# Economic challenges in the monitoring of greenhouse gas emissions

## Final Report

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**Foreword**

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## Introduction

The objective of this study is to assess the economic benefits of setting up a system for the dynamic monitoring of the concentrations of carbon dioxide and other greenhouse gases (GHG) in the atmosphere. The system being considered consists of a network of ground-based detectors and observation satellites. In this study, whose purpose is one of economic analysis, we will not be going into the technological details of the monitoring of GHG. The following advantages will be taken as a given: such a system improves public information on the dynamics of concentrations, reduces scientific uncertainty about the carbon cycle and allows us to better distinguish anthropogenic emissions from natural ones. Information that is coordinated by satellite observation has the advantage of being reliable, for it enables us to compare various local statements and cover poorly accessible areas. The scale of the project, in terms of ground-based detectors and observation satellites, will determine the frequency and accuracy of the observations. If put in place progressively, it will initially be used mainly to better understand the dynamics of concentrations on a global scale. Next, it could be used to carry out checks on emissions over large areas. Eventually, it will also be possible to monitor production units.

We aim at assessing the economic value of such informational improvements. Note first that an immediate benefit from a monitoring system is a better understanding of the carbon cycle, which has a considerable scientific value per se – though one that is difficult to precisely evaluate. A derived benefit is the ability to forecast more precisely the future climate, and thus the future damages caused by climate change. Moreover, information on the geographical origin of emissions, as well as on the importance of natural absorption by carbon sinks such that forests and oceans are also of considerable interest. In the following we focus on these types of informational improvements. Hence, only a portion of the project's potential economic benefits will be analyzed. Among the aspects that will not be assessed are the technological externalities in terms of space research, countercyclical fiscal policy-type effects brought on by funding through public debt, etc. Considerations with regard to support for firms involved in international technological competition will not be mentioned either.

The variety of these informational improvements is associated to multiple economic effects that will be carefully distinguished in the following. We have drawn upon concepts in economic literature regarding the value of information to identify the various potential benefits and propose a coherent analysis of the latter. Some effects have been studied and evaluated by economists; some other clearly requires more work. Research projects pertaining to this issue will thus be proposed in conclusion.

Here is a summary of our analysis. Better information on the dynamics of GHG, and of carbon dioxide in particular, should first and foremost facilitate the establishment of a concerted international response effort to address the challenge of climate change. The willingness to pay for the elimination of all uncertainty from ecoclimatic models ranges from 200 to 1000 billion dollars depending on the study involved. Given that the uncertainty on the reality of global warming is a crucial component of such models, the value of information on GHG dynamics probably represents several tens of billion dollars (section I.1). Moreover, such information would allow us to bypass the debate between wait-and-see strategies and precautionary ones, and establish a suitable policy that is not necessarily more restrictive in terms of emissions reductions (section I.2).

Better information should also strongly influence international climate negotiations. The more countries that ratify the agreement, the higher the value associated with the information. However, in theory, better information does not necessarily help to ensure the accession of all countries, but it does encourage the contracting parties to honor their commitments. We could nonetheless get round the problem of getting all countries to participate by setting up an efficient compensatory system to induce participation of the countries that are least affected by global warming. A global agreement would allow us to avoid a cost overrun of more than 10 of billions of dollars (sections II.1 and II.2).

One manner to proceed could be to channel compensations thanks to the Clean Development Mechanism of the Kyoto Protocol. This mechanism is however strongly criticized, due to monitoring difficulties and perverse incentives. Improved monitoring would help to make it more efficient by reducing the number of problems and the costs linked to the certification of emissions reductions. The latter represent more than 800 million dollars in the current state of the system (section II.3).

Second, better information on GHG dynamics should improve national policies on the fight against global warming. The regulation of polluting activities would be easier to put in place thanks to increased credibility. It would be more efficient based on yardstick competition systems (section III.1) and taxes (section III.2) that are better adapted to changes in behavior. The financial gains are potentially very high. As an example, an international carbon tax would generate close to 150 billion dollars by 2015.

The carbon finance markets would also benefit greatly from having frequent access to public information on emissions. The quality of bonds would also improve and market liquidity would increase (section IV.1). It might also be possible to establish a bidding system for permits, which would be much more efficient than the current allocation system (section IV.2). A contribution by markets towards the improvement of available information is also conceivable. For example, a 0.005% tax on transactions could bring in some 150 million dollars by 2020 (section IV.3).

