No 2016-10 – April

Working Paper

CEPII

Climate and Finance Systemic Risks, more than an Analogy? The Climate Fragility Hypothesis

Michel Aglietta & Étienne Espagne

Highlights

- The notion of climate systemic risk is developed.
- Climate change is usually considered as a negative externality, against which society can insure itself through a carbon tax or an emission trading market.
- A collective insurance approach to climate change has to target the financial sector, as well as its articulation with monetary policy.
- As in the financial world, climate change thus constitutes a systemic risk against which specific ex ante and ex post monetary policies and financial regulations should be deployed.

Abstract

In this paper, we develop the notion of climate systemic risk. Climate change is usually considered as a negative externality, against which society can insure itself through a carbon tax or an emission trading market. But except under the unrealistic efficient market hypothesis, there is little chance that such a simple approach to climate policy succeeds in mitigating climate damages. Financial and climate fragility reinforce each other. We argue that in concrete economies, a collective insurance approach to climate change has to target the financial sector, as well as its articulation with monetary policy. As in the financial world, climate change thus constitutes a systemic risk against which specific ex ante and ex post monetary policies and financial regulations should be deployed. The Paris Agreement of COP21 ignores the policy consequences of such an approach to the climate threat, but the exegesis of the text still offers some indispensable pillars to promote a new financial order mitigating climate systemic risk.

Keywords

Systemic Risk, Climate Fragility, Monetary Policy, Macroprudential Policy, COP21.

JEL

Q51, Q54, Q58, E42, E44, E58.

Working Paper

CEPII

CEPII (Centre d'Etudes Prospectives et d'Informations Internationales) is a French institute dedicated to producing independent, policy-oriented economic research helpful to understand the international economic environment and challenges in the areas of trade policy, competitiveness, macroeconomics, international finance and growth.

CEPII Working Paper
Contributing to research in international economics

Editorial Director:
Sébastien Jean

Production:
Laure Boivin

No ISSN: 1293-2574

CEPII
113, rue de Grenelle
75007 Paris
+33 1 53 68 55 00

www.cepii.fr
Press contact: presse@cepii.fr

RESEARCH AND EXPERTISE
ON THE WORLD ECONOMY

Climate and finance systemic risks, more than an analogy?
The climate fragility hypothesis

Etienne Espagne and Michel Aglietta

1. Introduction

In this paper, we develop the notion of climate systemic risk. Climate change is usually considered as a negative externality, against which society can insure itself through a carbon tax or an emission trading market. But except under the unrealistic efficient market hypothesis, there is little chance that such a simple approach to climate policy succeeds in mitigating climate damages. Financial and climate fragility reinforce each other. We argue that in concrete economies, a collective insurance approach to climate change has to target the financial sector, as well as its articulation with monetary policy. As in the financial world, climate change thus constitutes a systemic risk against which specific *ex ante* and *ex post* monetary policies and financial regulations should be deployed. The Paris Agreement of COP21 ignores the policy consequences of such an approach to the climate threat, but the exegesis of the text still offers some indispensable pillars to promote a new financial order mitigating climate systemic risk.

A new notion

Climate change impacts human societies and economies in both a non linear and unpredictable ways. Tipping points can arise and irreversibly change both the state of the planet, and the way we live on it. They have been analyzed to arise from many sources: the natural carbon cycle itself, through the non-linear absorption rate of the ocean and the terrestrial biosphere as well as its coupling with the climate[1]; the climate system, through a fast increase in the frequency and the severity of extreme events, the melting of Greenland's ice-sheet, an abrupt change in ocean circulation, a strong increase in CO_2 and CH_4 emissions through the melting of the permafrost. Some of these changes happen slowly, accumulating unnoticed disequilibria over long periods of time; some are very sudden and unpredictable, arising at some specific point of the planet, with potentially broader contagion affects.

There is thus a high level of uncertainty on the exact timing and impact of such events, not only because of the physical processes themselves, but also because they are intimately linked with humans' reactions and policies. Weitzman (2009) summarizes this deep uncertainty with his now famous « dismal theorem »: probability distributions of many climate parameters are such that the possibility of an extreme value cannot be ruled out. Uncertainty

[1] The standard DICE model developed by Nordhaus (Nordhaus, 1993) makes the hypothsesis of a linear absorption rate of the ocean module.

cannot be modeled through standard Gaussian centered distributions. Fat tails are a crucial element of representation of uncertainty. Indeed, the more we fail to act against climate change, the fatter the tails. Inaction is playing as a positive feedback loop against the stability of the climate system in probabilistic terms (Perrissin *et al.,* 2014).

In such a theoretical framework, as Weitzman goes on, climate policies should be looking more at insurance theory than at traditional externality theory. But the specifics and consequences of such an insurance approach are never fully developed, so that the final recommendation remains stuck with the usual anthem: “Price carbon, cap the flow of emissions, there is no other way out” (Weitzman, 2015). How can we induce from the insurance approach the definition of proper tool(s) to fight climate change? How can we insure society against an event that determines its own existence/destruction? Looking further, is the insurance analogy sufficient to stress out the climate change constraint? In financial terms, how far is financial risk hedgeable? In this paper, we try to fully appreciate the consequences of such a paradigmatic change in climate policies. For that matter, we introduce the notion of climate systemic risk, by analogy with the notion of financial systemic risk.

The notion of systemic risk, which has been widely rediscovered to analyze the fragility of the financial sector right after the 2008 financial crisis, and its policy implications in order to stabilize the system, can partly be used to tackle climate change issues. We thus apply this concept, drawn from Keynes’s radical uncertainty and Minsky’s financial instability hypotheses, to climate change debates, and discuss how it could pave the way to new types of climate policies, which would crucially complement the traditional carbon pricing as well as Weitzman’s insurance approach. Three fundamental reasons at least can justify this transposition of this financial concept to climate.

Three reasons

First, climate change impacts are systemic in nature. They affect the whole planet, in most of its dimensions. They have the ability to profoundly change the Earth system as we currently know it. This is a first-level definition of a climate systemic risk. Of course they affect society on the way, either through global damages or through localized extreme events which can propagate to larger portions of territory using different channels, physical, social or financial. We develop this first approach of a systemic climate risk in part 2 in a much more detailed manner, using recent literature from the climate science field. But we cannot consider these changes affecting societies and the Earth system as if they were coming from the outside. These negative global effects are the product of endogenous forces. In this regard, an insurance approach such as the one called for by Weitzman can only be effective if it is collectively pursued. Individual insurance policies will be powerless, and could even be counterproductive in aggregate if they lead to avoidance behaviors, where each agent tries to escape the shared responsibility of the externalities. Indeed, it is the very nature of systemic risk: a situation whereby the rational behavior of independent individual agents gives rise to a worst outcome for all, due to widespread market failures. An effective climate policy can thus be thought of as a collective insurance of society against its own potential destruction. Climate systemic risk may only be collectively hedgeable.

This leads us to the second reason why the notion of systemic risk is relevant for climate issues. Such a collective insurance of society is the equivalent of a value that society attributes to mitigation activities. The vehicle of such a value can theoretically take multiple forms. In the world of efficient markets, and perfectly rational self-interested agents, a carbon price only policy could do the job, realigning prices and portfolios according to the collective value given to the climate externality, given anticipated scenarios of climate damages. But in such a world, a systemic risk is also impossible, because it contradicts the fundamental hypothesis that markets give the full available information on prospective scenarios of climate damages. So we face a crucial choice: either stick to the efficient market hypothesis, but then reject the “fat-tail” form of climate damages distribution proven by Weitzman, that is the possibility of a climate systemic risk; or adopt the climate systemic risk hypothesis, and then consider that a price only mechanism will not be enough to prevent uncertain extreme events from happening. Obviously, as was demonstrated again in the 2008 crisis, systemic events periodically arise in capitalist societies. Moreover, the fat-tailed form of climate damages adopted by Weitzman stems from the best available research on climate change. We thus have to adopt the second choice. This means rejecting the efficient market hypothesis and adopting the radical uncertainty hypothesis that applies to concrete economies (Aglietta, 1991; Aglietta, 2003). Radical uncertainty precludes the capacity of financial markets to define common knowledge of fundamental values, thus giving rise to momentum-driven processes embodied in financial cycles. The basic reason lies in the limitation of knowledge. Unknowns of future events are treated in insurance by risk estimates. But unknowns unknowns*, i-e.* the impossibility to identify the range of future events and even their possible appearance, are the gist of social and natural phenomena, and of their interactions. Radical uncertainty adopts this second level of knowledge limitation.

