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Climate policies as a hedge against the uncertainty on future oil supply

Abstract:
Despite the inextricable link between oil scarcity and climate change, the interplay between these two issues is paradoxically an underworked area. This article uses a global energy-economy model to address the link between future oil supply and climate change and assesses in a common framework both the costs of climate policies and oil scarcity. It shows that, in the context of a limited and uncertain amount of ultimately recoverable oil resources, climate policies reduce the world vulnerability to peak oil. Climate policies, therefore, appear as a hedging strategy against the uncertainty on oil resources, in addition to their main aim of avoiding dangerous climate change. This co-benefit is estimated at the net present value of US$11,500 billion. Eventually, reducing the risk of future economic losses due to oil scarcity may appear as a significant side-benefit of climate policies to many decision-makers.

Keywords: Climate policies, peak oil, hedge, cost, uncertainty.

Les politiques climatiques comme protection contre l'incertitude de l'offre pétrolière à venir.

Résumé:
Malgré le lien inextricable existant entre la rareté pétrolière et le changement climatique, l'interaction de ces deux questions demeure paradoxalement un domaine peu élaboré. Cet article utilise un modèle global économie-énergie pour aborder le lien entre l'offre pétrolière future et le changement climatique et évaluer dans un cadre commun à la fois les coûts des politiques climatiques et de la rareté pétrolière. On montre que, dans un contexte de ressources pétrolières récupérables ultimes d'un montant limité et incertain, les politiques climatiques réduisent la vulnérabilité mondiale face au pic pétrolier. Les politiques climatiques, par conséquent, apparaissent comme une stratégie de protection contre l'incertitude des ressources pétrolières, en plus de leur objectif principal d'éviter un changement climatique dangereux. Ce bénéfice conjoint est estimé en valeur nette courante à 11 500 milliards US$. Finalement, la réduction du risque de pertes économiques futures du fait de la rareté pétrolière pourrait apparaître comme un bénéfice dérivé des politiques climatiques pour nombre de décideurs.

Mots-clés : politiques climatiques, pic pétrolier, protection, coût, incertitude.

Climate policies as a hedge against the uncertainty on future oil supply

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Abstract

Despite the inextricable link between oil scarcity and climate change, the interplay between these two issues is paradoxically an underworked area. This article uses a global energy-economy model to address the link between future oil supply and climate change and assesses in a common framework both the costs of climate policies and oil scarcity. It shows that, in the context of a limited and uncertain amount of ultimately recoverable oil resources, climate policies reduce the world vulnerability to peak oil. Climate policies, therefore, appear as a hedging strategy against the uncertainty on oil resources, in addition to their main aim of avoiding dangerous climate change. This co-benefit is estimated at the net present value of US$11,500 billion. Eventually, reducing the risk of future economic losses due to oil scarcity may appear as a significant side-benefit of climate policies to many decision-makers.
Key words : Climate policies, peak oil, hedge, cost, uncertainty.

Despite the inextricable link between oil scarcity and climate change (Toman, 2002; Brown and Huntington, 2008; Huntington and Brown, 2004; Turton and Barreto, 2006), the interplay between these two issues is paradoxically lacking a quantified analysis within a macroeconomic framework. This article uses a global energy-economy model to address this gap by assessing in a common framework both the costs of climate policies and oil scarcity, taking into account macroeconomic feedbacks. It shows that both costs are of the same order of magnitude. Moreover, our results suggest that, in the context of a limited and uncertain amount of ultimately recoverable oil resources, climate policies reduce the world vulnerability to peak oil. Climate policies, therefore, appear as a hedging strategy against the uncertainty on oil resources, in addition to their main aim of avoiding dangerous climate change (Mastrandrea and Schneider, 2004).