Altogether, the direct economic benefits of improving the information on GHG dynamics are potentially very significant. They clearly exceed the various costs involved in the setting up of the system in question. Nevertheless, in order for it to be optimal, the system should be entrusted to an international agency committed to the fight against global warming. Recommended by Jean Tirole in his recent report to the French Conseil d'Analyse Economique, such an agency would be in charge of establishing a renewed climate policy based on a global system of exchangeable emissions permits. This new international architecture would benefit from accurate information on GHG emissions and ensure the reliability of the latter.

## I. Value of scientific information and climate policy

More reliable and frequent measurements of GHG concentrations in the atmosphere would first and foremost enable an advancement in scientific knowledge on global warming. In an editorial of its publications of July 23, 2009, *Nature* voiced its sentiment on behalf of the scientific community and called for the establishment of an international system for the monitoring of emissions and carbon dioxide concentrations. According to the editorial writer,

improved knowledge of the carbon cycle would be beneficial to climate policy; therefore, investment in such a project would be "money well spent".

According to the Stern report, climate change would cause a loss in global welfare equivalent to a decrease of 5 to 20% in per capita consumption (Stern, 2007, p.10). This estimate accounts for the considerable doubt that is currently monopolizing public debate about climate change and has given rise to both skepticism and apocalyptic predictions. This uncertainty may be a brake on national and international public actions. Given that improved scientific knowledge would allow us to reduce this uncertainty, it is important to assess the economic value associated with this reduction.

**I.1 A positive value of information**

Economists developed the concept of the value of information in order to measure the financial gain associated with a reduction in uncertainty, where this reduction is defined as the result of information being revealed earlier than expected. Theoretically, this value may be positive or negative because the information modifies the behaviors of economic agents. In the case of global warming, all studies conclude that the value is positive: it is profitable to invest today in order to know tomorrow rather than the day after tomorrow. Economists have been debating about the magnitude of this value of information. Nordhaus (1994) was one of the first to introduce a probabilistic representation of uncertainty in the well-known ecoclimatic world model, the DICE. In the economic component of the model, the parameters that have the greatest effect on climate policy are the population and productivity growth rates as well as the discount factor. For the climate component, the important parameters are those relating to the climate change damage function, the level of carbon retention in the atmosphere and the climate sensitivity parameter, which measures the amount of global warming associated with a twofold increase in GHG levels in terms of carbon equivalents. Nordhaus (1994) estimates that the value associated with the obtaining of perfect information in 2000 rather than 2020 is more than 1000 billion in 1989 dollars, i.e. more than 3.6% of world GDP. Therefore, the willingness to pay for eliminating all uncertainty is very high.

This initial estimate by Nordhaus sparked much debate. The Intergovernmental Panel on Climate Change suggests a figure on the order of 100 billion dollars (IPCC, 1995, p. 68). More recently, Hopes and Alberth (2006) estimated using the PAGE2002 model that decreasing the uncertainty interval 1.5°-5° of the "climate sensitivity" parameter by half corresponds to a value of almost 500 billion dollars if this is achieved today, or on the order of 200 billion if achieved in 2040. Studies have nonetheless shown that the value of information is rather limited in ecoclimatic models if observation and data measurement errors cannot be reduced (O'Neil and Melkinov, 2008), and that several centuries might be necessary for a precise assessment of the key parameters of the global warming model (Leach, 2007).

**I.2 But an ambiguous effect on climate policy**

While scientific knowledge on GHG dynamics is undoubtedly of positive economic value, its effect on climate policies is however contrasting. Being aware today that we will know tomorrow rather than the day after tomorrow gives rise to two conflicting positions. The first is a wait-and-see attitude. When faced with uncertainty, waiting can be justified because the prospect of obtaining more reliable information enables us to better adapt policies. Such behavior is all the more justified if this information is revealed earlier rather than later. This position, known in economic literature under the concept of option value, characterizes well American administration policies of the 1990s. The second position, on the contrary, is based on the precautionary principle. By refraining from taking action now, the climate situation

worsens and may result in irreversible damage. Consequently, benefiting from better information earlier must not delay the putting in place of ambitious policies.

