology than with science.

However, the energy status quo, which this rationale seeks to maintain at any cost, is not characterised by a lack of public intervention. We need only acknowledge, as the *World Energy Outlook* [IEA (2018)] does, that over 70% of the $2 trillion of annual investment in energy worldwide – in all activities and sectors – is carried out by government-run entities or others whose revenues are supported and backed by public regulation.

It might thus seem that the defence of the energy status quo has no justification whatsoever when adopted by those positions allergic to public intervention. The justification of this apparent contradiction is as follows. Any fledgling economist knows that if resources are to be efficiently allocated in a market economy, certain conditions must be met. If some of them are not fulfilled, a market failure arises. Naturally, correcting such failures requires public intervention. Two types of government intervention in the economy may occur: the first corrects the market's failures and enables it to work better; the second, on the contrary, protects specific private interests to the detriment of the economy's competitiveness. The first type promotes and is in favour of the market economy, and the second simply favours specific firms, which in the energy sector almost always protect the status quo. This is why economic policies favouring the market should be clearly differentiated from those others favouring firms, in this case fossil fuel companies.

Lastly, mention should be made of the stance, in the face of CC, of those who, while accepting the predominant scientific interpretation, limit themselves to highlighting what they think are its positive aspects. They suggest routing investment against CC towards other economic activities that generate greater economic growth today, so as to be better placed to face the costs of adapting to future increases in temperature. These agents are known as "lukewarmers" [see Michaels and Knappenberger (2016)]. They thus take the line, for instance, that reasonable increases in temperature will be bearable, and will even generate benefits such as better harvest yields in many developed countries. Or they point to other types of advantages, such as the fact that the Arctic melt will enable an increase in maritime trade and traffic as the Arctic becomes more navigable. As is well known, control over an international trade route is a most valuable asset. This is why there are powerful incentives not to be concerned about the climatic catastrophe this loss of ice mass involves. These are, then, the types of benefits the "lukewarmers" perceive. While not rejecting CC, they assure that its intelligent management will bring benefits of this type. That enables them to continue playing in Nordhaus's "climate casino" (2015). Yet they do, in their discourse, make a special point of distancing themselves from the out-and-out deniers. That is to say, they are the diplomatic advocates of the status quo.

5 The energy non-transition

In the past ten years the costs of solar and wind energy have fallen by 90% and 70%, respectively, and this trend will no doubt continue. Yet even today fossil fuels – coal, oil and gas – provide 80% of energy worldwide. Going somewhat further back in time, it is worth noting that when the incandescent light bulb was developed in the late 1870s, its cost was four times greater than that of gaslight. Today, light costs 200 times less than in those days, although for a long time it was cheaper to use candles and oil lamps. These two examples of a drastic reduction in the prices of energy sources might suggest that technological changes of this nature should lead to authentic energy transitions. But we will see below that this is not the case.

Economists usually think it is not always a good idea to extend the life of old technologies, in regulated markets, with the aim of hampering the entry of future technologies. But this is what is happening. It would seem more logical to propose that new technologies replace old ones. That is when we would see a real transition. But such a transition has never taken place in the history of energy, and the CC challenge will no doubt require this. We can justify this statement by citing the figures set out by Newell and Raimi (2018).

The world has never undergone a genuine energy transition. What has actually happened is that new energy sources have added to the old ones already in place. They never replaced them. This has been the reality over the past 200 years, which is no doubt reflected in the records of GHG concentration levels in the atmosphere and in their annual growth rates.

Let us take the four basic fuels used over this period: biomass (chiefly wood), coal, oil and natural gas. These are at the root of the serious CC problem. In 1800 biomass provided almost 100% of the world's energy; today this figure is only 10%. Coal, the driving force behind the Industrial Revolution, accounted for 44% of global energy in 1925, and this figure has today dropped to 28%. Oil and natural gas began to be pivotal after the Second World War, and together rose to represent 62% in 1973, a figure that has since fallen to 53%. The course of these figures marks the narrative of the so-called "global energy transition". But properly viewed, this transition has never taken place. Let us see the developments from another angle.

Neither the consumption of biomass or of coal has actually diminished. From 1800 to the present day, biomass consumption has increased by approximately 275% and it continues to be the main source of energy for billions of people. Since 1900, the use of coal has increased more than eightfold; and since 2000, by over 60%. Nor have oil and gas consumption declined; indeed, it has approximately doubled since 1973. Clearly, then, the emergence of new fuels has never crowded out the old ones, since the latter have continued to grow at most considerable rates. Instead of ousting the former fuels, oil and natural gas, then nuclear power, and more recently wind and solar energy, have added to those already in place. There has been no substitution, only addition.

This non-transition is all the more worrying when we look at the latest figures for investment in the different types of energy, old and new alike. Indeed, according to the latest report by the International Energy Agency [see IEA (2019b)], investment in renewable power in 2018 amounted to $304 billion. While a respectable amount, it remains far off the figure of $933 billion for investment in fossil fuels. Expressed more specifically, only one-third of what has been invested in fossil fuel energy was invested last year in renewables. For a genuine energy transition we need a fossil fuel-replacement process, not merely a simple addition of renewable energies. Otherwise, it will hardly be possible to reduce the current flows of GHG emissions.