It is why concrete economies are necessarily characterized by imperfect and incomplete markets. Individual decisions are coordinated through rules, habits and institutions, which strongly influence their environment. Concrete economies can exhibit multiple equilibria. The selection of equilibrium depends on the characteristics of those intermediary institutions, among which financial institutions are crucial. The limitation of individual decisions through these sets of rules, habits and intermediary institutions is not suboptimal, as it would be in the world of efficient markets. It is rather a stabilizing social force, which helps aggregate individual expectations in line with the objectives of the legislator or the regulator. The vehicle of this coordination in such concrete economies lies in finance and in the institution of money. Understood as a structured network of payment systems, which validates or denies the socialization of private debts, the institution of money is the true catalyzer (or bridler) of systemic risk. Financial fragility to external risks may increase climate fragility through negative externality effects. Conversely, climate fragility incurs new risks that may reinforce financial fragility. Climate policy should then fully integrate the payment system structure into the carbon pricing debate. We propose a first attempt at this integration in part 3, detailing the positive feedback loops between financial and climate fragilities in part 4. Financial regulation options are discussed in part 5.

Finally, the notion of a climate systemic risk at world scale provides a powerful new rationale in the debate on international monetary reform. The key concept of the current international monetary system is the notion of market efficiency in internal settings, and externally the convertibility of currencies and free capital flows. The "Washington consensus" and the US$ as a key currency materialize this model, which has a hard time financing long-term investments while driving the world into secular stagnation (Teulings et al., 2012). The key concept to a reformed financial system incorporating the notion of climate systemic risk would be systemic resilience. It would use a multilateral currency to restructure finance around the production of global public goods and positive externalities. National and multilateral development banks would play a key role in such a framework, and could be seen as precursors of a new growth regime. Such a currency could also help build new forms of financial transfers between countries in order to respect the principle of "common but differentiated responsibilities", internationally recognized by the Paris Agreement of COP21 (UNFCCC, 2015). The notion of climate systemic risk is thus also a strong theoretical basis to elaborate a path towards international monetary reform. We venture into this issue in part 6.

Related literature and relevance to the policy debate

New research, both theoretical and applied, on the role of different aspects of the financial sector with regards to the low-carbon transition has recently arisen. In particular, (Rezai et Stagl, 2016) describe how recent literature has begun to merge ecological with macroeconomic thinking. In this new field, finance and financialization are seen as a key leverage for sustainability (Hourcade et al., 2012; Aglietta and Hourcade, 2012). The debates are mostly separated between the question of the desirability/feasibility of de-growth (Jackson 2015), and the ways of directing the volume and composition of investment (Fontana et Sawiyer, 2016; Aglietta at al., 2015), as a complement or substitute to carbon pricing. (Campoglio, 2015) summarizes the various financial channels which could be used so that a low-carbon financial policy could complement a more standard carbon pricing policy. In more policy-oriented literature, the UNEP Inquiry has produced various country reports on prudential and monetary policies already incorporating some long-term externalities issues, summarized in (UNEP Inquiry, 2015). We follow this second stream of research, while trying to push both the theoretical and policy implications farther.

Despite its crucial importance, there is in fact a lack of analysis regarding the theoretical foundations, which could back up such financial regulations/restrictions. For example, Campoglio (2015) remarkably investigates the potential role of the private banking system in financing low-carbon investment, if central banks and financial regulation institutions give them the right incentives, but the only justification of such interventions is the necessary increase of the amount of credit flowing to low-carbon activities. The immediate answer of a central banker to this kind of proposal can be summarized by this quote from the Gouverneur de la Banque de France, François Villeroy De Galhau, in a speech at the French National Assembly right before the beginning of COP21 (Villeroy De Galhau, 2015): “We must bear in mind the ultimate aim of monetary policy. It is designed to achieve macroeconomic objectives, not sector-specific goals.”. As (Campoglio, 2015) recognizes, “environmental sustainability is not usually part of the mandate of central banks”. If we rediscover today, in post-world-war II European monetary policies, some fruitful lessons for a monetary world where interest rates are incapacitated (Monnet, 2014) and long term social values are integral part of the mandate of central banks (Espagne *et al.*, 2015), a strong theoretical basis is still needed to get the central banks on board in the low-carbon transition.

This paper aims at filling this theoretical gap, by adopting the general view of climate change as a systemic risk both for societies in general and for the financial system in particular. In such a theoretical framework, monetary policy and the financial sector as a whole become central actors of an orderly low-carbon transition, or its failure, without imposing any “sector-specific goals” to the financial regulator (Villeroy De Galhau, 2015). The recent Paris conference has put to the fore the question of finance in relation to the transition to a low carbon economy. A few points in the final Text (articles 2 and 6 of the Agreement, paragraph 108 and 134 of the Decision), as well as the so-called Lima-Paris Action agenda, and the simultaneous mission given to the Financial Stability Board[2], are a few testimonies of the new encounter between financial actors and the climate challenge. But the most stringent specifics have also been put aside for future less mediated conferences of the Parties. It is thus the right moment to engage into this research agenda.

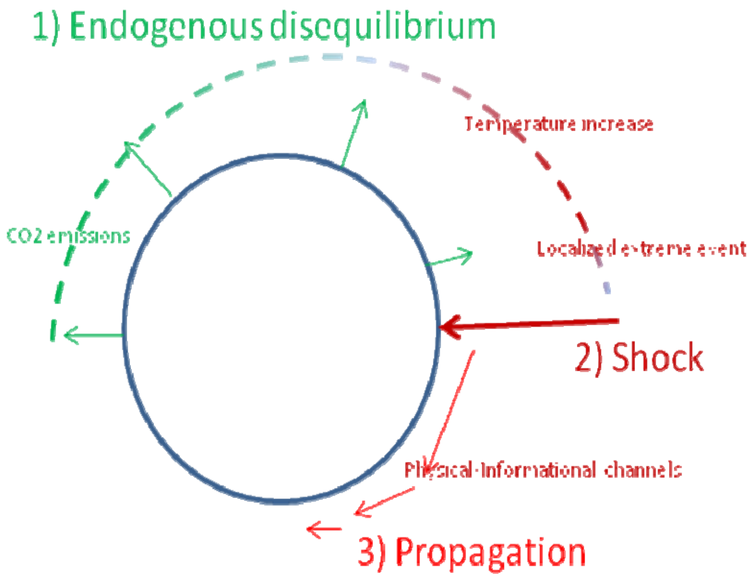
The structure of the paper is as follows. Section 2 briefly defines the materiality of a climate systemic risk. Section 3 emphasizes how the different dynamics of propagation of a climate systemic risk imply a fundamental change of perspective from simple carbon pricing discussions to the immersion into structural financial reforms debates. Section 4 develops the specific financial channels through which a climate systemic event can develop into a full-blown financial crisis, through circular causality effects. Section 5 proposes some policy measures to counter this outcome. It requires a safety net combining different means of action, which include but are not limited to a carbon price: collective insurance, prudential norms, information transparency, but also rules and incentives to influence the evolution of financial structures, as well as monetary policies aimed at reducing the instability of carbon values on financial markets. A roadmap for a reform of the international monetary and financial system which would be consistent with the systemic resilience of societies to climate change is drawn in Section 6. Section 7 concludes on the necessary improvements of financial research on the representation of the causes and cures of climate systemic risks.

[2] See https://www.fsb-tcfd.org/.

2. How climate systemic events arise

A systemic event is defined in economics by three essential elements: a shock, which can be a broad shock simultaneously affecting a wide range of institutions, or a limited shock followed by an important domino effect[3]; contagion effects through a web of interrelations; and the endogenous nature of this shock, meaning that it is caused by cumulated disequilibria over time. These disequilibria occur because conflicts between debtors and creditors are always latent when financial valuation is uncertain. The gap between the externalities generated by individual behaviors and the regulatory capacities of the institutions in charge to mitigate them can widen as a consequence. This conflict induces unsatisfying macroeconomic states, where the well-being of almost everybody is reduced. The possible transposition to climate change impacts on Earth, societies and their economies is striking, as figure 1 illustrates: IPCC (2014) shows that we evidently have the possibility of a global shock through an irreversible increase in temperature levels and more localized shocks through extreme events of all sorts; most of these shocks have been proved to be caused by human action (Pachauri *et al.*, 2014). Both types of shocks can of course be intertwined, leading to severe crises.

Figure 1 – Climate change has all the characteristics usually attributed to a systemic risk in the financial world.



