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Abstract

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Integrating unpaid costs of damage to natural assets

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The report from the Stiglitz Commission on measurement of economic performance and social progress, submitted to France's President last September, opens up new perspectives on measurement of growth that is more environmentally benign. New national accounting aggregates can be envisaged if it is possible to ascribe a cost to the damage done to natural assets but not borne by the economy. This article attempts to evaluate, and integrate into final demand, the unpaid costs that would make it possible to avoid global warming beyond a given threshold. This would lead to an indicator that is partial but that gives a fuller indication of the total cost of final demand. Its comparison with the traditional indicator would show how far we are off-course in relation to a pathway to sustainable growth defined in terms of given standards.

Introduction

The emergence of concerns over sustainable development has pushed forward thinking on the development of new indicators to measure countries' economic, social and environmental performance.
In line with this, the law on implementation of the decisions from France's *Grenelle de l'environnement* (environmental forum) meetings, adopted by parliament in August 2009, stipulates, in its Article 48, that the 'state sets as an objective the establishment of indicators allowing for evaluation of environmental public goods in national accounting by 2010'.
In response to a similar but wider concern, the Stiglitz Commission, set up in January 2008 by the French President, submitted its final report in September 2009 [1]. The report emphasises the inadequacy of current instruments, issuing notably from national accounting, to measure wellbeing and the conditions for its preservation for future generations. It outlines perspectives that emphasise the necessity for a multi-disciplinary approach.
This article forms a contribution to the debate, taking as a basis the current work of the *Commissariat général pour le développement durable* (general commissariat for sustainable development). The overall objective is to develop a new national accounting aggregate integrating into final demand certain environmental externalities that are largely ignored in national accounts. Currently, environmental damage − whether in the form of pollution, degradation of landscape or of biodiversity − has no effect on GDP, final consumption or saving unless it gives rise to repair or compensation. The purpose of this new indicator is to complete final demand at paid cost (FDPC) by measurement of its total cost. This would throw light on the path to be followed to achieve more sustainable forms of production and consumption.
The issue of climate change provides a complex example of externalities, as most of the associated damage is projected for a more or less distant future, is subject to numerous uncertainties and implies choices that are radically different for the present. The discussion below attempts to show how a new monetary aggregate could reflect the immediate and future unpaid costs of measures to limit mean global warming to a given level.
The estimates proposed apply to France, assuming certain given hypotheses. They are based on recent evaluations of the cost or price to be set for emitted carbon and on research into environmental economic accounting.

The unpaid cost of environmental damage

Including damage via a first partial aggregated indicator

Current national accounts do not cover all of the costs of avoiding environmental damage. They do not include the cost of numerous forms of damage to global public goods such as the quality of air and landscape or stability of climate when these are not the subject of trade or pricing or public sector intervention. Conversely, if repairs are undertaken to avoid damage or return damaged public goods to their former condition, current aggregates include them.
The aim is to devise one or several additional indicators that take account of the costs of different forms of environmental damage not borne by economic activities. Some environmental economists have strong reservations about the qualities of a single indicator, given the problem of substitutability of different forms of capital. Thus, from a 'strong sustainability' standpoint, growth in economic or human capital cannot compensate for depreciation of natural capital. In the case in point, this defect can be avoided upstream of building of the indicator. If the standards used to calculate maintenance costs are defined at the start for each type of asset included, there is no longer a problem of substitutability. Furthermore, by the indicator's construction, aggregation of different assets tends to increase the total cost of final demand and the difference between it and that measured at paid cost A difficulty remains, however, relating to possible double counting if implementation of standards for a given asset has positive effects on the state of one or other of the types of assets.

For the moment the exercise is focused on the climate. However, the approach is progressive and will cover estimation of maintenance costs for each type of asset (climate, air, water, etc.) in succession. Their aggregation to obtain a global aggregate of final demand at total cost (FDTC) will be undertaken step by step.

In the SEEA[1] classification of natural assets, the category covering climate is designated as 'atmospheric systems', which covers a slightly wider field. The climate can be considered as a global public asset of which the 'operation' is subject to various complex interactions. Changes to the composition of the atmosphere or disruption of the carbon cycle (exchanges between the atmosphere, biosphere and oceans) cause climate instability. These disturbances are, primarily, the result of emissions of greenhouse gases (GHG) of human origin, mainly from the use of fossil fuels. The indicator of the unpaid costs of final demand takes account of the maintenance costs that are required to preserve the state of the atmospheric systems[2] but to which the community has not yet committed.