Many studies have attempted to measure the magnitudes of the option value and precautionary principle. It seems that on the whole, neither effect is dominant and the answer is in fact related to the ecoclimatic model being considered (Lange and Treich, 2008). In the DICE model, for example, the prospect of resolving uncertainty in the future does not warrant a significant decrease in GHG emissions in the short run. This therefore justifies a wait-and-see attitude. The model by Ha-Duong (1998), on the contrary, brings to a different conclusion because of the irreversible nature of climate change. The prospect of less uncertainty thus should lead to more ambitious targets on emissions. The problem in contemporary research consists more in identifying and assessing the various environmental irreversibilities and weighing them against the irreversibility of the capital invested in the fight against global warming. Thus, Baker (2009) shows that the prospect of acquiring information can also further encourage investments in research and development techniques that would enable a future decrease in the marginal abatement cost for emissions. In addition, Baumstark and Gollier (2008) highlight that irreversibilities aside, the risk aversion and cautiousness of economic agents prompt significant first efforts. Overall the economic literature has well-analyzed the different effects that play a role. Nevertheless it is fair to say that no consensus on their respective strengths has been reached.

## II. International climate agreements

More reliable and more frequent measurements of GHG emissions would allow to more precisely estimating the contribution of each country. The errors on such measurements would be further reduced by the monitoring system that we study here, since this system is able to distinguish between anthropogenic and natural emissions. Overall this would have strong consequences on international climate negotiations, and on the willingness of governments to participate in agreements, to honor commitments, and to better channel compensatory transfers.

International agreements on GHG reductions constitute a textbook case for economists. The preservation of good climatic conditions does indeed have the characteristics of a global public good for which, by definition, there is no exclusion of any country from its use. Symmetrically, global warming is a public nuisance that knows no borders. National efforts to reduce GHG emissions do not only benefit the countries in question and can therefore also be analyzed as private contributions to a public good. In such a context, theory predicts suboptimal behaviors that are described as the free rider phenomenon: each country contributes little, relies on the effort of others and, in the end, everybody ends up with a suboptimal quantity of the public good. In practice, such behavior is reflected in the difficulty in obtaining an international agreement or, in the case of previously ratified agreements, in the failure to abide by the terms of the agreement. Several decades of international climate negotiations seem to confirm this theory.

Yet, limited country participation in climate agreements is potentially very costly. In the case of an agreement to restrict the average temperature rise to 2 degrees by the year 2100, Nordhaus (2009) calculated the cost, evaluated in terms of a decrease in consumption, as a function of the number of agreement participants. Hence, if the agreement is not ratified by all

but only by the ten most polluting countries that represent three quarters of the world population, the cost would be 60% higher. If only countries that represent half of the world population were involved, the cost would be higher by 230% and would amount to 13 billion dollars. The question here is to determine if the possession of more reliable information on GHG dynamics could help to limit free rider behavior and therefore reduce the cost incurred by the setting up of an imperfect international agreement. Thus, there are two types of behavior that may thwart climate agreements: one relating to the accession to a global agreement and another relating to the honoring of a past agreement.

**II.1 Information does not imply cooperation**

The connection between information and cooperation is complex. To begin with, consider a case without uncertainty. Then winners and losers from climate change are readily identified, and an international agreement may be difficult to reach. In a hypothetical scenario where there is no uncertainty and all countries are similar (in terms of the costs and benefits with regard to climate change), recent studies show that it is not certain that all countries would wish to participate in a program to reduce GHG. Thus, Carraro and Siniscalco (1993) demonstrate that it is in the interest of some countries not to adhere so as to benefit from the emissions reductions by countries bound by a partial agreement, but without having to bear the costs. The Kyoto Protocol is an example of an agreement that only involves a subset of countries. This result has been complemented by the work of Chandler and Tulkens (1997) who show that a treaty in which there is accession by all countries is possible if the participants anticipate that there will be no treaty in the event of a disagreement.