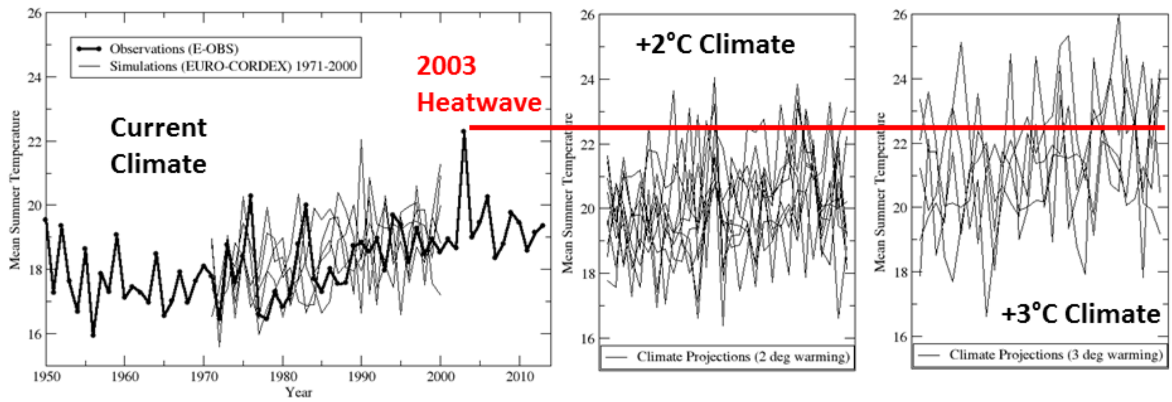
[3] We call a domino effect the mechanical transmission process of the initial shock. Contagion effects are supposed to arise through shifts in the expectations of economic actors, generally by means of financial markets.

Shocks

Idiosyncratic shocks that do not propagate widely are insurable in the sense that investors can protect themselves against them by diversification, or that society can easily pay for the incurred damages. On the contrary, systemic shocks are by definition non insurable or non diversifiable. But the limit between the two crucially depends on the possibilities of propagation. These propagation mechanisms are not directly linked to the shock itself, but are keys to determine if the initial shock will be systemic or just idiosyncratic. Three interrelated features can provide a basis for the propagation mechanisms: i) the structure of societies in relation with local risks of extreme events, i.e. their relative level of adaptation to climate change, ii) the interconnection of different societies through direct and indirect exposures, and iii) the information intensity of social, economic and financial contracts regarding emission intensity or exposure to climate damages. We detail these features in turn.

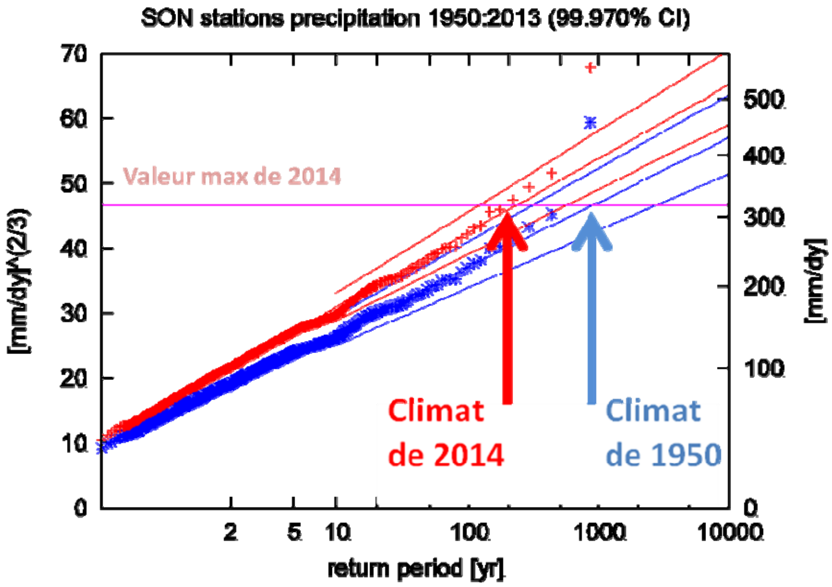
Societies are currently not adapted for the projected outcomes of the current emission trajectories. Pachauri *et al.* (2014) for example show that global warming will very likely lead to an increased number of temperature records. As figure 2 shows, heat waves such as the one experienced by France in the summer 2003, which is believed to have killed more than 15000 persons, would happen every 3 to 4 years in a +2°C world (depending on the climate projection chosen), almost every year in a +3°C (the current optimistic evaluation of the trajectory incurred by the INDCs). Extreme rainfalls are also likely to increase (Seneviratne *et al.*, 2012). We can give the example of a meteorological phenomenon called *épisodes cévenols*, which is defined by strong continuous rainfalls in the French region *Cévennes*. Vautard *et al.* (2015) show that the probability of occurrence of such events is about three times higher in a 2014 climate than it was in the 1950 climate. Figure 3 shows that the return period of such events was one every 1000 years in 1950; it is now at one every 250 years. Droughts are also very likely to rise in a warmer world, with very difficult adaptation paths for societies. The question of the attribution of a particular event to a global warming cause remains essential. Schaller *et al.* (2016) show for example how a succession of storms in South England in 2013/2014 increased flood risks from the Thames, which itself put nearby properties at risk. Insurance companies then are tempted to increase their risk premium in relation with the perception of higher future flood risks. These examples are of course an extremely incomplete and rapid overview of what climate science can bring us in relation to the notion of climate systemic risk. It is sufficient however to understand that the structure of societies in relation with local risks of extreme events is essential to capture the potential impact of a climate change related event.

Figure 2



Source: IMPACT2C.

Figure 3



Source: Vautard *et al.*, 2015.

Propagation

At the same time, the interconnections have never been so high, potentially transforming a localized event into a full-blown shock. We can distinguish between physical, and financial interconnections. If trade relations have stalled a little bit in the past few years since the 2008 crisis, they still keep growing at approximately the same pace as world growth. The notion of value chains, and the related data on trade in value-added by the OECD show a level of interconnection between the different parts of the world which contribute to these intermediate inputs probably never attained before (Baldwin *et al.*, 2015). These physical interconnections can affect the exposure to a localized extreme event. Financial relations will be dealt with in more detail in parts 4, 5 and 6, but let us just quote here the regular increase in financial transactions, and the extremely complex network of tightly linked financial institutions which constitute today's global economy (Roukny *et al.*, 2016). Under the assumption of efficient finance, one could argue that this trend gets closer to perfect financial markets, delivering a better access to liquidity, while maintaining a low-level of financial risk. Under uncertainty, financial history has shown on the contrary that the more interconnected and unregulated is finance, the more vulnerable it is to multiple equilibria, without any hint on the way to reach the best possible outcome. Such a level of financial interconnection in a politically fragmented world can just increase the chance of sudden stops, or brutal reversals of financial expectations. Liquidity would disappear in an instant, as already happened in 2008, while central banks would have more difficulty to re-establish confidence by providing huge amounts of money. Climate damages affecting a certain asset, or a certain asset type, could generate such a shift in expectations.

Informational relations go through different channels, and act in a very similar way as financial markets, disregarding long-term trends, while suddenly affecting a high weight to little almost insignificant events. Two phenomena can contribute to the occurrence of a climate systemic event. The first is the occurrence of a signal which coordinates the expectations of the public, without being related to the full understanding of a climate event. This can translate into financial behavior (Cass and shell 1983), but also into individual or collective behaviors in the economy at large, which can increase the initial effect of the event. The second is the release of a noisy informational signal which essentially hides or distorts the information available in the scientific world, contributing to prolong the political inaction period. We certainly see this in the debate around climate-skepticism in the media (Oreskes and Conway, 2011; Pottier, 2013). This second phenomenon induces the continuous endogenous accumulation of emission disequilibria.

Endogeneity

This leads us to the endogeneity of systemic climate risk. It is now an almost certain feature displayed by climate science. Human actions are a major cause of the increase in global temperatures, through emissions. The global endogeneity of global warming cannot be put into question. By theoretical construction, all emissions have been deemed equivalent in terms of their effect on climate change. Of course, emissions are not the same once we consider other dimensions such as development, equality, … But the notion of "CO2 equivalence" epitomizes the universal source of climate changes.

However, true endogeneity implies that we are able to trace some singular events all the way through to global warming. As we have seen in the previous part, climate science has recently made progress in the attribution of extreme events to global warming, and more generally in the projection of the frequency of localized events in a world where temperatures would have increased by more than 2° (Hulme, 2014). Conversely, endogeneity could also mean that we are able to impute the costs of global warming to a specific emitter. This amounts to the possibility of liability procedures against moral, public or private actors deemed responsible of global warming. If this question has so far been put aside by most judicial courts, it is likely to arise more and more in the future (Allen, 2003; Munich Re, 2010).

So far we have developed the notion of a climate systemic event based on the three properties that any systemic event has: shock, propagation, and endogeneity. We now investigate in more details the specific policy implications of such a shift from standard externality theory.

3. The climate systemic risk hypothesis opens new policy perspectives

We call standard externality theory the view, derived from Coase (1960) and Pigou (1920), that climate change can be dealt with just by putting a price on emissions, either through taxes, or through a cap-and-trade system. Although these authors were mostly talking about localized external bads with mostly localized external effects, it has been supposed until today that this approach deliver the “first-best” solution for global problems also. Under this line of thought, social, technical, political or economical elements of interference with this first-best objective can be taken into account and lead to slightly under-optimal policies, also called “second-best” solutions (Lipsey, 1956). All subsequent research derived from these premises plays with these different elements in order to obtain specific “optimal” trajectories of emission reductions. This dual “first-best/second-best” approach can only move the optimal carbon price profile a little sooner or a little later depending of the chosen element of interference. The debate ends around the question of who among current (Stern, 2007), later (Nordhaus, 1993) or intermediate generations (Chichilinsky, 1996) will be sacrificed on the altar of a stabilized climate (Espagne *et al.*, 2012).