There is an enormous contradiction between what governments say they are going to do and what they actually do. And then in turn, too, between what they do and what the world needs to move to an energy system with the aim of decarbonising the production of electricity and reducing the energy obtained from fossil fuels heeding the criteria of effectiveness and economic equity. The question then is the following. Why are we stuck in this situation?

We must acknowledge that the characteristics of the negative externalities that were outlined in detail hamper any solution enormously. This is because neither the tools nor the institutions to solve problems of this nature are at present available. At issue are global long-term losses set against necessarily local and immediate investments. Against this background, the Governor of the Bank of England talked in a landmark speech about the "tragedy of the horizon" [see Carney (2015)].

Years earlier, this dilemma was admirably summed up in the first paragraph of Chapter 1 of *The Oxford Handbook of Climate Change and Society* [see Dryzek et al. (2013)], in which its three editors state that: "Climate change presents perhaps the most profound challenge ever to have confronted human social, political, and economic systems. The stakes are massive, the risks and uncertainties severe, the economics controversial, the science besieged, the politics bitter and complicated, the psychology puzzling, the impacts devastating, the interactions with other environmental and non environmental issues running in many directions. The social problem solving mechanisms we currently possess were not designed, and have not evolved, to cope with anything like an interlinked set of problems of this severity, scale, and complexity. There are no precedents. So far, we have failed to address the challenge adequately. Problems will continue to manifest themselves – both as we try to prevent and as we try to adapt to the consequences of climate change – so human systems will have to learn how better to respond. One of the central social, political, and economic questions of the century is: how then do we act?".

6 International agreements: effectiveness, equity and credibility

The global nature of the negative externality CC represents and scientific forcefulness regarding the anthropogenic character of CC have led to attempts to create international coalitions to define a carbon price that takes into account its social costs, and smooths transition to another energy system. However, as the 2014 Nobel Prize winner Professor Tirole (2017) acknowledges, the results forthcoming to date have, in practice, been disappointing.

The United Nations Framework Convention on Climate Change (UNFCCC) was signed in 1992 as part of what is known as the Rio de Janeiro Earth Summit. The Kyoto Protocol, adopted in December 1997, gave binding force to what had not been achieved five years earlier. It is the first attempted international agreement aimed at reducing GHG emissions. It did not come into force until February 2005. In 2009, 187 states had ratified it, although the United States never did, despite the fact that until its entry into force this country was the biggest GHG emitter; since 2005 China has been the main emitter.

The “Parties to” or members of the Convention met several times in successive years. Notable among these meetings was the XV International Conference on Climate Change in Copenhagen in 2009, known as COP15 (Conference of the Parties). The aim was the “conclusion of a legally binding agreement on climate, valid worldwide, to be applied as from 2012”. However, this summit was promptly declared a failure, as actually came to light years later in practice.

As a result of the limited participation in the Kyoto Protocol, and given the lack of agreement at the Copenhagen 2009 summit, the European Union (EU) forged an extensive and ambitious coalition of 195 developed and developing countries, that had been present at the December 2015 Paris Conference. An initial binding agreement to reduce GHG emissions was signed, establishing a transition between current policies and the climatic neutrality that should be in place at the end of the current century. This transition should lead to GHG emissions peaking as soon as possible, although they acknowledge that in the developing countries the process will be longer. Subsequently it should be possible to apply rapid reductions based on the improved scientific criteria available. A global action plan has been determined to maintain the cap on global warming far below 2 °C above pre-industrial levels, with the aim of achieving a maximum of 1.5 °C. In this connection, before and during the Paris Conference, known as COP21, countries unveiled their related national action plans against CC.

At the Paris Conference the IPCC was invited to prepare a report which, on the latest scientific evidence, would analyse the impacts of global warming of 1.5 °C above pre-industrial levels. This report [IPCC (2018)] was presented in October 2018. Among other conclusions, it warns that on current GHG emission trends an increase of 1.5 °C between 2030 and 2052 is very likely. This would assume there is an appreciable risk of not meeting the more ambitious Paris Agreement target in little more than a decade. One of the conclusions of this latter report, as indicated at the outset of this article, is that the reality of climate change exceeds the most pessimistic forecasts. The energy transition required is on a large scale and unprecedented. It will need to have a bearing on electricity generation, transport, industry, agriculture and cities.

The most notable outcome of the COP24 in Katowice (Poland), in December 2018, was to have agreed on the rules regarding transparency and the calculation of gas emissions and the reduction commitments assumed by each country under the Paris Agreement. In any event, three years later after the signing of this agreement, it has still not been possible to finalise all the rules to be applied. The outcome is actually rather paltry. It highlights the difficulty of the international fight against CC. Moreover, and unfortunately, it should be stressed that at the Katowice Summit four countries of great significance in GHG generation, namely the United States, Russia, Saudi Arabia and Kuwait, prevented the acceptance of the aforementioned IPCC report commissioned four years earlier at the Paris Conference. Once again, fossil fuel interests stand above scientific evidence.