Evaluation of environmental costs not borne by economic agents

Nature absorbs pollutants and renews ambient air or surface waters, within the limits of its regenerating capacity. It thus provides free services to economic activities. However, once subjected to a certain level of pressure, its usual storage, absorption or regenerative functions are affected. A cost of damage to nature is then incurred and free provision of services to the economy should no longer be the rule. Uncompensated damage by economic activities should therefore be identified as consumption of natural assets. The costs not borne by the economy equate to a transfer of capital from nature to the economy [2]. At this point, it must be pointed out that these costs do not correspond to all of the services provided by nature or by different ecosystems but only to the contribution of certain natural assets to functioning of the production system.

What do these costs amount to? They are equal to the expenditure required to maintain or restablish the capacity of nature to provide services. In the past this equated to, for example, the investments made to absorb or filter discharges into the atmosphere (e.g. particle filters) or to measures such as domestic taxes on petroleum products without which CO_2 emissions would certainly be much higher. However, the current price of products is a poor reflection of the cost of avoiding or treating the CO_2 emissions to the atmosphere generated by their manufacture or use. The current trend towards global warming, driven by global GHG emissions, tends to emphasise the unpaid environmental cost in spite of the various economic measures applied to reduce it (regulations, taxes, emissions trading).

1 SEEA: Integrated Environmental and Economic Accounting handbook. Last published in 2003.
2 This expression is not used systematically below, in the interests of readability.

Establishing a critical threshold

The unpaid environmental costs are based on the establishment of a critical threshold beyond which the natural processes of absorption of waste are disrupted. Determining this threshold is no mean task. Environmental standards or public health targets set in terms of toxicity thresholds can sometimes be used as a basis. The costs amount to the level of expenditure that would have to be committed to remain below the critical threshold or to return to such a position. However, thresholds are often set in relation to the harmfulness of a given product but rarely constitute the actual value beyond which natural assets are damaged. The process may be slow and progressive, with reference to threshold values being partially arbitrary. Where climate is concerned, the thresholds are defined with reference to research work in climatology, in terms of concentrations of GHG in the atmosphere (see below).

What adjustments are needed to accounting aggregates?

The general idea developed by A. Vanoli [2] [3] is to pass on the costs of certain services provided by nature to final demand, particularly those relating to nature's functions of storage or absorption of waste generated by economic activities. These services become costly when the pressure exerted on nature by economic activities exceeds the regeneration capacity of natural assets, leading sometimes to irreversible deterioration.
Final demand, currently measured at paid cost, must be re-evaluated to integrate the unpaid cost of degradation of natural assets. The economy's output and incomes remain unchanged.

Under current accounting rules, the GDP balance is given by:

$GDP + M = C + GFCF + \Delta S + X.$
Where C is final consumption; GFCF is gross fixed capital formation; ΔS is variations in stocks; M is imports; and X is exports.

To measure final demand taking account of the unpaid environmental costs, the accounting formula becomes:

$GDP + M + y = C + GFCF + \Delta S + X + y$

The term y is a measurement of the difference between the cost of the final demand at paid cost (current method) and its total cost including the economy's consumption of natural assets. In the case in point, this difference relates to the pressure exerted on the climate equilibrium by the atmospheric concentration of GHGs in excess.
Lastly, if the focus is turned to domestic final demand, to be consistent with emissions generated within national boundaries, the formula becomes:

$GDP + M – X + y = C + GFCF + \Delta S + y$

Towards a new aggregated indicator for sustainable development

The indicator to be developed should emphasise the difference in relation to a more sustainable mode of production defined in reference to a given standard or set of standards.
The relationship between FDPC and FDTC takes account of the economy's inability to compensate for damage to natural assets. In terms of sustainability, it can only be interpreted in terms of the elements that are internalised, bearing in mind that other forms of environmental damage are ignored.

$$\frac{\mathrm{DFCT}}{\mathrm{DFCP}} = \frac{\mathrm{C} + \mathrm{FBCF} + \Delta\mathrm{S} + \mathrm{y}}{\mathrm{C} + \mathrm{FBCF} + \Delta\mathrm{S}}$$

$$\frac{\mathrm{DFCT}}{\mathrm{DFCP}} = \frac{\mathrm{DFCP} + \mathrm{y}}{\mathrm{DFCP}} = 1 + \frac{\mathrm{y}}{\mathrm{DFCP}}$$