We argue here that the combination of increasing uncertainty on critical climate parameters with the complex political economy of climate policy action cannot be apprehended in a satisfying manner through this traditional first/second-best policy nexus. First, climate policy action cannot be separated from all social, technical, political or economical parameters. Saying that a first-best solution exists independently of all social, technical or political consideration amounts to validate the idea of a totally independent economic sphere, which can derive its own precepts. This amounts to a dogma without any scientific underpinning (Aglietta, 2016). Second, it is uncertainty, rather than risk, which drives climate change issues. In other words, it is not so much the unknowns, but more the unknown unknowns of climate parameters, which are essential to assess the potential damage incurred. Using a more probabilistic vocabulary, that is not fully appropriate to deal with uncertainty, we cannot deal with uncertain parameters by just considering their average value, we must consider the whole distribution range, which is often not Gaussian. The example of climate sensitivity, or climate damages, is striking (Weitzman, 2012). The more we fail to act, the more skewed the distribution of climate sensitivity values, and thus the higher the probability of an extremely high value. The same goes for damages. There is no optimal trajectory in concrete economies, but rather prudent policies, trying to avoid irreversible and dangerous shifts.

Unknown bifurcation points totally change the whole dynamic and make the assumption of a single model of continuously evolving damages with average temperature rise worthless.

The climate systemic risk hypothesis radically departs from the premises of standard externality theory. It suggests that we might want to drastically diminish the probability of occurrence of some very bad outcomes for society, which might lead to its quasi-destruction. It is thus a collective prudential approach, which intends to act on eliminating possible future outcomes more than on internalizing an externality, because of radical uncertainty. But it also goes a crucial step farther than Weitzman, in the sense that a systemic risk approach necessarily arises in concrete economies with incomplete and imperfect markets. In concrete economies, decentralized decisions give birth to endogenous uncertainty, which paralyzes the decentralized decision framework. In such economies, the question coordinating the decisions of the economic agents becomes crucial. Markets are not the only coordination procedure for individual decisions. Individual decisions themselves echo and evolve with the immediate environment, through routines (Nelson et Winter, 1982; Nelson 1995), imitation or discussion (Kahneman, 1996; Varey et Kahneman, 1992), procedures (Conlisk, 1996). The convergence of expectations is thus a condition and a consequence of the harmonious functioning of a decentralized economy. This convergence occurs through the emergence of institutions. But institutions themselves do not emerge spontaneously. They are the product of layers of historical necessities. They are thus not well equipped for unique events such as climate change. This is an important reason why a carbon price only policy, targeted to modify individuals' behaviors only, will not be enough. In a climate systemic risk context, climate policy should specifically target these rules, habits and intermediary institutions.

Table 1

	Efficient market hypothesis	Radical uncertainty hypothesis
Seminal works	Pigou (1920), Coase (1960)	Knight (1921), Keynes (1936)
Key concept	negative externality	Systemic risk
Vision of the future	All information about future possible states is available	Unforeseen events might arise
Objective	Optimal approach	Collective insurance approach
Pivotal economic actors	Individuals	Intermediary economic and financial institutions
Coordination of expectations	Carbon market price/ Carbon tax	Social value of carbon/money
Role of carbon pricing	Internalize the climate externality	Reduce climate uncertainty

Among these intermediary institutions, money and finance are key elements. In financial capitalism financial markets act as coordinators of the expectations of economic agents. In the best case, finance deals with the constant tension between the unknowns and the unknown unknowns, between risk, which can be quantified and evaluated on the markets, and true uncertainty, which gives birth to systemic risk. But very often, financial markets are purely self-referential (Keynes, 1936; Orléan, 2011) so that they can coordinate around pretty much any value, almost independently from fundamental values. Financial regulation theoretically tries to circumvent both the possibility of too important bubbles, and the emergence of systemic events. Furthermore, finance cannot be separated from the institution of money, since in times of crisis, the two strongly interact through the elusive quest for liquidity. It is the institution of money which allows to bridge the gap between the economic sphere and the social, technical and political elements. Furthermore, by proceeding from sovereignty, money is not alike other institutions, and can deal with radical uncertainty.

As we will see in the next part, the realization of a climate systemic risk translates into potential financial turmoil and this in turn can increase the tension around the provision of the ultimate liquidity. This feature is common to any systemic financial crisis. The true difference with climate systemic risk however lies in the fact that the power of the ultimate liquidity to restore confidence into the payment system can potentially also be put into question. The reason is that the crisis not only affects a segment of the economy, the society or the financial system, but the fundamental support of life as we know it. The ethical confidence is endangered (Aglietta and Orléan, 2002). The articulation of money and finance is crucial to manage the prevention or adaptation to the realization of climate systemic risk. Carbon prices are not ruled out as efficient climate policy tools, but it is their role as coordinators of the expectations of economic agents which is now looked for, with the outspoken goal of drastically diminishing the probability of certain outcomes.

These differences of approach between the efficient market hypothesis and the radical uncertainty hypothesis are summarized in table 1. We now look into more details into this specific articulation between financial fragility and climate fragility, and show some elements of positive feedbacks between the two.

4. Climate and financial fragilities: a positive feedback loop?

First, climate systemic risk is a potential source of financial disruption. Climate fragilities increase financial fragilities. There is thus a strong need for the financial sector to anticipate such an outcome. This is the most largely admitted part of the loop. In his speech at Lloyd's in London on 29 September 2015, Bank of England governor Mark Carney (Carney, 2015) underlined these key channels through which climate change can affect financial stability:

- *Physical risk*: impacts on the value of financial assets of climate events such as floods, storms, *etc…* This physical risk could be better understood by taking into account the results of climate science. Knowing that climate science has a tendency of "erring in on the side of least drama" (Brysse *et al.*, 2012), radical uncertainty will still remain on potential damages to financial assets.

- *Liability risk*: impacts of lawsuits by those who might have been victims of natural disasters that they would try to link to climate change, aimed at those deemed responsible for these changes. This risk currently seems to be far-fetched (Munich Re, 2010). But we can see early signals of such liability procedures from numerous NGOs and civil society, which may become a powerful political force in case of realization of a physical risk.

- *Transition risk*: the financial risk that would result from an adjustment to a decarbonized economy. Changes in policies, technologies, institutions and behaviors might lead to a new valuation of a whole set of assets once costs and benefits of climate action become more and more apparent. This shift to a "2°C portfolio" has to be managed by accompanying monetary policies.

If we wait too long, the extreme solution of geo-engineering might arise (Wagner and Weitzman, 2015). This possibility amounts to realizing these three types of risks into one single technological move. Using such a technology, physical risk is both postponed and multiplied, since stopping geo-engineering abruptly scales up the greenhouse effect, making climate sensitivity skyrocket. The liability risk can be easily targeted to the firms and States responsible for the use of this technology. The burden of the proof is much lighter since we can directly attribute climate effects to the use of such a technology. And adopting this ultimate technology represents in itself the utmost transition risk, since it is a last minute transition, when no sustainable technology can be of any use anymore. This extreme-case scenario has to be present in our climate systemic risk mapping, as it makes climate systemic risks singular among financial systemic risks.

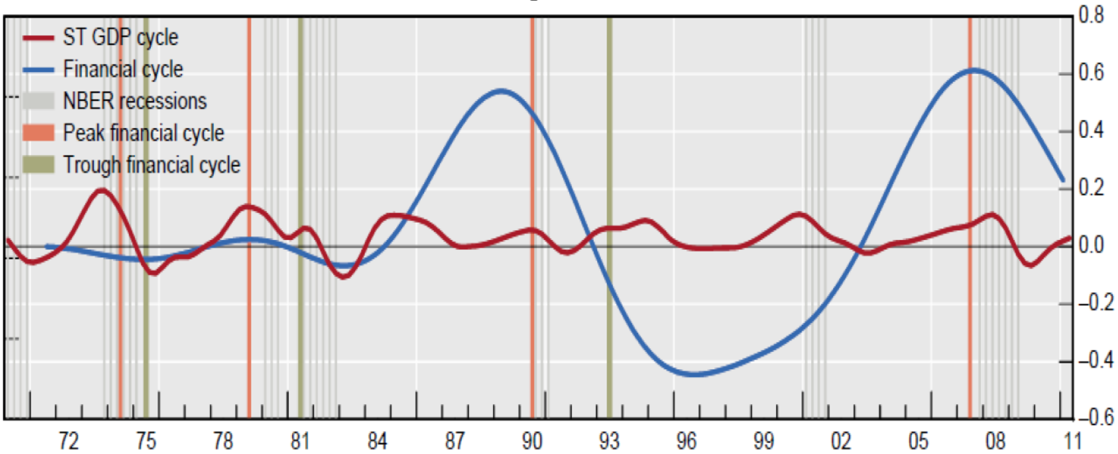
In any case, it is the addition of new risks to an already fragile financial system, which have the potential to transform an idiosyncratic event into a financial crisis. The 2008 crisis has revealed the importance of "too-big-to-fail" institutions, a problem which does not seem to be fully solved today (Kashkari, 2016). Since then, shadow-banking has emerged as a new source of potential systemic risk (FSB, 2015), in relation with the notion of "too-connected-to-fail" institutions. In 2016, financial institutions are also experiencing a debt-overhang of oil-related debts, because of current very low oil prices. So that the current state of the financial system is admittedly highly vulnerable (Aglietta, 2016). Adding three new types of risks to this situation can only worsen financial fragilities. A true analysis of this fragility of the financial system to climate related risks requires a spatialized network approach (Battiston *et al.*, 2016, Espagne *et al.*, 2016).