The Paris Agreement was very ambitious and considers the correct solution. Undoubtedly, it was a notable diplomatic success. Yet as Tirole (2017) indicates, to be really successful in practice and promote the necessary energy transformation, such agreements should be effective from the economic standpoint, and equitable and credible. That is to say, there must be incentives in place so that what was agreed may be observed. Let us see to what extent this latest major agreement on the energy transition meets these three requirements.

Regarding effectiveness, the reality was that the diplomatic objective of reaching a unanimous agreement among the 195 delegations ignore the pressing need to set a carbon price. As earlier indicated, this carbon price is the basic recommendation for the internalisation of the negative externalities of GHGs.

If an agreement binding all countries is not reached, those who do not feel bound act as free-riders, i.e. they would have the rest resolve the problem without they themselves being prepared to do anything. This situation is not exclusive to the problem of CC; it also arises in those cases in which what are known as “common goods” are present, and climate stability is one such good. One of the characteristics of this type of good is non-excludability, meaning that there is free access to the use of this good whereby nobody may be excluded without prohibitive costs.

To avoid this situation, many economists have proposed an alternative to and more realistic solution than the unanimity of all countries. Two recent Nobel Prize winners are among them: Tirole (2017) and Nordhaus. Professor Nordhaus (2018b) revisited the issue in his above-mentioned lecture on 8 December at the University of Stockholm, on the occasion of the Nobel Prize award. The solution consists of creating an “international climate coalition”, which he calls the “climate club”. This club would initially bring together a significant number of countries based on the GHGs they emit. They would all commit to setting a carbon price. Countries that did not participate in this initial phase would be encouraged over a limited period of time to join the coalition. These types of coalitions have three basic characteristics: their members benefit from certain economies of scale by advancing together; they all pay to belong to the coalition;

and, finally, they have the capacity to exclude from the coalition those countries that are not prepared to pay to join it, and whose behaviour would be tantamount to commercial dumping. As a result, the coalition members should have the capacity within the World Trade Organization (WTO) to impose a tariff on the exports of non-member countries. The WTO, it should be recalled, has over 160 member countries accounting for 98% of world trade. The pillars on which it rests are the agreements negotiated and signed by member countries and ratified by their respective parliaments.

Regarding problems of fairness, it should be borne in mind that the more prosperous countries are those that have most contributed to the stock of GHGs. For example, since the Industrial Revolution, the United States and the EU are responsible for half of the emissions. That said, various other nations such as China, Russia and India are increasingly contributing to this stock. In particular, China's emissions last year represented 30% of the total. Accordingly, the Paris Agreement is committed to annually providing funds to developing countries, amounting to $100 billion in 2020, and to increasing this figure before 2025. However, an explicit and detailed allocation of these amounts to the various developing countries is lacking. Over three years since this agreement was signed, it now seems clear that the developing countries will not receive next year the $100 billion agreed on.

Moreover, as Chancel and Piketty (2015) have highlighted, there is not only a problem of inequality in emissions among countries, but also among individuals. These authors estimate that 10% of the world's wealthiest population is responsible for 45% of global emissions. Approximately, this same ratio holds for each of the countries considered individually. Accordingly if, when setting a price for GHG emissions, the different carbon footprints of citizens are not taken into account, those with the lowest income levels may wrongly be penalised. The solution to this problem is not complex and the idea is that of the "double dividend": the setting of a price which, in addition to reducing GHG emissions (first dividend), allows, using all or a portion of the revenues raised by this tax, for the reduction of other types of taxes, in particular those on the lowest incomes (second dividend). This redistribution process is readily applicable in a most transparent way through income tax. Even if the refund were total and equal for all citizens, without taking into consideration their level of income, this transfer would have a progressive effect.

Similar situations can be presented when other types of decisions needed in the energy transition process are applied. This is the case of the elimination of the subsidies or tax benefits that the majority of the most polluting fossil fuels enjoy today. Frequently, the political justification for this type of subsidy is the protection of low-income citizens. In practice, exactly the opposite occurs, i.e. they have clearly regressive consequences. Indeed, a recent paper by Gass and Echeverria (2017) drawing on several international studies indicates that only 7% of fossil fuel subsidies are targeted on the lowest distribution quintile, i.e. the 20% of the population with the lowest income. Meantime, the 20% of the highest incomes receive 40% of the subsidies.

When evaluating the social effects of specific measures aimed at smoothing the energy transition, the starting disparities which were just referred must be borne closely in mind. Naturally – and essentially – this is for reasons of fairness, but also to avoid, or to explain more rigorously, such spontaneous and clear-cut movements as the “yellow vests” in France. This movement arose against increases in the duties on certain types of fossil fuels. As indicated, it is not exactly those who took part in these protests who are the main beneficiaries of the low duties and subsidies on the fossil fuels that they use in their productive activity.

Finally, regarding the credibility of the agreements adopted in Paris, we should acknowledge that the only mechanism envisaged for all countries to meet the objectives to which they have committed is to name and shame those that do not comply with them within the periods established. Clearly, this must be done, and it is a necessary condition. However, such “stigmatising” of countries is not sufficient, as is shown by the experience stemming from the Kyoto Protocol more than 20 years ago. Non-compliant countries always have the possibility of brandishing all types of excuses to justify their failure to comply, e.g. an economic recession, budgetary problems or corporate and employment difficulties in the fossil fuel sectors affected by the commitments acquired.