Therefore, cooperation is not always obtained in a theoretical framework with no uncertainty. Consider now the more realistic case in which uncertainty is very important. Each country is afraid of bearing important damages, and thus is more ready to participate in an international agreement. Moreover such an agreement could be strengthened by providing to each a signatory insurance against damages from climate change. In such a case, more information could be socially harmful, as it reduces the possibilities for an agreement. The intuition for this result is based on an insurance mechanism. If countries do not know whether they will suffer the consequences of global warming, it could be in their interest to cooperate in order to share out the risks. By reducing such opportunities for cooperation, information can thus reduce global welfare and therefore have a negative value. Ulph and Maddison (1997) studied this issue in a simple ecoclimatic model involving several countries. They have shown that the value of information increases with the parameter for the damage correlation between countries. If this parameter is small enough, the value of information is negative. More recently, Kolstad and Ulph (2008) showed that the number of countries in whose interest it is to sign an agreement on GHG reductions decreases with increasing information. All these studies insist upon the fact that a reduction in uncertainty can reduce the vague desire to cooperate of countries who initially adopt a precautionary stance but then discover that they are not greatly affected by global warming. A recent study, however, opposes this consensus. Boucher and Bramoullé (2009) suggest that a reduction in uncertainty with regard to the consequences of global warming could encourage accession to an international agreement. Their argument is that it would reduce the precautionary efforts of signatories, which would render the international agreement less costly and therefore more attractive. To date, there has been no study that has measured the relative importance of insurance and precautionary behaviors. It is therefore difficult to spell out a definite conclusion.

**II.2 But information does encourage the honoring of commitments**

Better information on GHG dynamics can nonetheless play a major role in the durability of international climate agreements. These agreements suffer from the lack of a supranational authority to ensure that signatories honor their commitments. In this context, information that is reliable, in that it cannot be manipulated by actors, is very important, especially if it allows distinguishing between anthropogenic emissions and those that arise from natural variations in ecosystems. Such information enables us to assess the true efforts of each country. It is obvious, on the contrary, that in the absence of local information, free rider strategies may manifest themselves and call into question the stability of the initial agreement.

Economists analyze the durability of international agreements using the modeling of repeated cooperation games as climate negotiations are continually renewed over time. Here, the cartel example that was studied by Green and Porter (1984) is most instructive. The authors demonstrate that in the event that one of the participants underperforms and the others are unable to identify the cause of this, i.e. either through failure to abide by the agreement or because of external circumstances, cooperation ceases for as long as the availability of information is low. This original idea has been taken up by many authors. In a more general framework, Fudenberg, Levine and Maskin (1990) show that the probability of cooperation ceasing decreases with increasing quality of information. In this way, Barrett (1994) shows that with regard to GHG emissions, the prospect of a treaty failure can encourage participants to honor their commitments. In all these studies, improving available information therefore gives rise to a significant increase in welfare since it reinforces the stability of agreements. Cooperation can be sustained because a country that would deviate from it would be rapidly identified, and punished. This is clearly highly dependent on the quality of the monitoring system.

Better information strengthens existing agreements but may, in theory, reduce the probability of including all countries in a given agreement. If there is information that reveals that a particular group of countries will only be slightly affected by climate change, it is unlikely that this group would want to take part in efforts to reduce GHG. Similarly, the poorest countries may have a lower willingness to pay for the fight against global warming than others.

**II.3 Development aid and climate agreements**

The studies mentioned above do not take into account the fact that better information allows us to better define the rules regarding cooperation. Compensatory mechanisms for compensating developing countries or those that are not greatly affected by climate change may garner greater support to solve the climate change problem. Better information on the heterogeneity may constitute the foundation of a compensatory system between countries. Barett (2001) insists on the fact that financial compensations can improve cooperation and increase the probability of an international treaty being ratified. They may also constitute the foundation of renewed development aid.

In concrete terms, the financial compensations that Barett (2001) refers to can take the form of investments in emissions reductions projects for developing countries. Indeed, this is the idea behind the Clean Development Mechanism (CDM) program. Defined in article 12 of the Kyoto Protocol, the CDM is a program involving financial transfers between developed and developing countries in order to fund projects to reduce GHG emissions. It allows countries listed in Annex I who have committed themselves to reducing GHG emissions within the framework of the Protocol to obtain certified emissions credits, which helps them to honor

their commitments thanks to emissions reductions in developing countries who are not bound by commitments involving figures. In practice, this implies to invest in a developing country in exchange for credits for emissions reductions issued by a United Nations certification organization, the UNFCCC (United Nations Framework Convention on Climate Change). In most cases, there is a specialist intermediary between the investor and the party managing the project in the developing country. To date, more than 1800 projects have been registered for investments amounting to more than 8 billion dollars. However, although there are about fifty developing countries participating in the program, most of the projects are intended for China, India and Brazil. Yet, we have not observed any turning point, with respect to a reference scenario, in the evolution of GHG emissions in relation to these three main beneficiaries. Today, many economists are skeptical about the opportunities of such programs.