Second, as we have only suggested so far, the financial sector might also be a powerful driver and accelerator of the realization of a climate systemic risk. Very little research tries to address this particular causality, but some sector specific studies can give us hints of an effective impact of financial misallocation on the worsening of the environment. Financial systems have undergone several hundred crises since the 1970s, the 2008 one endangering economies and societies worldwide (Reinhardt and Rogoff, 2009). The magnitude of damages on the environment, society and the economic spheres, because of acute blindness of the financial sector to external effects, only begins to be revealed: inequalities

(Domansky *et al.*, 2016), health (Karanikolos *et al.*, 2013), the environment (Romero et al., 2012), ... In these few examples, it is the direct ignorance by the financial system (and the economic policies which follow a financial crisis) of its external impacts which generates an immense cost for everyone. Upstream, it is also the capacity of the financial system to generate sustainable investments in the long run that should be questioned. Subsequently endogenous processes arise: inequalities increase the probability of occurrence of financial crisis (Kumhof *et al.*, 2015), deficient public health situations degrade public budgets and environmental risks generated by unsustainable investment choices are responsible for new risks looming (Carney, 2015; Espagne, 2016).

This argument of bad capital allocation by the financial system can be coupled with another more fundamental argument. We now know that since the early eighties, a singular phenomenon of financial cycles has emerged. The financial cycle lasts much longer than the more traditional business cycle, and is crucial to the growth dynamics (see figure 4). An upward oriented financial momentum brings with it high levels of growth, while the decreasing trend reveals the unsustainability of most of the previous period investment choices. The financial cycle is explained by financial variables mostly (Borio, 2014), but also by the volume of real-estate transactions. It may thus be a good proxy to estimate the specific damage incurred to the environment and indirectly to the climate by “excessive” financial developments in comparison with a sustainable growth trend. A new trend of research should look at the impact of financial globalization, and the new financial cycles, on an excessive use of environmental resources, and thus on an overshoot over sustainable emission targets. The financial bubble that accompanied shale gas development and the huge financial investment in deep sea water exploration contributed to the collapse of oil prices and subsequent financial hardship, while a substantial part of underground oil fields would admittedly be stranded if ever the 2°C objective be reached. Therefore the irrationality of present-day unbounded finance, due to the short-run horizon induced by shareholder value predominance on equity return targets, is a crucial contributor of systemic risk.

Figure 4



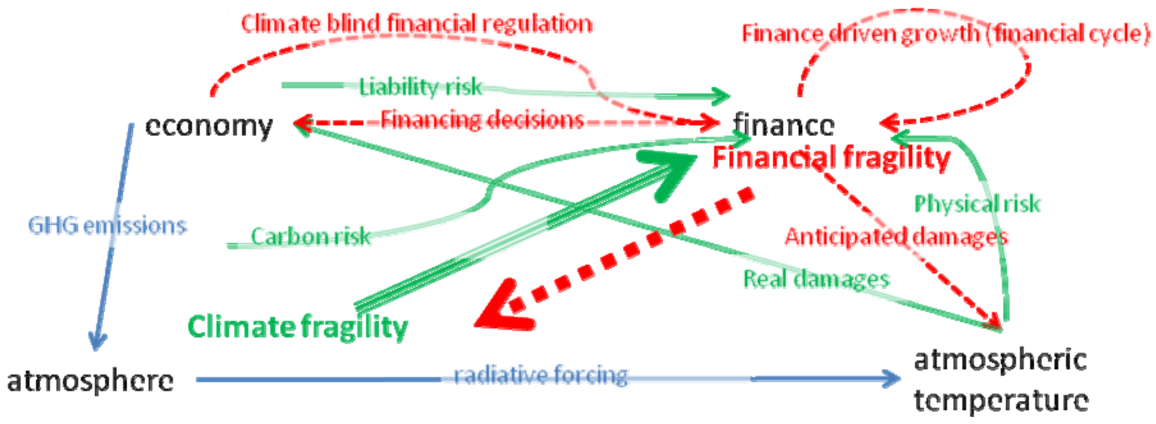
Source: Borio (2014), Financial cycle and business cycle for the US economy.

It leads to a third type of argument showing that financial fragility impacts climate fragility. It is a political economy argument. Except during the COP21 momentum, it is the financial crisis agenda which drives most of the political agenda, either to cope with the long-lasting consequences of the 2008 crisis (and its European developments), or to try to build new, more resilient and more efficient financial institutions. But could the financial system become resilient and efficient while avoiding systemic events by being isolated as an independent object of research, blind to signals given by the economy, society, and the environment? This would drive us into the equivalent of the efficient market hypothesis' mistake, implying that all the available information about pretty much everything is incorporated into prices, if these prices can be soundly established in transparent enough financial markets. Had this axiom had any bearing on real-world financial systems, systemic financial crises could not logically occurred. Indeed, the efficient market hypothesis gives rise to the Modigliani Miller theorem according to which the fundamental values of assets are independent of the financial structure and therefore equal to market prices in equilibrium. This would imply that finance could become more resilient and useful for society without considering the impact of its structure on externalities, and vice-versa that the external world could not have any role in suggesting ways or signals to shape the financial system. The still reduced, but growing, integration of non-financial criteria in financial actors' strategies shows just the opposite (Aglietta and Rigot, 2012). This political effort is thus too narrowly focused and bears the risk to miss the link with the new risks emerging from longer-term analysis, including climate changes.

Finally there is a fourth type of argument, of institutional nature. The financing of energy and primary resources is an essential part of private financial institution's activities, at least since the early seventies, if not more (Yergin, 2011). The financialization of these products is considered by Gkanoutas-Leventis and Nesvetailova (2015) to have been an essential transmission channel of the 2007 financial shock in the US to the global real economy. Institutional inertia tends to make these very same financial institutions keep financing carbon intensive industries, such as shale gas, ultra-deep-water offshore projects or arctic oil drilling. They become stuck with stranded assets (Wolf, 2016) without much intelligence on how to move away from an inconvenient position, or any willingness to do it. North (1992) argues that institutional changes are usually slow and incremental and that players will attempt more rapid institutional revisions only when they believe that they consistently lose under the existing system and when it has been such a case for a long time. Current low-growth/low-return financial situation might drive such a momentum. New types of financial institutions, which would be intrinsically responsible investors (Aglietta, 2015), would have to emerge and be seen as credible institutions for a majority of players, so that financial fragility does not accelerate climate systemic risk. Meanwhile, institutional inertia in the financial system plays in favor of more climate risks.

There are thus strong arguments defending the case that financial and climate fragilities are intertwined into positive feedback loops, as figure 5 illustrates. So that climate systemic risk also incurs financial systemic risk. We must now understand how we could break this circularity and reduce these systemic risks.

Figure 5



5. Reducing climate systemic risk in breaking the circularity: some financial regulation options

Financial systemic risk is usually dealt with through a combination of *ex ante* and *ex post* policies. We can follow that analogy for climate[4].

Ex ante, financial regulations can try to mitigate this collective risk. This requires a combination of oversight, collateral requirements, position caps, etc…The incorporation of some kind of climate signal in monetary policy and financial stability oversight is required, not because the central banks should be a direct actor of the low-carbon transition, but as part of their financial stability mandate. They have to ensure that the financial system be resilient even when confronted with a chosen or a forced low-carbon transition, and as a facilitator of the emergence of effective financing tools. Several undertakings can be grouped into this *ex ante* approach: information sharing, specific investment tools, macro prudential instruments, and new monetary policy orientations.