Despite the failings – or rather shortcomings – of the international agreements to define and implement a genuine energy transition, not everything is a reason for pessimism. Some years ago James Hansen, ex-director of the NASA Goddard Institute for Space Studies (today part of the University of Columbia), and one of the scientists most active in transmitting to society the need to change our energy model, said that the scientific consensus on CC was not passing through properly to public opinion. He stated that society was receiving the message that a low carbon-emissions economy would mean all sorts of deprivation, which is obviously not true. Since then, public awareness that this is the most serious and complex collective action problem in the history of humanity has increased notably. Examples and surveys substantiating this statement abound. Moreover, several dozen countries, including most notably some in Europe, have taken and implemented in practice, with differing levels of success, the decision to set a carbon price. The EU has also pursued a series of initiatives and proposals since the early 1990s. The most recent of these was unveiled on 28 November 2018. It represents the long-term strategic view for an economy to be prosperous, modern, competitive and climate-neutral in GHG emissions by 2050. It is a proposal in line with the Paris Agreement, whose weaknesses have been discussed above.

7 The financial system in the energy transition

The economic and social problems currently addressed by both the developed and the developing countries – many of which stem from the last financial crisis – might lead us to believe that there are more important issues to be prioritised, ahead of the possible impacts that CC may have on the levels of well-being of future generations. However, we should remember that the financial crisis, the effects of which we are still suffering, was basically a consequence of over-emphasis on the short term for too long when setting profit targets and the incentives for economic agents. Moreover, prices and risks were mismanaged and wrongly valued. The result has been an excess of toxic assets and over-indebtedness of governments, businesses and households.

Similar mistakes are now being committed in relation to CC, with an over-emphasis on short-term problems and the use of excessively high discount rates for others, the full extent of which, as in this case, will only become apparent over a longer time horizon than that of a financial crisis. For some time the financial system has been generating too many toxic assets. Similarly, the current energy infrastructure has for decades been producing excessive GHGs. These situations both illustrate once again that when the price of a good does not reflect the costs and risks entailed by its use it will be consumed excessively. And that is precisely what has happened in the financial system and what is happening in the energy system.

Likewise, risks are being wrongly valued today, given the basic characteristics of the negative externalities that GHG emissions generate: they are global, their impact is in the long term, they are uncertain and the damage generated may be radical and irreversible. This misvaluation leads, as indicated, to fossil fuel prices failing to reflect environmental costs, especially the costs of GHG emissions and therefore sends the wrong signals to the market regarding the true cost of their production.

On 21 March 2019, the European Commission organised a conference on a global approach to sustainable finance [see EC (2019a)]. It was recognised that developed and developing countries today face a serious investment gap in delivering on the Paris Agreement. In fact, as referred to by the Commission, the Organisation for Economic Co-operation and Development (OECD) [see OECD (2018)] estimated that $6.9 trillion of annual investment in energy, transport, buildings and water infrastructure will be required up until 2030. We are clearly far from being able to ensure financing of this volume over the 15-year horizon since the Paris Agreement. Even greater investment will be required if, instead of 2 °C above pre-industrial levels, it is intended to cap global warming at 1.5 °C, as recommended by the ICCP. An unprecedented transformation of current infrastructure is required to achieve the proposed targets. During this conference it was made clear that the financial sector needs to play a fundamental role in mobilising private investors to finance projects of this type. This situation presents the financial system with a significant set of opportunities. Even so, this transition process also involves major, real risks, which by their nature are not readily quantifiable.

In an acclaimed, and already mentioned, speech in 2015 Carney put great stress on the fact that the potentially catastrophic effects of CC will only become fully and brutally apparent over time horizons beyond those considered by financial institutions in their strategic planning exercises. These costs will basically fall on future generations, so that today there are no direct incentives to address possible solutions. Moreover, monetary policy horizons are usually two to three years, while those for financial stability are linked to the credit cycle and may stretch to 10 years. However, the most serious problems arising from CC will only become fully apparent over longer time horizons. Hence, Mark Carney's "tragedy of the horizon".

But, the problem is that the type of risks that arise from CC only materialise over long horizons, while they would be all the more manageable the sooner that a true transition begins to a low carbon economy begins. This would follow predictable patterns, based on scientific results and specified in binding, credible agreements.

Basically there are three types of risk that the financial system needs to consider in the CC process. First, there are physical risks, arising from adverse climate-related phenomena, such as floods and storms, which may damage property and even disrupt production and commercial activity. Insurance companies began to recognise this type of risk some years back [see Lloyd's (2014)].

Second, there is the risk arising from the compensation that may be sought from businesses and activities responsible for GHG emissions. These are known as liability risks.

Third, there are so-called transition risks, which arise from the implications for the financial system of the transition to a lower carbon economy. This process will necessarily lead to a significant change in the value of some of the assets of fossil energy intensive businesses, the activity of which will be replaced by new renewable energy technologies. The reduction in the value of many of these assets will occur as a consequence of the regulations that eventually fix a price for GHG emissions and of the fall in the demand for fossil energy, given the more competitive prices of renewable energy.