Note du traducteur : versions anglaises de formules ci-dessus

$$\frac{FDTC}{FDCP} = \frac{C + GFCF + \Delta S + y}{C + GFCF + \Delta S}$$

$$\frac{FDTC}{FDPC} = \frac{FDCP + y}{FDPC} + 1 + \frac{y}{FDPC}$$

Costs relating to GHG emissions

Avoiding major climate changes

Climate change is a particularly complex issue since the associated risks are projected over coming decades, even though initial signs are already appearing. Different threats are foreseen between now and the end of the 21st century: lower crop yields, risk of famine, threats to water resources and to biodiversity, occurrences of extreme weather events, loss of coastal urban areas and major population migrations.
The link between concentrations of GHGs in the atmosphere and climate variation has been established by the results of much scientific research. A succession of reports from the Intergovernmental Panel on Climate Change (IPCC) has pointed out the part played by human activities in the increase in GHG concentrations as a result of increased emissions to the atmosphere. In its 4th report, published in 2007, the IPCC estimates that, without reductions in anthropogenic GHG emissions, the Earth's average temperature will increase by 1.8−4 °C over the course of the 21st century.

Choosing a threshold value for GHG concentrations and emissions

A massive reduction in GHG emissions to stabilise their atmospheric concentration at 450 parts per million[3] (ppm) would lead to an acceptable level of risk in terms of the occurrence of the most severe climate disturbances associated with a global temperature increase of more than 2 °C. That supposes a reduction by half of global GHG emissions in 2050 in relation to 1990 levels. The cost of the measures required to obtain that reduction represent the cost of maintaining or restablishing the quality of the 'atmospheric systems' at their baseline level (i.e. the year 1990).

Measuring the cost of GHG reductions

The cost of GHG reductions corresponds to a cost that is currently unpaid. It is linked to an excessive consumption of products that are at the root of these emissions in relation to the level of consumption that would permit natural assets to regenerate automatically and, in the case in point, for the climate to stabilise.
The approach must allow for the inertia of ecosystems − continuous emissions have accumulated over several centuries − and the decision between undertaking major efforts today or postponing them.

A distinction must be made between, on the one hand, estimation of the cost of damage to the planet and its populations that would result, under various scenarios, from a global temperature increase if GHG emissions exceed by a given proportion a threshold considered as a limit value and, on the other hand, estimation of the cost of the measures required to, in a given configuration, reduce GHG emissions to a level that has been decided upon.
The first of these approaches seeks to establish the social cost of damage to the planet resulting from GHG emissions: what would be the cost to society of emission of an additional tonne of carbon with a time horizon of 50−100 years? This requires a clear idea of future damages and of their distribution over time, as well as hypotheses on technological progress. The question therefore arises, for example, as to which hypotheses to accept up to 2050 regarding energy efficiency and the uptake of

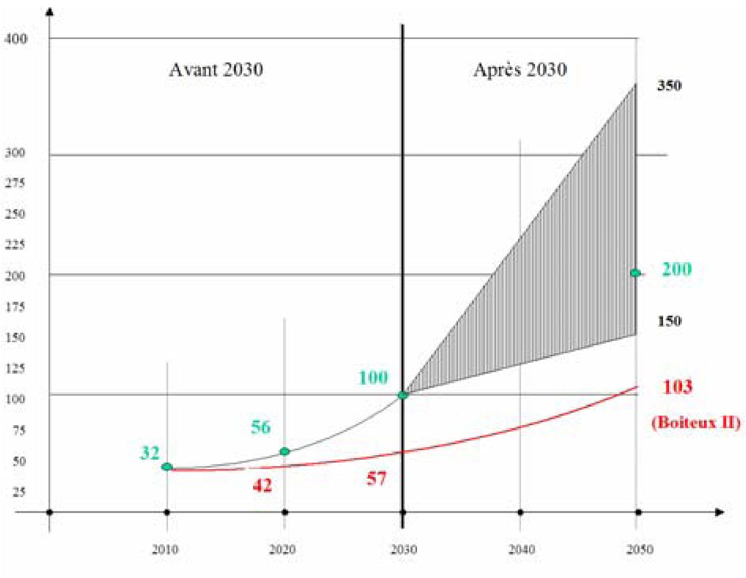
[3] This figure of 450 ppm means 450 molecules of a gas per million molecules of dry air. It is applied to all of the six main greenhouse gases and is expressed in terms of an equivalent amount of CO_2 taking account of its global warming potential over 100 years.