Reliable measurements of local emissions would enable a significant and efficient development of the CDM program since satellite observations are ideal for ensuring the overall coherence of local statements. Indeed, a project is given certification provided, on one hand, that it gives rise to real advantages that are measurable, durable and associated with climate change abatement, and on the other hand, that the reductions in emissions add on to those that would have occurred in the absence of the project. Therefore, to meet the requirements for certification, it is necessary to be able to measure emissions before and after the project is put into place. In the meantime, intermediaries need to turn to independent audit offices in order to obtain UNFCCC certification for their projects. These offices bill 10% of project costs on average for their services. Making available high-quality, public information on local emissions would be greatly beneficial since it would make these audits less useful. Furthermore, it would enable the development of other similar mechanisms relating to forestry and agriculture, such as the Reduced Emissions from Deforestation and Forest Degradation (REDD) program by the United Nations, or the AFOLU (Agriculture, Forestry and Other Land Uses) projects. A monitoring system would be clearly valuable for two reasons. Firstly, it would help increase participation in international agreements: countries like Brazil could be attracted by the prospect of valuing their efforts to avoid deforestation. Secondly, this would allow giving proper incentives for reforestation

## III. Improving the efficiency of national policies

Better information on GHG dynamics would enable the establishment of tools that are more efficient, and also more economical in terms of public finance, to encourage reductions in GHG. There are various advantages, but the very first of these, although not easily assessed, is potentially of great importance. It has to do with the credibility of public information.

Citizens are increasingly wary of messages issued by governments concerning sanitary or environmental risks. Governments are suspected of dramatizing or, on the contrary, underestimating certain risks, or of overpromoting their actions for electoral reasons. The case of global warming, in particular, speaks for itself: in spite of there being a consensus among scientists, there are many debates in civil society which, in putting opposing views on the same level, make the information seem less credible. In this context, it is difficult to be convincing about the merits of environmental measures that require immediate economic sacrifice. The debate on the carbon tax that took place in September 2009 is a good illustration of this. From a theoretical viewpoint, Barigozzi and Villeneuve (2006) show that distortive taxation is less efficient if citizens receive little information but are nonetheless

aware that the government may have some interest in communicating biased information. Similarly, the temptation to pass the responsibility of unpopular measures on to supranational institutions and the defiance with regard to such institutions do not allow the establishment of ambitious policies. A system for monitoring GHG levels that integrates non-manipulable satellite observations can provide elements that are on the whole deemed credible by citizens. The support for national policies on the fight against global warming can therefore only strengthen the feasibility and efficiency of these policies.

**III.1 Introduction of proper regulation of polluting activities**

Currently, there is no system in France that regulates the carbon emissions of firms. The European system for emissions permit markets constitutes some form of regulation that will be discussed in section IV. However, assuming that a national system for regulating firms will be set up, an increase in available information on emissions would be extremely beneficial. Symmetrically, poor quality information on emissions has, to date, prevented the setting up of an efficient regulatory system. Any benefit would come from the simultaneous decrease in distorsions imposed on the economy and in rents left to firms. Such benefits may be estimated using specific procedures but presently, there are no studies available for the case of GHG emissions.

The main difficulty encountered by regulators comes from the lack of information on the actions (moral hazard) and the (antiselection) characteristics of actors alike (Laffont and Tirole, 1993). Moral hazard arises from the fact that it is difficult to distinguish anthropogenic emissions from natural ones. If information is improved in the sense that it allows us to better distinguish between these two types of emissions, then the Sufficient Statistic Theorem (Holmström, 1979) would apply and regulation would be more efficient as the system of incentives would become less costly. The risk that we impose on actors in encouraging them to reduce their emissions would therefore be smaller. The antiselection phenomenon is also potentially significant. For example, this is the case if the regulator wishes firms to adopt less polluting technologies without being aware of the associated marginal costs involved. The decrease in informational rent enables the introduction of higher taxes or lower subsidies to achieve the desired objective. Nevertheless, the difficulty lies in the fact that a system for monitoring GHG dynamics, as efficient as it may be, does not allow to directly observe the cost of efforts in reducing emissions. It does however allow to use Yardstick Competition, as in the case of water services in the United Kingdom.