A number of professional and academic institutions have analysed the maximum amount of GHGs that may be emitted before the year 2050 for the temperature rise to remain within the limits envisaged in the Paris Agreement. This maximum amount is known as the "carbon budget". The various models and hypotheses used for this calculation are summarised in a Carbon Tracker Initiative (CTI) paper [see CTI (2018)]. We need to be aware of these as they are one of the reasons for the differences between figures published. For example, the carbon budgets published by the IEA and the IPCC are not directly comparable. The IEA only calculates the carbon budget for the energy sector, the major source of GHG emissions. By contrast, the IPCC budget takes into account all anthropic sources of GHG. At all events, the existence of this “carbon budget” constraint has a significant impact not only on the value of the fossil energy reserves recognised in the financial statements of energy businesses, but also has a significant impact on many of the assets of businesses that transform or use fossil energy. Among other institutions, the IEA, the IPCC and the Grantham Research Institute on Climate Change and the Environment have been warning about this situation for years.

McGlade and Ekins (2015) point out in an article in *Nature* that only about one third of the GHGs contained in the estimated coal, oil and gas reserves can be used if the Paris Agreement are to be complied with. Carney (2015) stresses this fact, noting that 19% of FTSE 100 companies are in natural resource and extraction sectors, and a further 11% in power utilities, chemicals, construction and industrial goods sectors.

In any case, these “stranded” or unusable assets in fossil energy reserves only affect “upstream” activities, i.e. exploration and production, and not “downstream” refining and processing activities. However, as mentioned above, the assets in other sectors that may be stranded in the energy transition process are also very important. Analysis taking this into account has been carried out by, among other institutions, the International Renewable Energy Agency (IRENA), commissioned by the German government at the time of its presidency of the G20 leaders’ summit in 2017. The IRENA (2017) study extends to 70 countries accounting for 80% of global fossil energy use. It considers for these countries, not only the assets related to upstream activity but also those related to downstream activities, industry and construction. These sectors are responsible for approximately 75% of GHG emissions. The analysis is based on two scenarios: first, the one envisaged by the Paris Agreement; and second, business as usual. Under certain assumptions, it is found that delaying measures to undertake the energy transition would double the amount of “stranded assets”, from $10 trillion to $20 trillion. The latter is equivalent to 6.3% of global wealth, according to Credit Suisse (2018) data, and of the same order of magnitude as US GDP.

These figures clearly illustrate the potential risk of an abrupt energy transition having destabilising effects on the financial system. It is not enough, however, simply to be aware of the economic magnitude of stranded assets; a feasible energy transition process also needs to be defined, based on a credible policy that can help businesses pursue long-term strategies to ensure the adjustment in the value of their assets is gradual rather than sudden. The European Systemic Risk Board (ESRB) is aware of this situation. In its February 2016 report [see ESRB (2016)] it warns of the risks that the transition will be carried out late and abruptly. It points out that this adverse scenario could jeopardise financial stability, for three reasons in particular: the macroeconomic impact of sudden changes in energy use; the revaluation of carbon-intensive assets; and a rise in the incidence of natural catastrophes.

Apart from the figures already discussed, public and private economic agents clearly lack the appropriate information to tackle this problem. For the markets to anticipate and facilitate the energy transition, in accordance with the Paris Agreement, they need to have accurate information on the basis of which to define appropriate risk management within a credible and consistent public policy framework.

To this end, in December 2015, the Financial Stability Board (FSB) announced the setting-up of the Task Force on Climate-related Financial Disclosures (TCFD). The current supporters of the TCFD include more than 70% of systemic banks, eight of the top 10 global asset managers, the leading pension funds and insurers, major credit rating agencies and the Big Four accounting firms. In total, these financial firms manage around $110 trillion of assets. In September 2018, the TCFD published its first status report on the recommendations for voluntary energy transition-related financial disclosures, which it presented in July 2017 to the Hamburg G20 Leaders' Summit.

In his speech to the above-mentioned European Commission conference on sustainable finance on 21 March 2019, Carney (2019) recognised that, three years after the announcement of the creation of the TCFD, the results presented in this status report fell well short of what was required to assess the CC-related risks of the firms evaluated. Specifically, the financial implications of the energy transition are often not disclosed, disclosures are often made in multiple reports – so that comparisons between firms and sectors were very difficult to make – and disclosures vary greatly by industry and region. He also said that higher percentages of European firms, and higher shares of those in the energy sector, had most disclosed information aligned with the TCFD's recommendations. The second report of the TCFD was presented to the 2019 Osaka G20 summit. Once again, there was evidence of the slow incorporation of fossil fuel-related firms into this initiative to disclose CC-related financial information. There was also renewed insistence that the information provided by those that had joined the initiative was far from useful for channeling the investment needed to meet the Paris Agreement targets. In view of the disappointing results to date, substantial improvements in the quantity and quality of the information of this nature that the markets should have at their disposal are not to be expected. It should be recalled that these are voluntary decisions and the TCFD's initiatives merely seek to create a virtuous circle that encourages the firms in question to comply with its recommendations.