The amount of recoverable oil is extremely uncertain, and yet the world economy highly depends on it. Nevertheless, it is barely the only uncertain factor that may have a significant impact on all economies in the future. Major sources of uncertainty include, *inter alia*, future investments to sustain oil production; the strategy of Middle-East oil producers that have a significant market power in the oil market; future coal prices; the ability of synfuels (biofuels and coal-to-liquid) to penetrate energy markets; the existence and penetration of carbon-free power generation technologies and of low-carbon end-use technologies in the transportation and residential sectors (Pacala and Socolow, 2004); and future development patterns in the developing world. From a methodological point-of-view, this assessment has two consequences : first, the climate–energy issue should not be investigated assuming a Hotelling–like framework in which the final amount of recoverable oil is known and oil prices are perfectly anticipated by all actors (see for instance Pindyck (1978); Devarajan and Fisher (1982)). A modeled world in which all actors know how and when oil production will decrease and energy prices will increase is qualitatively different from the real world, in which all actors have to make decisions in a context of high uncertainty on these important world-economy drivers. It may thus be useful to introduce the effect of imperfect anticipations in the analysis, in order to take this difference into account. The second consequence is that it appears as inadequate to assess climate policies in a modeled world assuming that only one baseline scenario is possible. Today, any investment has to be assessed taking into account many uncertainties, including the one on future energy prices. Investing in climate policies is no different.

Designing climate policies requires decision-making methods that go beyond deterministic cost-benefit analysis and account for uncertainty and progressive arrival of new information, like sequential decision-making (Ha-Duong et al, 1997) or robust decision-making (Lempert, 2000). Informing such decision process demands quantifying the level of uncertainty associated to long-term scenarios. This paper presents an approach to address this requirement, through a sensitivity analysis of our energy-economy model, IMACLIM-R.

IMACLIM-R is a hybrid simulation model of a second-best world economy (Hourcade et al, 2006): it represents in a consistent framework the macro-economic and technological world evolutions, taking into account the possible under-utilization of production factors (labor and capital) due to inadequacy between flexible relative prices (including wages) and inert capital vintages characteristics. Importantly, the model is not based on perfect foresight or rational expectations, but on adaptive expectations reacting on price signals and past trends. A more developed description is available online (see Supporting Online Material), the model is fully detailed in Sassi et al (2009) and tested against real data in Guivarch et al (2009).

IMACLIM-R produces long-term scenarios of the world economy evolution and allows to explore the uncertainty that depends on unknown exogenous trends (e.g., future population) and poorly-understood mechanisms (e.g., penetration of new technology through investment). To get a better understanding of this uncertainty, we carried out a sensitivity analysis on selected exogenous parameters.

One difficulty arises from the multiplicity of parameters; we identified hundreds of parameters on which a sensitivity analysis can be useful, and each parameter can take an infinite number of values. To avoid combinatory explosion, the parameter domain has been simplified. First, the 369 selected parameters are aggregated into a few consistent parameter sets. For instance, all parameters describing the future availability of oil and gas are aggregated into an "oil and gas markets" parameter set. Then, two or three sets of values are associated to each parameter set. For instance, the "oil and gas market" parameter set has three possible options of increasing scarcity for both oil and gas; each of these options consists of values for the 27 parameters that compose this set.

In this analysis, we selected eight sets covering the major drivers of macroenergetic contexts with assumptions on natural resources, technologies and international economic trends. These sets have been built based on expert opinion in such a way that the eight sets are as independent as possible. In this analysis, we assume also that the different possible values of each set are of equal probability. All sets are described in details in the supporting online material ; the two most important for this study are:

Oil and gas markets: this set describes (i) the amount of ultimately recoverable resources; (ii) the amount of Middle-East investment to sustain oil production at the oil field scale and to explore for new fields; (iii) the inertia in non conventional production development; and (iv) the indexation of gas prices on oil prices. In "option 1" scenarios, these parameters are combined so that resources are abundant and easily extracted: oil production can reach 115 Mb per day. In "option 3" scenarios, oil and gas supplies are very constrained: production peaks below 95 Mb per day. "Option 2" represents an intermediate situation with a production plateau around 95 Mb per day.