Yardstick Competition (Schleifer, 1985, Crémer and McLean, 1988) consists in trying to obtain more information on the characteristics or actions of a firm by using information about other firms. Theoretically, noting performance measurements for all firms in a single sector, whether industrial or geographical, enables us to eliminate the common factors that come in the way of these measurements; factors that are unknown to the regulator itself, e.g. the precise economic situation, the cost of certain technologies that are more or less polluting, etc. Thus, by comparing the data on the emissions of firms within the same industrial sector or geographical area, it is possible to obtain better information on the investment costs of less polluting technologies. Yardstick Competition only works well if there is sufficient correlation between the structure and the costs of the businesses being considered. In the case of emissions reductions, there is probably a strong correlation between the two. The benefits associated with en efficient Yardstick Competition system may be assessed using a pioneer experience carried out in England and Wales. The water services there are regulated by an agency, the Ofwat, which uses data available for all firms in the sector to authorize, or not, consumer price increases and to assess the necessity of carrying out further investments. The

competing authority must take into account the fact that mergers cause the agency to lose a very useful element of comparison in the regulation of firms within the sector. This is why, on several occasions since 1996, it has opposed to mergers, arguing that the potential fall in prices generated by such mergers was small in comparison to the potential losses caused by the disappearance of an element of comparison. This is an instructive example as it demonstrates that the value associated with more information for regulation is high.

**III.2 Efficient taxation on polluting activities**

"Green" taxes are currently a popular subject of public debate. Their alleged negative effects on the competitiveness of national businesses or inequalities appear all the more important as their impact on the environment is uncertain. Would better information on GHG dynamics make taxation on polluting activities more efficient? First of all, economic literature insists on the advantages of taxing production factors rather than products or consumption. However, due to the lack of information, the second option is usually favored. For example, the carbon tax proposed by the French government is based on gasoline consumption and not on emissions generated by petroleum extraction. Secondly, information is necessary in order to set the tax at an appropriate level. Indeed, the tax must be high enough to prompt a change in behavior, i.e. encourage agents to consume a larger proportion of goods and services associated with low emissions of pollutants. On the other hand, it must not be too high in order for it to remain politically and economically acceptable. The definition of an appropriate tax level is all the more tricky when this tax is redistributed, in which case the redistributory effects of taxation are added on to distorsive ones.

Thus, the lack of information makes regulation through taxation difficult. And it is all the more so from a dynamic point of view. As Schubert (2009) points out, the crucial issue at stake when it comes to the carbon tax is its evolution over time. If there is no overall uncertainty, the taxation problem is one involving information asymmetry between the regulator and the regulated. To private individuals, the carbon tax then resembles a sort of fixed price regulation: a price is fixed for a tonne of carbon and each household receives a fixed subsidy. This type of regulation is very efficient and should be durable. By maintaining the tax constant (or at a predefined growth rate), the policy provides the right incentives. In the event of a lack of information, the tax is likely to be changed more or less frequently over time in order to take into account the arrival of new information. Since such adjustments are anticipated by actors, the taxation scheme then resembles a *cost plus* type of regulation. In studying the regulation of urban transport systems by local authorities, Gagnepain and Ivaldi (2002) show that this method is more frequently used in the absence of information, and in spite of it being suboptimal. These results suggest that by improving information for regulators, a system for measuring emissions would enable these regulators to adopt a fixed price type of regulation more often; one that would provide better incentives to reduce emissions.

It is important to note that the financial yield of a carbon tax can be very significant. The TSE-LERNA has a computable general equilibrium model, calibrated on real data, which allows us to calculate this yield. There are various possible scenarios. If, for example, the energy and climate contribution announced by the French government (amounting to 17 euros per tonne in 2010 and subsequently increasing by 6% annually on average) were applied on a global scale, the receipts would reach some 100 billion euros before 2015. Allocating just one percent of these receipts to improving the quality of information on GHG dynamics would therefore be more than sufficient to finance a high-quality system.