The first one is fulfilled through a transparency policy, the sharing of information. It first aims at facilitating informed decisions by actors in the financial system. The voluntary disclosure of article 73 in the energy transition law of 2015 in France, or the mission given to an ad-hoc task-force by the FSB in 2016 to study the possible voluntary disclosure of the carbon content included into financial portfolios, go in this direction. But it also aims at allowing an informed supervision by the regulator, so that it can evaluate as an early signal the exposure of financial institutions to climate-related events and intervene as soon as possible before the negative financial externality has propagated. But this requires that information disclosure becomes mandatory and not simply voluntary, with clear established methodologies

[4] ESRB (2016) deals with the possibility of a systemic risk for the European financial system arising from the assumption of a late and sudden climate policy. We develop the concept of climate systemic risk in a more general way, even if our notion entirely includes theirs.

(Bellassen *et al.*, 2015), and that this information is widely shared among different national financial surveillance authorities. Collective (and not just individual) stress-tests should be carried out using this particular climate-related information (Battiston *et al.*, 2016).

The second one is more proactive. Carney's argument on the tragedy of the horizons can be understood in a minimalist way, by saying that central banks and financial regulators should encourage private finance institutions to engineer the tools required to help financial flows target specific low-carbon projects. Andersson, Bolton and Samama (2014) show that it is possible to create low-carbon financial indexes that have the same return as the "benchmark" index, which is indifferent to the environmental constraint. By investing in such an index, investors have at their disposal a "free option on carbon", which hedges its return against a possible limit on emissions, a non-negligible probability in the medium or long run. It is, or so it seems so far, the direction taken by the already mentioned working group commissioned by the FSB to investigate the possibility to voluntarily reveal the carbon content of financial portfolios. This approach alone however fails to recognize the collective nature of climate systemic risk.

A third (complementary) undertaking, more in line with the notion of a climate systemic risk, involves thinking on financial structural reforms. It consists in the search for better rules and better incentives to promote particular changes in the financial structure, so that a greater resilience follows. New fields of research automatically emerge: is the current globalized financial network structure fit to confront the new risks implied by climate change? What should be the size of financial institution in order to arbitrage between inside financial risks and bankruptcies? Is there an optimal level of financial concentration to deal with the efficiency/resilience dilemma? Should financial institutions hold a certain amount of "green assets" on the asset side of their balance sheet, in the same way they must meet a liquidity ratio under Basel III.? The fundamental principles of a climate-related macro-prudential policy remain to be written (ESRB, 2016).

Finally, we must consider that monetary policy should also integrate a reaction to climate-related signals and not pursue a policy exclusively oriented towards goods and services inflation. The central bank can act on the expectations of financial actors and try to align them with the long term stability of the financial system, i.e. a smooth transition out of a carbon economy. It can use several tools to reach that goal. It can lean on the announcement by EU Commission of an objective in terms of climate risk mitigation. Such a tool has been used with mixed results in the past since the 2008 financial crisis. The credibility of the announcement is key, so that it must be accompanied by possible or effective use of various instruments in order to really affect financial markets' anticipations. Such accompanying tools can be asset purchase programs, qualitative mandatory reserves at the central bank, or more direct actions on the quality of credits created by commercial banks, such as a "green funding for lending scheme" (Churm *et al.*, 2012), or even financial repression measures (Monnet, 2015), which force commercial banks with various tools to lend to particular sectors with a high climate-related reward.

Ex post, the climate systemic risk approach becomes a crisis management issue. The central bank can have a direct role as a lender of last resort. This notion was first developed in the 19th century by the English economist Walter Bagehot (1888). It was invented to justify the temporary suspension of the payment constraint on financial markets when dangerous financial events arise by the reference to a superior level of payment. It is of course an exorbitant operation in a market economy, and it is the art of the central bank (constructive ambiguity) to reduce the risk of moral hazard which can emerge when financial actors make the implicit hypothesis that their payments will always be guaranteed. Lending in last resort is a sovereign decision, contingent to the specific situation involved and not subject to definite rules. A traditional lender of last resort action can occur either through a general monetary policy expansion or an emergency liquidity assistance targeted to individual institutions. Both methods potentially generate moral hazard issues.

In the case of a climatic systemic risk, the moral hazard issue is very different and probably less stringent than in a more traditional financial systemic risk, because much more is at stake. In Aglietta and Orléan (2002), three levels of confidence, horizontal, hierarchical or ethical, guarantee the provision of liquidity in the economy. Typical financial systemic crises affect the horizontal level of confidence when the mechanical daily payment system becomes dysfunctional (such as interbank lending in the 2008 crisis). In deflationary financial crises, whereby the rollover of debt gets frozen, the role of the central bank is to make its liabilities available to would-be solvent borrowers in the clearing settlement mechanism if enough liquidity is available. In that type of financial crisis, the *ex post* intervention of the central bank, the involvement of the hierarchical level of confidence, is enough to restore the liquidity in the system with the implicit guarantee of the central bank. In the opposite case, when the bail-out of banks and public debt becomes systematic by issuance of an unlimited amount of money, inflation can become a self-sustaining spiral, being fostered by competing private indexations. The official unit of account is not trusted anymore, meaning that the monetary order is rejected because it has degenerated. In that case ethical trust has collapsed. A drastic monetary reform, often anchored on a foreign currency, is required to restore the monetary order. This means that the principle of sovereignty itself had to be modified in order for the currency to be accepted again and the financial system to resume its function.

How can we transpose the logic of the lender of last resort to systemic climate events? It is clear that no provision of central bank liquidity can ever exactly restore the pre-crisis situation. Only the confidence in the payment system will be reestablished, and this is often sufficient to also restore the previous level of economic activity. But the provision of central bank liquidity for a systemic event linked to a physical climate damage might never be able to restore the previous level of economic activity. The implicit guarantee of the central bank cannot cover irreversible climate damages. Such damages are likely to affect the ethical level of confidence: it is the principle of sovereignty itself which is at stake if a portion of territory is irreversibly transformed due to the climate externality. Liability procedures, if they ever happen, could have such tremendous consequences for societies that they are also likely to take the form of a new social contract. So that central banks will not be the best tools to counter their effect. Moral hazard issues between financial institutions and the central bank are thus less stringent in this case also. The same kind of argument can be put to the fore for the so-called carbon risk. If a climate policy is implemented urgently and at an ambitious level (ESRB, 2016), there is only very little the central bank can do to restore confidence in the payment system. Confidence will also probably be restored first by the change in politics showing that political authorities are committed to handle the issue.

So at the end, the good news is that moral hazard may not be so much of an issue in the case of a climate systemic risk; the bad news is that the central bank will be of limited power in *ex post* reactions to a climate systemic crisis. It will only be able to restore liquidity in a new adapted economy, which will have very little to do with the previous one. This fact should be internalized now by all actors in order to facilitate the implementation of *ex ante* policies. It must be underlined that the four pillars of *ex ante* mitigation of a climate systemic risk cannot be pursued separately, but rather in a combined coherent way. Mark Carney's argument that the simple existence of financial tools driven toward low-carbon investments could by itself create enough demand for low-carbon funds is not convincing enough; the doubt is reinforced by his use of the metaphor of Say's law. However, his argument that a virtuous cycle should be created, so that firms, financial actors and governments move ever closer to the 2°C goal, is very thoughtful, with the rather provocative idea that climate policy should be conducted more as a sort of monetary policy than as the simple expression of an externality. Monnin (2015) shows how monetary policy already unintentionally drives a sort of climate-oriented policy, through the use of very low interest rates. Macro-prudential policy alone, without acting on the expectations, while at the same time giving better climate-related information, as well as specific investment tools, cannot avoid in itself a climate systemic event. Together, the four pillars may induce a self-reinforcing positive feedback loop away from both financial and climate fragilities. We now discuss how these four pillars may turn into a new financial order.

6. Climate systemic risk as the pillar of a new international financial order

After 2010, financial globalization has expanded incommensurably relative to world trade or world GDP. Unregulated shadow banking has become the leading intermediary, substituting to the banking system, in channeling trillions of liquidity poured out by central banks. $4trns of liquidity injected by the Fed were channeled mainly to the corporate sector of emerging market economies (EMEs). They converted into $7trns through cascades of leverage to finance huge excess production capacities in industry and commodity production, generating the collapse in world production prices. Subsequently financial vulnerabilities surged with the fall in investment in the oil-producing sector, the sharp slowdown in China's manufacturing and spillovers from emerging market economies to advanced economies. This utter misallocation of capital reflects and magnifies both the mimetic behavior and the tragedy of horizons in finance.

Financial spillbacks from equity markets in EMEs to global asset markets are entirely new. They spread risks and vulnerabilities on a larger scale (GFSR, April 2016) while capital inflows therein have been reversed since mid-2014, after an early episode in the spring of

2013, the so-called “tapering tantrum”. Those new linkages stem from the change in international finance with the retreat of market making by banks following Basel III rules. It has been replaced by the international activity of mutual funds in search for yield, the concentration of asset management and the generalization of securities trading. The three processes amount to the rise of common investors that encompass all world markets and intensify financial interdependence. Those investment fund exposures are vectors of financial spillover. They increase both cross-asset correlations and cross-country correlations of the same types of assets. When losses arise anywhere in the world, whatever their origin, the concentration and interconnection of asset management spread asset sale through portfolio rebalancing, as much as banks are more reticent to do market making under Basel III constraints.