In these circumstances, it is hard for the banking sector to manage CC-related risks on the basis of quality information. It should be recognised that, in practice, we are a long way not only from starting to consider the impact of extreme weather phenomena on sovereign risk, but also from rigorously taking into account transition risks. These include, for example, the risk of exposure to carbon-intensive sectors or simply transactions relating to transport systems that use diesel. The truth is that, as of today, these types of risks are mentioned by banks solely in relation to corporate social responsibility and are very far from being recognised as genuine financial risks. Based on a recent pilot study, Lautenschläger (2019) concludes that European banks are aware of the risks CC entails, but this is nevertheless an issue that they only consider within the realm of corporate social responsibility.

Following the particularly useful criterion of Professor Diebold et al. (2010), risks may be classified into three categories: known, unknown and unknowable. From this perspective, a known risk is one that can be identified and modelled. By no means is a known risk certain to occur, but it can be characterised by a probability distribution function of potential profits and losses. An unknown risk is one that is known to exist, but cannot be satisfactorily modelled. Finally, an unknowable risk is one that simply cannot be known in advance and that becomes an unknown risk when it occurs. The latter – called "black swans" by Taleb – have a very low probability, but may give rise to huge losses. For these risks we have no generally accepted theory to enable us to foresee them.

A large part of the development of risk management techniques in recent decades has consisted in converting unknowable risks into unknown risks and the latter, in turn, into known risks. Owing to the process of constant innovation and change in the social and economic environment, the boundaries between these risks are not immovable. In fact, there may be certain situations in which known risks become unknown risks and others that result in new unknowable risks eventually becoming decisive. In this context, when science confirms that the origin of CC is anthropic, it will no longer be appropriate for financial risks arising from the energy transition to be categorised as unknowable risks. Instead they should be categorised as unknown risks, to the extent that we will know they definitely exist, even though the uncertainties still present in the course of the energy transition, under the Paris Agreement, may mean that their probability distribution function cannot be determined. This is a characteristic they share with operational risks, which include, inter alia, legal and other risks arising from human error or system or process failures. Obviously this type of risk is not readily quantifiable from a statistical point of view, but that is no reason for not taking it into account. Risk assessment, as is well known, must be based on both quantitative and qualitative criteria if it is to be feasible and accurate.

Evidence that climate risk is not taken into account in the actual management of financial risks is the increase in the financing that the banking system as a whole continues to provide to businesses strongly linked to GHG emissions. For example, between the signing of the Paris Agreement and the end of 2018, the 33 major global banks lent $1.9 trillion to the fossil fuel companies [see BankTrack (2019)]. This flow of resources is of course consistent with proposals such as that made by the giant ExxonMobil, which announced, when presenting its results of 2018, an ambitious growth plan, based on the assumption that oil and gas production in 2025 will be 25% higher than in 2017 [see The Economist (2019a)]. Admittedly, this activity is made, in many cases, to square with clear pronouncements in favour of sustainable finance in their public reports on corporate social responsibility.

Since the adoption of sustainable development targets in February 2015 and, naturally, since the signing of the Paris Agreement in December 2015, the EU has been placing special emphasis on the commitments arising from compliance with such targets for the public sector and private sector. An up-to-date summary of all those relating to the sustainable financing strategies can be consulted at EC (2019b).

Central banks have been aware of the impact that CC can have on their microprudential and macroprudential responsibilities. This lay behind the creation of the Network for Greening the Financial System (NGFS), which at the outset comprised eight central banks and supervisory authorities and which now boasts 42 members and eight observers from all five continents. The most notable absence is that of the Federal Reserve. The aim of this project is to help reinforce the global response needed to meet the Paris Agreement targets and, specifically, to strengthen the role of the financial system in the management of CC risks and to promote the routing of resources towards green and low-carbon investment. The Network published its first report in April 2019 [see NGFS (2019)].

Also, the three main credit rating agencies have integrated environmental risk and green certification into their ratings. And international organisations such as the Climate Bonds Initiative [CBI (2019)] and the International Capital Markets Association (ICMA) have developed frameworks for definition, certification methods and validation for green or ecological financing.

The asset management industry, both in individual and collective initiatives, has been incorporated in recent years into investment in projects that comply with environmental, social and governance (ESG) criteria. A notable initiative is that of the Principles for Responsible Investment [PRI (2019)], which has more than 2,000 signatories who manage a total of $80 trillion.

In theory, as pointed out by Carney (2019), firms that comply with ESG criteria may be more profitable for three reasons: they are better placed to anticipate risks and opportunities of the energy transition; the market recognises their long-term planning and thinking criteria; and they may be favoured by the tendency of investors, especially the younger generations, to commit more strongly to economic sustainability values.

The question to be asked, therefore, is whether in the current situation the markets are taking into account climate risks and the banking system is adequately financing the energy transition process. A sign of the growing sensitivity of the market to climate risks might be considered to be the relatively rapid growth in the issuance of so-called green bonds. The funds raised by these bonds are used to finance or refinance assets related to the energy transition or projects to improve the environment. Specifically, they must comply with the principles that some of the above-mentioned institutions, such as the Climate Bonds Initiative or the International Capital Markets Association, have developed.