## IV. The carbon finance market

A system for monitoring GHG emissions that is sufficiently accurate and frequently updated should revitalize the markets for carbon dioxide emissions permits. At the moment, the latter, especially the European market, only involve the industries that emit the most carbon, i.e. about half of European emissions. The transaction volumes are also relatively small. These markets are, however, due to develop. Better information on GHG dynamics should allow us to enhance the quality of bonds, increase market liquidity and set up more efficient procedures for the allocation of permits. In return, markets could contribute to the funding of the emissions monitoring system.

### IV.1 Enhancing the quality of bonds and market liquidity

The first beneficial effect that can be expected of better information on GHG dynamics involves the quality of bonds. The latter depends mostly on the issuing conditions. In principle, there is a fixed number of bonds that are allocated or auctioned, and the market operates within this quota framework. In practice, things are more complicated. Each emitter is subjected to verifications, which require it to possess a number of bonds that matches the observed emissions. These verifications fall within the province of each government and we can imagine that it will continue to be so in the future. Yet, public authorities have less and less power when faced with the economic interests of firms and so their verifications are more or less reliable. Any imperfection allows an emitter to exceed its bond quota. In financial terms, this is equivalent to secretly issuing bonds. By and large, this harms both the quality of the bonds and investor confidence in these bonds. Better information on carbon emissions will not enable to avoid all individual frauds, which are too small to be detected and attributed to a particular emitter, but will nonetheless allow to compare aggregate issuances of a region or country to the sum of bonds introduced. Any discrepancy will lead to suspicion concerning the verification system put in place by the government. Thus, an efficient monitoring system should first and foremost have the virtue of disciplining the controllers themselves (Kofman and Lawarree, 1993), and in the same way enhance the quality of bonds and hence market liquidity.

The second benefit has to do with market liquidity. Regular, public and frequent communication of information enables us to bring market prices closer to their fundamental value. In addition, the time available for benefiting from private information is reduced. According to Vives (1997), this has two consequences. The first consequence is positive. More public information leads to private information being revealed on the market more rapidly. The operators are more inclined to exchange since they know that the rent for private information is low. As a result, market liquidity increases. The second consequence is paradoxical. Few agents are willing to search for private information because they know that it does not pay as well. Therefore, the supply of private information declines and some authors have shown that this supply is socially insufficient in the face of the public information available. On the contrary, if public information is more accurate than private information, or if it is initially inaccurate, the second effect is weaker than the first, and so the supply of public information is always socially positive (Morris and Shin, 2002, and Hellwig, 2005).

This second effect would not be so significant in the case of permit markets. Most private information comes from the individual projects of each emitter and, as we have seen, the latter introduces these to the market more quickly. Unlike stock markets, in which certain information regarding the health of firms is essential and generates common value effects, the

permit markets is a simple one: the supply of permits is fixed and the hazards concern economic growth, for example, which is a macroeconomic phenomenon for which it is more difficult to obtain private information.

The effects analyzed above highlight the fact that the benefits of the system being considered have to do with market liquidity and efficiency. Assessing the social value of an improvement in these two characteristics ultimately boils down to assessing the social value of financial markets. In the case of permit markets, especially their counterpart on futures markets, they enable the evaluation of the return on an investment that would reduce future emissions. It therefore matters that prices incorporate as much information as possible. To this effect, the supply of public information on aggregate issuances allows us to better evaluate the basic value of a permit and to limit short-term fluctuations. It allows planning investments better. In the energy and industrial sectors, investment is often programmed over long horizons; the availability of reliable markets, including forward and derivative markets, is clearly very important to provide high-quality price signals. Besides, the second role of financial markets is to enable risk sharing. Energy-related markets are naturally volatile for many reasons, most of which are political. Improving market liquidity guarantees an emitter that it will be able to buy or sell high volumes of bonds without drawing unfavorable reactions. Higher liquidity also allows the opening of more markets for derivatives, which improves the hedging options.