Implementation of climate policies: the model simulates (i) a "Business As Usual" (BAU) world with no constraint on emissions, or (ii) a "stabilization" world in which a carbon price reduces emissions such that CO_2 concentration is stabilized at 450 ppm in the long run. In stabilization scenarios, revenues from carbon tax or auctioned emissions allowances are either entirely given back to households, or recycled following a lump-sum principle in which each sector receives back what it paid.

We carried out an exhaustive exploration of all the combinations for the eight sets, leading to 576 scenarios.

In our exercises, we measure the costs of oil scarcity and of climate policies using the same metric, namely the sum of the Gross World Product (GWP) over the 2010-2050 period, discounted at a 3% discount rate. The costs are measured as the relative difference (in percent) between the discounted summed GWP in two scenarios (e.g., with vs. without climate policies). We find that, in our model, the cost of oil scarcity is

Table 1: Changes in the 3%-discounted GWP over the 2010-2050 period (**mean** [min ; max]) caused by fossil fuels constraints and climate policies. The reference case has abundant oil ressources and no climate policies. Losses from the combination of climate policies and strong oil scarcity are smaller than the sum of both effects taken separately.

	Oil and gas, option 1	**Oil and gas, option 2**	**Oil and gas, option 3**
BAU	Reference case	**-1.3%** [-0.6 ; -2.1]	**-2.6%** [-1.8 ; -3.7]
450 ppm	**-1.7%** [-0.4 ; -4.4]	**-2.3%** [-1.0 ; -4.8]	**-3.3%** [-2.0 ; -5.7]
Net cost of climate policies	1.7% [0.4 ; 4.4]	1.0% [0.0 ; 3.1]	0.7% [0.0 ; 2.7]

significant (see figure 1). In the BAU scenarios, for instance, oil scarcity has a large impact on Gross World Product (GWP), and the 3%-discounted GWP over the 2010-2050 period is reduced on average by 2.6% in option 3 scenarios (oil is scarce) compared with option 1 scenarios (oil is largely available). Depending on assumptions on the other parameter sets (see supporting online material), these BAU losses range from 1.8% to 3.7%. They are due to changes in oil price trajectories, which affect production costs and purchasing power. Because of various macroeconomic effects (exchange rates appreciation, changes in investment decisions, modification of capital and goods international flows, and technologies), the additional rent transfer due to higher oil prices is not neutral at the global scale and reduces GWP. The impact of climate policies is significant as well, since they cost 1.2% GWP on average.

Most importantly, oil scarcity and climate policy interact with each other. Our results demonstrate that GWP losses from the combination of climate policies and strong oil scarcity are smaller than the sum of both effects taken separately (see table 1). The cost of climate policies is indeed strongly correlated with oil resources: with large resources (option 1) this cost is much higher (1.7% on average) than when oil resources are scarce (0.7% on average in option 3). It is important to note that this lower cost when oil is scarce does not arise from lower baseline emissions. Even in the scenario of highest oil scarcity, baseline emissions in 2050 are well above the 450 ppm target, in particular because coal consumption replaces oil through coal-to-liquid. Consequently, the reduction in emissions between the baseline and the stabilized scenario is about the same in the three options of the oil and gas parameter set, and tighter oil scarcity does not necessarily help meet the CO_2 concentration target.

In fact, climate policies are less costly when oil is scarce because, in addition to their benefits in terms of avoided climate impacts, they bring important co-benefits in terms