renewable energy sources. Lastly, the choice of discount rate is of prime importance. Via a cost-benefit analysis, the cost of (future) damage is compared to the cost of emission reductions (today or in the near future) that would avoid the damage. The Stern report [4] can be referred to as an example of such an approach.
With the cost-efficiency approach the question asked is simply that of the cost of keeping concentrations of GHGs below a critical threshold. The question relates to the costs required to reduce GHG emissions so as to comply with the 450 ppm limit. It must nonetheless be borne in mind that there are uncertainties, which the IPCC's models express as a level of risk, as to the assumed absence of major damage from a surface temperature increase limited to two degrees. Furthermore, the cost-efficiency analysis is based on a hypothesis as to the effects of the expenditure: is it sufficient and are the modalities of its application optimum? This raises, in particular, the question as to the effectiveness of the price signal for a carbon tax or investments in new technologies.
The exercise described in this article covers only the cost of emission reductions and is therefore solely concerned with the cost-efficiency approach. The problem of uncertainty and the level of risk associated with the choice of a threshold remains whole, even if the incorporation of new data into climate models tends to reduce it.

What price for a tonne of CO_2?

The question is: what cost can be put on a reduction of one tonne of CO_2? The Strategic Analysis Centre (CAS − *Centre d'analyse stratégique*) [5] proposes a value of €100 per tonne of CO_2 for the year 2030. This value has been retropolated to 2010, where it is set at €32.[4] Beyond 2030, the price increases at an annual discount rate of 4 per cent, leading to a value of €200 in 2050. How should this price be interpreted? The CAS report indicates that it is a price signal addressed to the economy so that France can achieve its target of a 75 per cent reduction in its GHG emissions by 2050[5]. It represents the marginal cost of a reduction of one tonne of CO_2: the amount that must be spent for one less tonne to be emitted. If, for a variety of reasons, a lower price per tonne of CO_2 is set, the actual reduction in emissions should − other things being equal − be lower than the target. However, to estimate the unpaid costs it is the price/cost required to meet the target that should be retained, since it represents the cost of maintaining or returning the atmospheric systems to their targeted quality level.

Figure 1: changes in the value of carbon between 2010 and 2050



Source: Centre d'analyse stratégique (2008).

[4] In the CAS report the decision was made to use the value from the report from the Boiteux Commission (€27/tonne of CO_2 in 2000 updated to €32 € for 2010).
[5] This is, in some ways, the contribution of Europe and of France to halving global emissions by 2050, considered as a prerequisite if GHG concentrations are to be maintained at 450 ppm.

Internalising the cost of CO_2 emissions

Taxation is the prime instrument used by numerous countries to curb environmental damage. In France this instrument has returned centre stage after the decision by the government to introduce a carbon tax in 2010. To combat climate change, it will apply to fossil fuels (oil, gas, coal, LPG), electricity being exonerated. Its rate, fixed by the government at €17 per tonne of CO_2 emitted, implies an increase in fuel prices. The revenue from the tax is to be repaid to households in accordance with their size and distance from urban centres.

Other instruments using market mechanisms have emerged in recent years, in line with commitments under the Kyoto Protocol.

Europe's overall goal of an 8 per cent reduction in GHG emissions in relation to 1990 levels was spread over the member states of EU-15. These states have been operating an emissions trading scheme since 2005 covering the major emitting facilities in the energy, mining, paper and ferrous metals sectors. The market was set up over two periods: 2005−2007, which constituted a test phase; and 2008−2012, which corresponds to the period of the Kyoto Protocol commitments. Under the framework put in place by the EU, each state issues CO_2 emissions permits annually to the industrial facilities that are the major emitters in the different sectors. There was an obligation to issue 95 per cent of permits for free during the first phase, 90 per cent during the second. Any facility exceeding its permitted level of emissions has to buy permits equal to its excess emissions at the current European market price.