**IV.2 Initial allocation of permits**

Better information could also have a significant effect on market efficiency, especially in the setting up of an auction system that is designed to completely replace the permit allocation one. The allocations that were introduced in the past have been highly criticized and, most notably, accused of having caused the recorded slump in prices by virtue of their abundance. The allocation of permits has until now been based on a free distribution to emitters, based on observations of past emissions (grandfathering). One must recognize that prior to the first distribution, the regulatory authorities only had estimations of past emissions at their disposal. Nevertheless, many economic works show that even if it were available, the information provided by price changes cannot necessarily be exploited, mostly owing to the small number of participants. Given that future allocations will depend on their current behavior, market actors may adopt strategic behaviors that interfere with information provided by the market. This mechanism, which is known as the ratchet effect in economic literature, makes the permit allocation system unattractive.

A system for the auctioning of permits is notably planned for the third phase of the European market. An auction system is very lucrative when the good being auctioned is a private value, i.e. when its value is unique to each bidder. In this case, the auction allows the seller to allot the object being auctioned in an efficient manner, to whomever awards the highest valuation to this good, and at a price equal to the second highest valuation: the difference between the latter and the winning bidder's valuation constitutes an informational rent left to the winner. In the case of permit markets, the private value is the marginal cost for a firm to acquire an emissions-reducing technology. The difficulty with this type of auction is that permits also have what is known as a "common" value, which corresponds to their market price. Many theoretical and applied works have studied the negative effects of uncertainty on common value auctions. Here, the uncertainty mainly concerns variations in GHG concentrations that could strongly influence permit prices. The first of these effects is called the winner's curse. The firm that wins the auction probably overestimated the value of the permit since it made a higher offer than all other bidders. It therefore risks making losses. In order to avoid such losses, each bidder reduces his/her bid, and all in all, the auction is not very remunerative. A

second effect rests on the asymmetries of information among bidders. As in any market, certain actors have greater financial soundness and are better informed than their competitors. The latter anticipate that they will incur greater than average losses in the auction and usually prefer not to take part at all. We generally observe low participation rates in auctions of uncertain common value goods. By diffusing information that is widely recognized as being public to all participants, the system for measuring emissions can reduce overall uncertainty and information asymmetries among bidders. It would make auctioning a more efficient procedure for distributing permits.

**IV.3 A potentially very important source of funding**

Better information on GHG dynamics would also benefit the carbon finance markets. It may be legitimate to think that the latter could contribute to the funding of this public good since the market would then finance the gathering of the information it needs. The issue of a tax on the total value of transactions performed on markets is regularly brought up in public debates. It is the subject of many conflicting debates, but in the case of carbon, it could make some sense since the market partially finances the information that it needs. Given the volume of transactions recorded in the past, such a tax, if it had been established, would have raised relatively small sums. For example, in spot markets and eventually on the BlueNext stock exchange, the total value of transactions amounted to 60.4 billion euros in 2008. Taking 0.005% of this sum, i.e. the rate recently proposed by Bernard Kouchner for all financial markets, would have freed up a mere 3 million euros, assuming constant behavior. A higher rate would, of course, give higher receipts. The likely development of carbon markets does however suggest that this source of funding could increase considerably. Thus, the agency Point Carbon, believes that the world volume of transactions on these markets should reach 3100 billion dollars by 2020. In this case, more than 150 million dollars would be raised annually from a 0.005% tax.

## Conclusion

Better information on GHG dynamics would result in very significant economic benefits and facilitate the establishment of an ambitious policy for fighting global warming. The value of this information is unquestionably positive if all countries get along and make the fight against global warming a common objective. In the absence of a global agreement or a supranational authority, a system permitting reliable monitoring of anthropogenic emissions of different countries would enable the development of an efficient compensatory system. Such a system would also be indispensable for a national permit market, if the latter were to be set up. In each country, better information on the emissions of various economic actors would allow the introduction of specially adapted regulation. Improved regulation, fair taxation and developed carbon markets would enable each country to meet its objectives in terms of emissions reductions.

This study has identified the economic benefits of improved information on the dynamics of GHG. It also suggests several possible subjects for research that should be explored in order to evaluate these benefits in a precise and convincing manner. The value of information associated with the uncertainty pertaining to GHG dynamics should first and foremost be calculated in an ecoclimatic model. This involves updating the works of Nordhaus (1994) by integrating the various irreversibilities whose existence is no longer doubted today. It would also be interesting to develop economic research on carbon markets. Indeed, there are

significant problems relating to the value of information when the market is imperfect and the design of more efficient allocation systems for permits.

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