This idea seems attractive, and their boom in recent years would confirm that. In 2017, issuance of green bonds amounted to $173.5 billion. In 2018, all analysts had predicted a substantial increase, but total issuance amounted to $174.9 billion. Thus, the market for green bonds, created barely more than 10 years ago, was worth over $500 billion at the close of last year. All of these figures were provided by Environmental Finance (2019).

The green bonds are not the only green financing instrument, but they are by far the most successful ones. The market currently includes a broad range of issuers, notably governments, but also private companies have a relevant share, especially energy businesses. In 2018, the banking sector issued 30% of the total and increased its share with respect to 2017, when it was 22%. To analyse the importance of this market in the annual financing requirements, it suffices to point out that total green bond issues in 2018 accounted for only 2.5% of the annual financing required by the energy transition. And such annual financing, as stated and acknowledged by the European Commission amounts to $6.9 trillion. It would be illusory to think that this financing instrument, as currently designed, can play an important role in the energy transition, despite the greater attention afforded to it by institutions and markets.

There are a number of grounds for this claim. Firstly, the commercial strategy of asset managers and the market of analysts surrounding them. As noted by an editorial in The Economist (2019b), given the collapse of their traditional business, they more than happy to be involved in the sale of green instruments for which they expect to obtain higher commissions. The truth, however, is that very few large institutional investors have ruled out continuing to invest in companies connected with fossil fuels. Also, despite the large amount of publicity they pour into the market, the commitment of the major oil companies to the energy transition is irrelevant.

In today's market, it is still not easy to state when an issue of green bonds can be characterised as such. Several criteria and standards are applied in practice. According to Schoenmaker and Schramade (2019), it is legitimate to ask to what extent green bonds issued by countries such as Indonesia, Poland or China comply with the restrictions observed by those of other countries and businesses. It is sufficient to recall that 80% of Poland's energy is coal-based and that Indonesia, which is the fifth largest CO_2 emitter in the world, generates half of its electricity using coal power stations. Moreover, the guidelines and standards set by the National Development and Reform Commission of China [see NDRC (2019)] reveals they apply little strictness in the characterisation of their green bond issues. Note that in 2018 China was the second most active country in this market, with issuance of $33.1 billion.

In the current situation, numerous criticisms may be levelled about whether, in reality, green bonds meet the targets they announce or whether, simply, they offer an evidence as to the financial system's understanding of CC.

If we consider outstanding green bonds, it should be noted that their risk is determined by the issuer's credit rating, and this will be the same as that for any other type of bond issued. This is why no difference in the prices of these and other types of bonds should be expected. For example, a study by Morgan Stanley (2017) based on a broad sample of bond issues concludes that, having adjusted for their different characteristics, green bonds have the same price as conventional ones. Similar findings were obtained by the study of NN Investment Partners (2018). There are other analyses which, in their attempt to justify that the capital markets adequately quantify the carbon risk, provide different conclusions. But the truth is they are only so in appearance, since statistically these differences are not conclusively significant. It seems clear that the markets, with regard to the energy transition, do not believe what science says. This is not the first time, nor will it be the last.

The funds raised by green bond issuers are fungible, i.e. their source is irrelevant for their subsequent use. Accordingly, it cannot be ruled out that funds raised from this type of issue may have ended up financing fossil fuel projects. Avoiding this situation would require detailed disclosure of the investment flows of the issuer, which would not only involve more time, but also additional cost.

Mindful of this scenario, the High-Level Expert Group on Sustainable Finance set up within the European Commission published in June this year a report laying down the criteria for future European legislation for the classification or taxonomy of sustainable projects [see EC (2019b)]. This is an essential requirement for the proper channeling of financial resources to the energy transition. As a result of this taxonomy, standards and labels will be created for green financial instruments, in order to give them greater visibility and to transmit greater confidence to investors. Also linked to this process is the debate on the incentives for sustainable investments ('green supporting factor'), and the penalisation of carbon-intensive investments ('brown penalising factor'). Ultimately, this process of project taxonomy will allow the capital requirements of financial institutions for both types of investment to be set and differentiated.

However, the EU should go a lot further. As De Grauwe (2018) rightly indicates, the budgetary constraints imposed on the Monetary Union (MU) countries do not allow for ready financing of the energy transition. They oblige any costs arising from the investment needed to fall on current generations, either through an increase in taxes or through a reduction in spending. Misgivings here are understandable, since governments are aware of the electoral cost they will incur if they take either decision, or both simultaneously.

This situation has led, in practice, to the investment needed being postponed or to its amount being drastically reduced. As De Grauwe indicates, the issuance of bonds is the appropriate procedure for distributing costs among successive generations, given that the interest payments are distributed in horizons lasting several years. Since current expenditure accounts for approximately 95% of the MU countries' budget, De Grauwe proposes that the aforementioned constraints be confined to the budget for such expenditure; in that way a specific budget not subject to such constraints is defined to address the investment needed for the economic transition. In light of the current climate situation characterised in this article, it would be desirable for the initiative posited to be within the EU framework. Unquestionably, investments of this type would meet the basic principle whereby the expected return should exceed the cost of capital. A recent paper by Blanchard (2019) on fiscal policy with low interest rates allows for grounded discussion of the conditions of public finances sustainability and also for the justification of financing the energy transition with the issuance of green public debt.