The market, covering around half of the CO_2 emissions from European countries, involves more than 11,000 facilities. To date, it is the largest carbon market in the world. The scheme does not extend to agriculture, transport (9 and 19 per cent of Europe's GHG emissions respectively) nor to building, services or small industrial facilities.

The climate change and energy package adopted by the European Parliament on 12 December 2008 aims for a 20 per cent reduction in GHG emissions by 2020. It includes the air travel sector in 2012 and progressive introduction of permit auctions from 2013. A target of a 10 per cent reduction in emissions in Europe and 14 per cent in France by 2020 is set for sectors not covered by the emissions trading scheme. Europe's objectives could be tightened by an international agreement at the United Nations Framework Convention on Climate Change Conference, to be held in Copenhagen in December 2009.

The essential difference between fiscal instruments and emissions trading is that in the former case the price is fixed (by the tax rate) but not the amount of reduction whereas, in the second case, the amount of emissions is regulated by a cap, with the price varying in accordance with the volume of trade in the market. There is little point in attempting to decide between these two types of instrument as their relevance is closely related to context (sectors covered, technologies, cost structure, exposure to competition, etc.).

Unpaid cost relating to GHG emissions

This corresponds to the financial effort required for the economy to follow an emissions path that would not exceed 450 ppm. The aim is to determine the amount by which emissions need to be reduced in relation to the currently observed trend. This can be done on the basis of the quantified difference between two prospective scenarios. The first is ‘business as usual’ (BAU), supposing relative stability of environmental taxation and of the rules governing the European CO_2 emissions trading scheme. The second plots the effects of a four-fold reduction in emissions between 1990 and 2050. This ambition, referred to as ‘Factor 4’, corresponds to the target set by France. However, it can only be meaningful if the goal is shared internationally, leading to a halving of global GHG emissions by 2050.

The difference between the annual amount of emissions under BAU and Factor 4 scenarios represents the emissions excess that will exert a pressure on climatic functions in the long term. To evaluate the unpaid cost corresponding to transfer of capital from nature to the economy (estimated value of damaged assets) this amount is given a value at the price per tonne of CO_2 determined in the CAS report. The assumption is made that, for a given year, the average unit cost is approximately the marginal cost.[6] Conversely, year on year, a progressive increase in marginal cost is observed, reflected in the increase in the price per tonne of CO_2.

An application: final demand including the unpaid cost of GHG emissions

Determining the baseline scenario

A BAU scenario is used as baseline, that is to say with no additional effort over and above the current situation: same tax levels, no change in current operation of European CO_2 market. The CAS report (volume II) considers a baseline scenario with an annual increase of 0.3 per cent in GHG emissions[7] in France. This projection differs widely from France's Factor 4 objective, since emissions would reach the equivalent of around 600 million tonnes of CO_2 ($MtCO_{2eq}$) in 2050, whereas the target is for 141 $MtCO_{2eq}$ (the 1990 level of 563 $MtCO_{2eq}$ divided by 4).

Even though rebound effects are possible, projected emission increases of + 0.3 per cent per year to 2050 seem a little pessimistic for France, since the average annual variation between 1990 and 2007 is – 0.3 per cent per year, and even – 0.6 per cent if only the past ten years are considered. The issues surrounding global warming and implementation of the European Emissions Trading Scheme (ETS) have doubtless led numerous players to become proactive and to invest in new low-carbon technologies.
Taking as baseline a scenario for an annual reduction in emissions of 0.3 per cent, their level − 458 $MtCO_{2eq}$ in 2050 − is far above the Factor 4 target, but is lower by one quarter than the level in the previous baseline scenario.

Calculation of unpaid cost

Calculation of the unpaid cost is based on the excess emissions in relation to a Factor 4 target. Using the two BAU scenarios described above, the excess is between 171 and 180 $MtCO_{2eq}$ in 2010 and between 317 and 456 $MtCO_{2eq}$ in 2050. The unpaid cost is calculated by assigning a value to these quantities at the price per tonne of CO_2 stipulated in the CAS report, depending on the year in question.
For 2010, the start of the projected period, the unpaid cost is fairly low given the price and quantity in question. It reaches €5.8 billion for the first scenario, against €5.5 billion for the second.
In 2050, the unpaid cost would be €63.4 billion or €91.2 billion, depending on the baseline scenario applied. Account must also be taken of the uncertainty as to the price given by the CAS for 2050 (150−350, see Figure 1), leading to bracketing of the cost of €91.2 billion between values of €68.4 billion and €159.6 billion.