We can thus see the source of climate systemic risk as part of a more general market failure. Because cross-country contagion depends heavily on investment funds, the systemic risk they can propagate thus requires macro prudential measures. All the financial reforms of the last decades have tried to get closer to a state of market efficiency by discouraging all sorts of financial regulations. But long term projects such as the one needed for a low-carbon transition (90 trillions needed according to IEA (2015)) bear specific risks that financial markets cannot handle. Upfront costs are very high, risks are difficult to assess, the gap between private and social return is maximum. Public action is thus needed. The question is then which financial framework best provides for such an outcome.

First, the theory of public-private partnerships relies on a weak version of the market efficiency hypothesis: it explicitly admits the possibility of market failures, which justifies a combined intervention of public and private investors. This path has been followed for quite a long time now, but it appears that PPPs have almost no role in developing countries (UNCTAD, 2015), that new and risky projects are avoided, and that costs increase in comparison with public financing because the private partners are mostly interested in detaining monopolistic positions, as well as return guarantees. The World Bank has created its own Global Infrastructure Facility in order to mobilize institutional investors and facilitate PPPs. This structure tries to compete with the second institutional possibility, which is based on the use of development banks.

A second path thus relies on the use of public development banks. These banks are the main financing institutions for sizeable and long maturity projects with positive externalities. Their mandate is generally targeted to this kind of investment. Their capital belongs to sovereign entities, either national or international, with a high level of financial credibility. They have a good capacity to borrow on international bond markets. They generally also have the expertise to select, evaluate and monitor such projects, so that they often also become partners, participating in technological, geographical and scale choices. Their good notation allows for a high leverage on other potential lenders (UNCTAD, 2015).

This trend is already emerging in Asia around the development of Chinese investments abroad. The recently created Asian International Infrastructure Bank has public funds from more than 40 countries. Most of its capital is detained by Asian countries. It issues bonds on the regional or international markets in order to build up infrastructures around Asia. The Banco del Sur was supposed to help the regional integration of the Mercosur. It could not realize this program though. National development banks have also often become international: it is the case for example of the KfW in Germany, of CDB and Ex Im Bank in China. These banks can be tightly linked to their national central bank, while we can imagine that the IMF could play pretty much the same role on the international level, whether it is empowered with the capacity to issue SDRs endogenously.

Table 2

Washington consensus + US dollar as the key currency	Regional integration through infrastructure financing + SDR as multilateral currency
Key concept: market efficiency	Key concept: systemic resilience
- Financialization of the firm (shareholder value) at the global level - Capital flows linking all aquity markets in the world - Intermediation by investment banks with a market making power - International Lender of last resort through a network of swaps granted by the Fed to countries respecting political criteria imposed by the US Treasury - Developing countries forced to accumulate reserves in dollars for self insurance - Incapacity to finance real long term investments	- Long term investments as growth engine - Finance structured to mobilize trillions of dollars of investments - Globalization by the production of global public goods and positive externalities - Intermediation by national and multilateral development banks - IMF as last resort lender (SDRs) - Risk of political conflict in the definition, monitoring and exploitation of investment projects

In order to be at the forefront of a transformation of global finance, development banks should be first and foremost able to change their criteria of allocation of private capital. They should introduce new financing methods to make inclusive and sustainable investments. They could contribute to create the space of stable macroeconomic states which we are looking for as the best *ex ante* policy against climate systemic risk, because they could align the expectations and behaviors of economic agents to their long term objectives. The limitation of individual choices by a set of rules necessary to the right functioning of institutions is not a source of handicap or inefficiency, as it would be in a world of perfect competition. On the contrary, this limitation is a powerful stabilizer because the behaviors are adapted to the intermediary institutions, here the development banks, which themselves contribute to reduce systemic risks. Such a financial infrastructure should be prone to reduce climate fragility.

7. Conclusion on climate systemic risk: making the elephant in the room fully visible

New financial instruments and financial reforms to make the financial system more resilient to climate risks can build on important statements embodied in the Paris Agreement, such as carbon pricing[5], or a social, economic and environmental value of emission reductions[6], following many proposals which have popped up in the months leading to COP21 (Espagne, 2016). Paragraph 108 in particular can be regarded as important in the process of joining financial and climate policy reform agendas. Latest IMF forecasts emphasize the weakening of world growth (WEO, April 2016) and the buildup of renewed financial fragilities due to tighter interconnections between emerging and advanced financial markets and intermediaries (GFSR, April 2016). These trends point to secular stagnation (Teulings *et al*., 2014) under possibly negative natural rate for a long time to come. Europe is facing the alternative between exploring the unknown but probably dangerous world of negative interest rates (Aglietta and Valla, 2015) or rediscovering the experience of post-World War II European monetary policy (Monet, 2014) and reframing it with today's environmental externalities. The second option requires the complete integration of social values into monetary policies. It could derive from Paragraph 108, while giving it a whole new meaning (Aglietta *et al.*, 2015).

COP21 was conceived as a large multi-level discussion process which goes beyond the traditional actors of the UNFCCC negotiations. The French presidency has named this attempt to include all social, economic and regional actors in the Paris Alliance. Section V of the Decision, in particular, officially recognizes at paragraph 133 the financial institutions as key actors for change. The Governor of the Bank of England Mark Carney underlined in the already mentioned speech in 2015 (Carney, 2015) the great dangers looming from what he called the tragedy of the horizons: the temporal mismatch between the financial investor's agenda, the financial regulator's and the constraining physical climate change process. This seminal speech has triggered new policy initiatives for 2016: the Financial Stability Board has been tasked by the G20 in Antalya (November 2015) to study methods appraising climate risk included in financial portfolios and to propose a voluntary disclosure process to financial actors, the G20 in Shanghaï (February 2016) has given the Bank of England and the People's Bank of China the mission to investigate the reality of climate change as a financial risk, as highlighted by Mark Carney in his speech.

These results however fall short of acknowledging the full implications of climate change for societies, the economy and the financial system. Voluntary disclosures cannot mitigate climate risks in a reliable way, in the same way as shared public/private banking stress-tests

[5] Paragraph 136 of the Decision.
[6] Paragraph 108 of the Decision.

are always inefficient in restoring confidence. Furthermore the joint realization of three highly correlated risks cannot have less than systemic consequences for the financial system. Climate change constitutes a typical example of systemic risk for societies as well as the financial system. This disclosure, as well as its policy implications, seems to have been the elephant in the room of both the UNFCCC process and the broader Paris Alliance. As a consequence, it is also the main task of climate research in all disciplines to characterize this systemic risk at all scales.

Bibliographie

Aglietta, M. (1991). Le risque de système. *Revue d'économie financière*, (18), 61-89.

Aglietta, M. (2003). Le risque systémique dans la finance libéralisée. *Revue d'économie financière*, 33-50.

Aglietta, M. (2015). What is the Quality of Growth? Sustainability and Inclusiveness. *Growth is Dead, Long Live Growth*, 19.

Aglietta, M., (2016). *Le pouvoir de la monnaie dans l'économie mondiale*. Etat du Monde 2017.

Aglietta, M., Espagne E., and B. Perrissin-Fabert. "A proposal to finance low carbon investment in Europe." *France Stratégie: Paris* (2015).

Aglietta, M., & Hourcade, J. C. (2012). Can indebted Europe afford Climate Policy? Can it bail out its debt without Climate Policy. *Intereconomics*, *3*, 160.

Aglietta, M., & Orléan, A. (2002). *Monnaie (La): Entre violence et confiance*. Odile Jacob.

Aglietta, M., & Rigot, S. (2012). Investisseurs à long terme, régulation financière et croissance soutenable. *Revue d'économie financière*, (4), 189-200.

Akerlof G., (1991), Procrastination and Obedience, in *American Economic Review* , vol 81, n°3.

Allen, M. (2003). Liability for climate change. *Nature*, *421*(6926), 891-892.

Andersson, M., Bolton, P., & Samama, F. (2014). Hedging climate risk. *Columbia Business School Research Paper*, (14-44).

Bagehot, W. (1888). *Lombard Street: A description of the money market*. Kegan, Paul & Trench.

Baldwin, R., & Lopez-Gonzalez, J. (2015). Supply-chain Trade: A Portrait of Global Patterns and Several Testable Hypotheses. *The World Economy*, *38*(11), 1682-1721.

Battiston, S., Mandel, A., Monasterolo, I., Schuetze, F., & Visentin, G. (2016). A Climate Stress-Test of the EU Financial System. *Available at SSRN*.