Public policies will be called on to play a pivotal role in the energy transition: not by regulating more, but by doing so better. For example, by avoiding extending the life of old fossil fuel technologies, in markets that are already highly regulated, with the aim of hindering the entry of future technologies. Theory and experience show that it is not reasonable to transfer to the market economic and political responsibilities that are incumbent upon democratic governments, and that markets' known failures should be corrected, since the final result is a deterioration in the market and in the basic rules underpinning its workings.

8 Epilogue

Clearly, a description of the activity and agendas of the many organisations playing an active role in combating CC might have merited more space. And so too might too those of the various international financial agencies acting diligently in this area. They all give a good account: they accept the seriousness of the situation and make a set of sensible proposals from the economic and financial standpoint. Yet as may be inferred so far from this article, the results obtained have, in practice, been very disappointing if, for instance, we take the 1992 Rio de Janeiro United Nations Framework Convention on Climate Change as our reference. Returning to the core of this text, it is not reasonable to expect the financial system to play a key role in the necessary routing of financial flows towards non-carbon-intensive activities if the problem posed by the negative externalities of GHG emissions is not being tackled rigorously and definitively. The solution to this problem is well-known: a price must be set on each unit of CO_2 emitted. This basic economic principle has been recalled in the public statement by more than 3,500 of US-based economists on 17 January 2019 [see CLC (2019)]. Among those backing it are all the former Chairs of the Federal Reserve, 27 Nobel Laureate economists, 15 former Chairs of the Council of Economic Advisers and two former Secretaries of the US Department of Treasury. The statement, published in the Financial Times, The Wall Street Journal and The Washington Post, notably includes among its signatory economists both Democrats and Republicans.

As indicated, setting a price on each unit of CO_2 emitted is not a sufficient condition for effectively addressing the problem of CC; but it is undoubtedly a necessary prerequisite. At this stage, with almost 30 years having elapsed since the Rio de Janeiro Convention, 57 initiatives setting a price on CO_2 are today in place in 46 national jurisdictions. These initiatives have entailed, in some cases, setting a tax and, in others, creating markets for transferable emission permits. However, it should be stressed that, overall, they cover only 20% of global GHG emissions, according to the data provided by the World Bank's Carbon Pricing Dashboard (CPD) [see CPD (2019)]. Notable in this connection is the EU, a pioneer in setting in place markets for transferable emission permits in 2005. Currently this is the world's most outstanding initiative, as it involves more than 11,000 electric power and industrial plants, along with airline companies, in the 28 EU countries and the three associated countries: Norway, Iceland and Liechtenstein.

However, for one reason or another, not all these initiatives are yielding the expected results. For example, under its approach, currently in its third phase (2013-2020), the EU has had to introduce successive changes from the outset. Among other reasons, this has been to avoid the excessively low prices a ton of CO_2 had reached. But this is a more general situation since half of the emissions subject to the aforementioned 57 initiatives are priced at below \$10 per ton of CO_2. That is far below the margins set by the World Bank's High-Level Commission on Carbon Prices, co-chaired by Joseph Stiglitz and Nicholas Stern, for intervention to be effective. These minimum values have been estimated at \$40-\$80 per ton of CO_2 for 2020 and at \$50-\$100 per ton of CO_2 for 2030 [see CPLC (2017)]. In sum, it is not a very flattering picture.

The process is encountering many difficulties along the way. True, the CC narrative appears to have changed in the past decade, and the deniers are less prominent than was the case some years back. But it is not difficult to appreciate that the discourse is one thing and specific action something quite different. The real players in the fossil fuel industry and the lobbies surrounding them continue to act by pursuing the well-publicised strategies that have been described in this article, namely to hamper the vital energy transition needed. For example, as once more signalled [see CTI (2019a)], none of the major European oil firms are in step with the Paris Agreement targets, in light of the investment projects their boards have since approved. This is particularly worrying since these firms are precisely those that have most adhered to the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD). It is disheartening to see, once again, how incongruous this behaviour is. Corporate and social responsibility involves saying what you are doing, and doing what you say.

All told, incentives have a key role to play here too. And this is highlighted in a recent paper covering the 40 biggest US companies in upstream oil and gas activities [see CTI (2019b)]. As recently as 2017, 92% of the companies analysed included, for their managers' remuneration, metrics directly incentivising growth in the use of fossil fuels, in relation to reserves and production. The paper notes the small number of firms that have included measures directly relating to CC, but also flags up the somewhat perverse situation whereby many of them are compatible with the incentives to increase fossil fuel generation.

The obstacles fossil fuel companies are placing in the way of a genuine energy transition are, then, no surprise. We might well recall the words of the US novelist Upton Sinclair: "It's impossible to make a man understand something when his salary depends on him not understanding it".

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