A scenario in which efforts are made

It can be assumed that the costs calculated above for 2050 are sums based on excesses, as the amounts of excess emissions represent the difference between emissions under a highly ambitious Factor 4 scenario and those under BAU. However, this latter scenario is fairly unlikely and it seems to already be the case that new requirements and measures − carbon taxes and strengthening of the ETS market in Europe − will apply in a not too distant future. These (costly) measures should bring about greater reductions in emissions, implying a reduction in the non borne costs. If France attains a 50 per cent reduction target by 2050 (instead of Factor 4), the efforts made will have limited emissions to 282 $MtCO_{2eq}$ in 2050. The excess emissions in relation to the Factor 4 target will fall to 140 $MtCO_{2eq}$ and their cost will be somewhere between €21.1 billion and €49.1 billion.

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6 Strictly speaking, the total annual cost should be calculated with the integral of the marginal cost curve from the first to the last quantity to be reduced. Assimilating the average cost to the marginal cost means assuming a relatively constant unit cost for elimination of a certain annual quantity of emissions.
7 Emissions covered by the Kyoto Protocol: 6 GHGs excluding emissions from land use, changes of use and forests (carbon sinks) and excluding international maritime and air transport.

Table 1: unpaid cost of GHG emissions under different scenarios

	Changes in emissions between 1990 and 2050	Excess GHG emissions ($MtCO_{2eq}$)		Unpaid cost (billions of euros) [uncertainty bracket in 2050]*	
		2010	2050	2010	2050
Target: emission requirements/Factor 4	Division by 4 - 2.3% / year	0	0	Null	Null
Baseline scenario 1 (CAS)	+ 6% + 0.3% / year	180	456	5.8	91.2 [68.4 ; 159.6]
Baseline scenario 2	- 18.7% - 0.3% / year	171	317	5.5	63.4 [47.5 ; 110.9]
Proactive scenario 1	- 50% - 1.5% / year	153	140	4.9	28,1 [21.1 ; 49.1]
Proactive scenario 2	- 60% - 2% / year	140	85	4.7	17.0 [12.7 ; 29.7]

Key: in baseline scenario 2, excess emissions in relation to the Factor 4 target would go from 171 $MtCO_{2eq}$ in 2010 to 317 $MtCO_{2eq}$ in 2050, with respective unpaid costs of €5.5 billion and of €63.4 billion respectively.

** Uncertainty as to the value of the tonne of CO_2 applied in 2050, i.e. €200 bracketed by €150 and €350.*

NB: the annual rate of variation in emissions is calculated for the Factor 4 target over the 1990−2050 period and for the different scenarios over the 2007 (last known year)−2050 period.

Re-evaluation of final demand integrating unpaid environmental cost

The cost of preventing environmental damage, if not effectively borne by economic players, adds to the paid value of final demand. The various values calculated above allow for re-evaluation for different time periods and under different hypotheses. Calculations are performed below for the years 2010 and 2050, assuming a nominal value for economic growth of 3 per cent per year.

Final demand at paid cost and at total cost in 2010

Final domestic demand is the national accounting aggregate to which re-evaluation is applied. For 2008, it amounted to €1,997.2 billion (provisional account, Insee). At the assumed rate of growth[8], its value in 2010 would be €2,118.8 billion.
For 2010, the unpaid costs relating to GHG emissions is €5.5 billion under baseline scenario 2. This corresponds to the annual fraction of the cost required to achieve a four-fold reduction in emissions in 2050. In the present regulatory regime, this cost is not borne by the economic players via higher prices or taxes to maintain the regenerative capacity of natural assets (climate in the case in point).
This sum is added to the FDPC to arrive at the FDTC, which is €2,124.3 billion. National saving is reduced by the same amount[9] as production and incomes are not changed. To balance the value of final demand at total cost, the economic players are considered as having benefited from a transfer of capital from nature equal to the unpaid costs.