Bellassen, V., & Stephan, N. (Eds.). (2015). *Accounting for Carbon*. Cambridge University Press.

Borio, C. (2014). The financial cycle and macroeconomics: What have we learnt?. *Journal of Banking & Finance*, *45*, 182-198.

Brysse, K., Oreskes, N., O'Reilly, J., & Oppenheimer, M. (2013). Climate change prediction: Erring on the side of least drama?. *Global Environmental Change*, *23*(1), 327-337.

Campiglio, E. (2016). Beyond carbon pricing: The role of banking and monetary policy in financing the transition to a low-carbon economy. *Ecological Economics*, *121*, 220-230.

Carney, M. (2015). Breaking the Tragedy of the Horizon–climate change and financial stability. *Speech given at Lloyd's of London by the Governor of the Bank of England*, *29*.

Churm, R., Radia, A., Leake, J., Srinivasan, S., & Whisker, R. (2012). The funding for lending scheme. *Bank of England Quarterly Bulletin*, Q4.

Conlisk, (1996), « Why Bounded Rationality? », in *Journal of Economic Litterature* , Vol. XXXIV, n°2, juin, pp. 669-700.

Domanski, D., Scatigna, M., & Zabai, A. (2016). Wealth inequality and monetary policy. *BIS Quarterly Review March*.

Etienne Espagne , 2016. "Climate Finance at COP21 and After: Lessons Learnt," CEPII Policy Brief 2016- 09 , 2016 , CEPII.

Espagne, E., Perrissin Fabert, B., Pottier, A., Nadaud, F., & Dumas, P. (2012). Disentangling the Stern/Nordhaus controversy: beyond the discounting clash. FEEM working papers.

Espagne, É., Hourcade, J. C., & Fabert, B. P. (2015). La finance au secours du climat? La Nature entre prix et valeur. *Natures Sciences Sociétés*, (Supp. 3), 117-121.

Espagne, E., Dron D., Goerner S. and R. Ulanowicz (2016). A financial system for the age of the Commons. Using ecological principles and methods to understand and assess systemic risk in financial systems. Working Paper.

European Systemic Risk Board (2016). Too late, too sudden: transition to a low carbon economy and systemic risk. Report of the advisory scientific committee. N°6.

Fabert, B. P., Pottier, A., Espagne, E., Dumas, P., & Nadaud, F. (2014). Why are climate policies of the present decade so crucial for keeping the 2° C target credible?. *Climatic change*, *126*(3-4), 337-349.

Financial Stability Board (2015). Global Shadow Banking Monitoring Report 2015. *http://www.fsb.org/wp-content/uploads/global-shadow-banking-monitoring-report-2015.pdf*

Fontana, G., & Sawyer, M. (2016). Towards post-Keynesian ecological macroeconomics. *Ecological Economics*, *121*, 186-195.

Gkanoutas-Leventis, A., & Nesvetailova, A. (2015). Financialisation, oil and the Great Recession. *Energy Policy*, *86*, 891-902.

Hourcade, J. C., Fabert, B. P., & Rozenberg, J. (2012). Venturing into uncharted financial waters: an essay on climate-friendly finance. *International Environmental Agreements: Politics, Law and Economics*, *12*(2), 165-186.

Hulme, M. (2014). Attributing weather extremes to 'climate change'A review. *Progress in Physical Geography*, 0309133314538644.

International Monetary Fund (2016). *Adequacy of the global financial safety net.*IMF staff report. March 2016.

International Monetary Fund (2016). *The growing importance of financial spillovers from emerging market economies. Global Financial Stability Report, Chap. 2.* April 2016.

Kahneman D., (1996), New Challenges to the Rationality Assumption in Arrow et alii (1996), pp. 203-219.

Karanikolos, M., Mladovsky, P., Cylus, J., Thomson, S., Basu, S., Stuckler, D., ... & McKee, M. (2013). Financial crisis, austerity, and health in Europe. *The Lancet*, *381*(9874), 1323-1331.

Kashkari, N. (2016). Lessons from the Crisis: Ending Too Big to Fail. *Remarks at the Brooking Institution, Washington, D.C.,* February 16, 2016.

Keynes, J. M. (1936). The general theory of interest, employment and money.

Knight, F. H. (1921). Risk, uncertainty and profit. *New York: Hart, Schaffner and Marx*.

Kumhof, M., Rancière, R., & Winant, P. (2015). Inequality, leverage, and crises. *The American Economic Review*, *105*(3), 1217-1245.

Monnet, E. (2014). Monetary Policy without Interest Rates: Evidence from France's Golden Age (1948 to 1973) Using a Narrative Approach. *American Economic Journal: Macroeconomics*, *6*(4), 137-169.

Monnin P. (2015). Supporting the Energy Transition: the role of Low Interest Rates. CEPII-France Stratégie Climate Finance Platform.

Nelson, (1995), « Recent Evolutionary Theorizing about Economic Change », in *Journal of Economic Litterature* , Vol. XXXIII, n°1, mars, pp48-90.

Nelson et S. Winter, (1982), *An evolutionary theory of economic change* , Harvard University Press, Cambridge, Mass.

Nordhaus, W. D. (1993). Rolling the 'DICE': an optimal transition path for controlling greenhouse gases. *Resource and Energy Economics*, *15*(1), 27-50.

North, D. C. (1992). *Transaction costs, institutions, and economic performance* (pp. 13-15). San Francisco, CA: ICS Press.

Oreskes, N., & Conway, E. M. (2011). *Merchants of doubt: How a handful of scientists obscured the truth on issues from tobacco smoke to global warming*. Bloomsbury Publishing USA.

Orléan, A. (2011). *L'empire de la valeur: refonder l'économie*. Seuil.

Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., ... & Dubash, N. K. (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Pottier, A. (2013). Le discours climato-sceptique: une rhétorique réactionnaire. *Natures Sciences Sociétés*, *21*(1), 105-108.

Reinhart, C. M., & Rogoff, K. (2009). *This time is different: eight centuries of financial folly*. princeton university press.

Rezai, A., & Stagl, S. (2016). Ecological Macroeconomics: Introduction and Review. *Ecological Economics*, *121*, 181-185.

Romero, J., Jimenez, F., & Villoria, M. (2012). (Un) sustainable territories: causes of the speculative bubble in Spain (1996–2010) and its territorial, environmental, and sociopolitical consequences. *Environment and planning C: Government and policy*, *30*(3), 467-486.

Roukny, T., Battiston, S., & Stiglitz, J. E. (2016). Interconnectedness as a Source of Uncertainty in Systemic Risk. *Available at SSRN 2726631*.

Schaller, N., Kay, A. L., Lamb, R., Massey, N. R., Van Oldenborgh, G. J., Otto, F. E., ... & Bowery, A. (2016). Human influence on climate in the 2014 southern England winter floods and their impacts. *Nature Climate Change*.

Seneviratne, S. I., Nicholls, N., Easterling, D., Goodess, C. M., Kanae, S., Kossin, J., ... & Reichstein, M. (2012). Changes in climate extremes and their impacts on the natural physical environment. *Managing the risks of extreme events and disasters to advance climate change adaptation*, 109-230.

Teulings, C., & Baldwin, R. (Eds.). (2014). *Secular stagnation: facts, causes, and cures*. Centre for Economic Policy Research.

UNFCCC. (2015). http://unfccc.int/files/meetings/paris_nov_2015/application/pdf/paris_agreement_english_.pdf

Varey et D. Kahneman, (1992), « Experiences Extended Across Time: Evaluation of Moments and Episodes » in *Journal of Behavioral Decision-Making* , vol. 5, pp. 169-196.

Vautard, R., Yiou, P., van Oldenborgh, G. J., Lenderink, G., Thao, S., Ribes, A., ... & Soubeyroux, J. M. (2015). Extreme Fall 2014 Precipitation in the Cévennes Mountains. *Bulletin of the American Meteorological Society*, *96*(12), S56-S60.

Villeroy De Galhau F. (2015). Changement climatique : le secteur financier face aux trajectoires 2°C – Discours, CEPII-France Stratégie Climate Finance Platform.

Weitzman, M. L. (2009). On modeling and interpreting the economics of catastrophic climate change. *The Review of Economics and Statistics*, *91*(1), 1-19.

Weitzman, M. L. (2012). GHG targets as insurance against catastrophic climate damages. *Journal of Public Economic Theory*, *14*(2), 221-244.

Wagner, G., & Weitzman, M. L. (2015). *Climate shock: the economic consequences of a hotter planet*. Princeton University Press.

Wolf, M. (2016). *Fossil fuel power plants will be stranded.* Financial Time column, April 5th 2016, http://www.ft.com/intl/comment/columnists/martin-wolf.

Yergin, D. (2011). *The prize: The epic quest for oil, money & power*. Simon and Schuster.