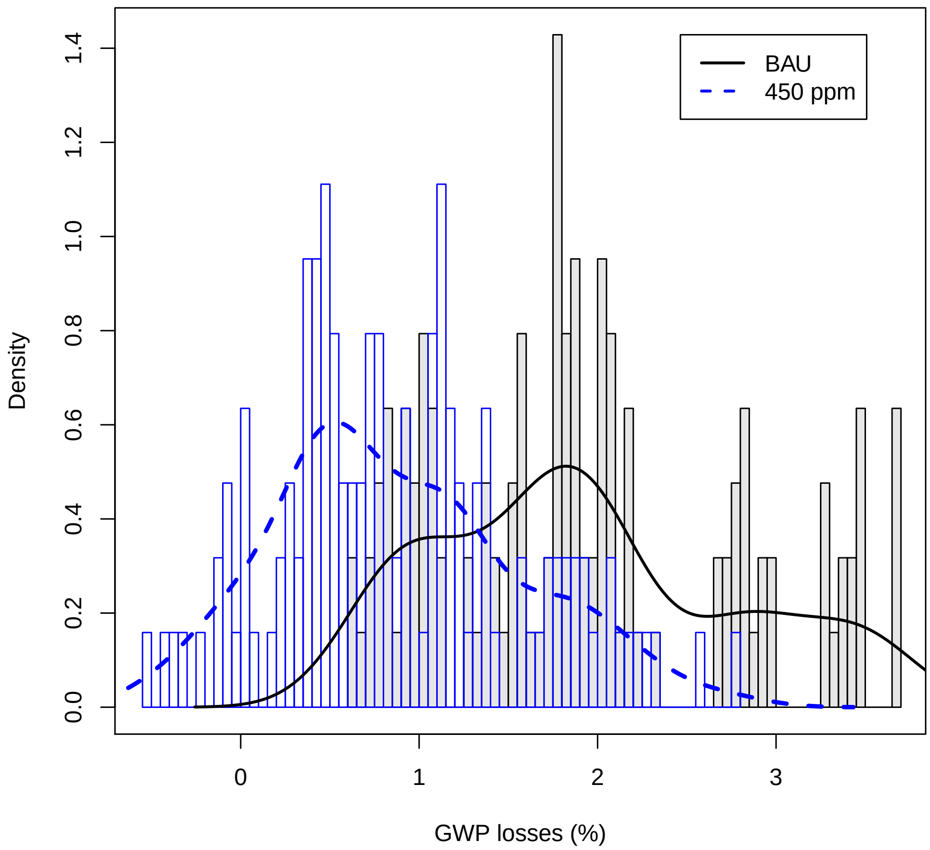

Figure 1: Histogram and smoothed densities of GWP losses (in %) due to constrained oil supply (discounted GWP between 2010 and 2050, with a 3% discount rate). Black filled bars and plain line for BAU scenarios; blue empty bars and dashed line for 450 ppm-stabilization scenarios. The 450 ppm histogram is shifted to the left compared with the BAU one, indicating that losses from oil scarcity are larger in absence of climate policies.

of energy security and resilience to oil scarcity. These co-benefits are illustrated by figure 1, which represents the histograms of GWP losses due to oil scarcity, with a distinction between scenarios without climate policies (BAU) and with climate policies (450 ppm). Two important results emerge: first, the 450 ppm histogram is shifted to the left, indicating that the mean loss due to oil scarcity is reduced by climate policies; second, the large right tail of the BAU distribution disappears in the 450 ppm distribution, meaning that climate policies eliminate a large number of scenarios with high GWP losses (larger than 3% and reaching up to 3.7%). These large mitigation co-benefits can be explained by earlier and more regular increases in final oil price. In a second-best world where anticipations are imperfect, indeed, brutal increases in energy prices cause larger welfare losses than regular increases (Nordhaus, 2007). Here, the more regular increase in energy price with climate policies prevents economic lock-ins in oil-dependent schemes and promotes the development of oil-free technologies before the beginning of the depletion phase in oil production.

Climate policies, therefore, can be considered as a hedge against the potential negative impact of oil scarcity on the world economy. This hedge parallels the climate-related hedge of early climate policies (see Yohe et al (2004); Manne and Richels (1992)). Its net present value can be calculated as the difference between economic losses due to oil scarcity without climate policies and the same losses with climate policies; see Supporting Online Material. A simple calculation suggests that this hedge has a net present value of about 11,500 US$b, that is 19% of the 2009 Gross World Product. The overall welfare cost of climate policies is thus significantly reduced, which is a powerful incentive to adopt more stringent climate targets. Eventually, reducing the risk of future economic losses due to oil scarcity may appear as a significant side-benefit of climate policies to many decision-makers.

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