The indicator $\frac{FDTC}{FDPC}$ reaches 100.3% or a value of 0.3% for $\frac{y}{FDPC}$

Where climate change is concerned, this percentage is an indicator of the sustainability of the mode of production and consumption, as a critical threshold has been established in accordance with the supposed limit for regeneration of the assets concerned, i.e. the atmospheric systems. It is a little higher than that given by the World Bank's evaluation of adjusted net saving. The amount for damage linked to CO_2 emissions is estimated by the World Bank at 0.12 per cent of France's gross national

[8] This annual rate of 3 % may appear optimistic for 2009 et 2010, but it is only meaningful over the full 2008−2050 period.
[9] Supposing (not taking account of time differences) that these €5.5 billion apply to all of final consumption without affecting capital formation.

income[10] in 2006, an exceptionally stable figure since 1992. The difference of around two-tenths of a point in relation to this estimate arises mainly from the difference in the price assumed for one tonne of CO_2.

Final demand at paid cost and total cost in 2050

On the basis of the assumed rate of increase, final domestic demand would be €6,916 billion in 2050. With baseline scenario 2, the excess emissions would be 317 $MtCO_{2eq}$ and their cost would be between €47.5 billion and €110.9 billion. In relation to final domestic demand, the unpaid cost would be between 0.7 and 1.6 per cent of this.

Interpretation of the FDTC/FDPP ratio may be different for other natural assets for which the standards adopted may not be in terms of an equivalent critical threshold. Without knowledge of the fraction of the total stock of the natural asset in question to which this ratio corresponds, it will be more difficult to interpret it strictly in terms of sustainability. It will, however, be a valuable indicator of balance or imbalance in the relationship between the economy and nature for the asset or group of assets in question. Imbalance will indicate that the observed course is not sustainable, without, however, being able to indicate the degree of unsustainability.

Conclusion

The indicator and approach proposed here constitute one of the possible responses to the recommendations of the Stiglitz Commission report. The relationship between the unpaid cost of GHG emissions and final demand at paid cost appears as an aggregated monetary indicator of sustainability responding to Recommendation 11 of the report.
The approach adopted is global and could be advantageous if applied on a sectoral basis[11]. The global aggregate could thus be applied to products or groups of products. A given product would have an associated unpaid cost relating to the GHG emissions generated by its manufacture throughout the production chain. The approach aiming to determine the carbon content of products − and not the associated cost of reduction − is similar, but the aim is different.

Another limitation: the scenarios envisaged are defined in reference to a GHG reduction target applying to national territory. Emissions occurring abroad as a result of imports into France are ignored, constituting a very important restriction.
Lastly, estimation of the total cost of final demand is not limited to atmospheric systems. The cost of damage to other natural assets should be evaluated in order to bring together all of the unpaid costs. These apply to pollution of the atmosphere and of water. Measures should also be widened to include imports and their damaging impacts in foreign countries.
If this type of indicator were to meet with a broad consensus on the way in which it is developed and on its relevance, systematic annual publication should be organised, complementing currently used aggregates in national accounts such as GDP or final consumption.

Limits of measurement in an uncertain field

The ideas expressed in this article are intended to push forward thinking on integration of certain phenomena − environmental externalities largely ignored − into an indicator derived from national accounts. Measurement of the prevention cost of damage arising from climate change is made extremely difficult by the uncertainties surrounding the actual occurrence of the various forms of disruption of the climate predicted for a given level of mean global warming over a given period, and their economic consequences.

Use of cost-benefit analysis to determine unpaid costs for France is only relevant in a global context of progressive reductions in GHG emissions leading to their halving between 1990 and 2050. In this situation, the contribution and therefore the cost to France, banking on a 75 per cent reduction, are somewhat higher.

[10] The GNI is derived from the GDP by adding primary incomes received from the rest of the world and deducting those paid to the rest of the world. The aggregate difference used in the denominator explains very marginally the difference between the result calculated here and that of the World Bank.
[11] See article on sustainable production and consumption in this issue.

Adopting a concentration threshold (450 ppm in this case) facilitates measurement of the maintenance costs required, but rarely corresponds to the single value below which no cost would be incurred and above which costs would appear and increase in accordance with distance from the threshold value. Multiple values or complex functions and models would then be necessary.

It also appears important to associate cost evaluations with probabilities. The IPCC has understood this in associating levels of uncertainty with the results of climate models. Mean values or single evaluations should be used with care in predictive calculations applying to distant time horizons. Confidence intervals should be used when it is possible to associate probabilities with future climate events.

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