CHEMICAL ENGINEERING TRANSACTIONS
VOL. 42, 2014
A publication of AIDIC
The Italian Association of Chemical Engineering
www.aidic.it/cet
Guest Editors: Petar Sabev Varbanov, Neven Duić

ISBN 978-88-95608-33-4; **ISSN** 2283-9216
DOI:10.3303/CET1442020

Gdyn-E: a Model for the Economic Assessment of Climate Policies

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In this paper we investigate the trade-offs between growth and low carbon targets for both developing and developed countries for the period to 2035. The issues examined include two policy options for being on track to meet the 450 ppm target: (a) national/regional targets without international trade in carbon permits and (b) a global market in permits. Policy options are evaluated with an original dynamic CGE (Computable General Equilibrium) model which relies on the static GTAP-E (Global Trade Analysis Project-Energy) structure. The model focuses on bilateral trade flows and links between economies and sectors that capture the realistic economy-wide nature of a globalized world. The results show higher costs of meeting the target than the average of previous models, although there are some previous studies that have costs in the same range. We then go on to investigate options for reducing these costs that are broadly consistent with a green growth strategy of supporting low carbon development. A green carbon fund financed through a levy on carbon taxation can benefit all parties. Potential larger benefits are associated with the investment of the green fund to foster energy efficiency.

1. Introduction

One of the politically most controversial climate change questions is how much will it cost to meet the targets consistent with a reasonable probability of avoiding major upheavals in the world's climate in the medium to long term. The issues under debate regard several aspects related to climate change actions, going from the quantification of abatement costs to the distribution of such costs across countries. The large uncertainty characterizing the assessment exercises implies a huge difficulty in reaching a global consensus upon the effective actions to be taken by the bargaining parties in the international negotiations.

The main purpose of this paper is to analyse a specific aspect of the difficulty regarding the assessment of alternative policy options aimed at reducing the abatement costs for developing countries in order to facilitate the achievement of a global consensus. The principle of Common But Differentiated Responsibilities (CBDR), introduced in the general framework adopted by the United Nations Convention on Climate Change (UNFCCC) and fully adopted by the Kyoto Protocol (KP), has acknowledged the different capacities and needs between developed and developing countries, proposing a differentiated approach to compute emission reduction efforts. Namely, although addressing climate change is a global challenge, national responsibilities should be differentiated, with developed countries having a heavier burden in both reducing emissions and providing resources for adaptation measures with respect to developing countries. The issue of CBDR is currently considered as a crucial issue in the Post-Kyoto negotiations since CBDR is mainly considered by developing countries as based on historical responsibility to Green House Gas (GHG) emissions whereas developed countries emphasize the role of current and future emissions. This different interpretation brings to substantial divergence in bargaining

Please cite this article as: Antimiani A., Costantini V., Markandya A., Martini C., Palma A., Tommasino M.C., 2014, Gdyn-E: a model for the economic assessment of climate policies, Chemical Engineering Transactions, 42, 115-120 DOI:10.3303/CET1442020

positions of developed vs. developing economies with respect to a potential agreement upon the burden sharing question.

As a mere example, developing countries are now responsible for more than a half of global GHG emissions (Klemeš and Varbanov, 2013) and they are now asked for actively participating to abatement actions by developed countries.

Starting with the Copenhagen Agreement the interpretation of CBDR has started to be soften, reflecting both the developed countries' position of a more stringent abatement effort for major developing economies and the developing countries' demand for maintaining differentiation in burden sharing. It is clear that positive outcomes in terms of reducing global warming are reliable under the sole condition of adopting a strategy according to which the climate challenge should require global efforts (Brunnée and Streck, 2013). At the same time, several concerns about potential abatement costs in terms of economic growth expectations reduce the propensity of developing countries to accept binding constraints on GHG emissions since they consider them as a strong reduction in their development perspectives. Furthermore, the question of equity in climate change should also include how the burden of reducing GHG emissions should be shared across social groups (Markandya, 2011).

Clearly, in such a context climate finance could represent a useful solution to assess these concerns, considering the differences between developed and developing countries and helping the last ones to ease potential negative development impacts. Given the huge amount of uncertainty it is surprising that there are relatively small differences in the cost of meeting different stabilization targets across different analysis. Taking one of more recent reviews (Edenhofer et al., 2010), the discounted present value of costs of following a path that results in stabilisation of CO2 concentrations at 450 part per million (PPM) (a value consistent with a reasonable probability of not having world global mean temperatures rise by more than 2º degrees Celsius) range from 1.2 to 1.5 per cent of world Gross Domestic Product (GDP). As Nordhaus (2013) shows, the costs can be much higher if the reductions are not shared by developing countries: indeed it may be impossible to reach the 450 PPM target in this case.

Given these results from a formidable set of analysts the question arises, why is the political appetite for adopting carbon policies consistent with these targets so anaemic? Research on possible impacts of not meeting the 450 PPM target indicates these could be very significant and destabilizing for the world. Yet, with the exception of the European Union (EU), practically no country or region is currently following policies that will take us to a 450 PPM stabilisation target along the paths identified in the mitigation research. The phenomenon is stark enough to deserve the title of a Climate Mitigation Paradox.

There are a number of reasons to explain this paradox. First is the point that even though these costs are small they are significant in the short term and the benefits in terms of avoided damages, while potentially large, are further in the future (2050 and beyond). If we use a high enough discount rate, the net benefits of a 450 PPM action do not come out positive. Second is disagreement about the results presented. The cost of mitigation may be underestimated if model runs that yield less optimistic results are not presented. This argument has been looked at by Tavoni and Tol (2010), who find that for the more stringent target the number of scenarios and 'runs' is smaller than for the less stringent targets (for this purpose the 450 PPM is considered as stringent). Third is the question of the time profile of costs, which is perhaps the most important factor of all. These estimates of costs are based on discounted values going to 2011, using discount rates of 3 to 5 %. Decisions to act, however, are much more influenced by the costs to be borne in the immediate future. The pressing imperative of current budgets and impacts on the living standards of people today play a role that is much greater than can be captured by the 2100 net present value costs. Moreover, it is not a case of simply raising the discount rate, which does not pick up these short term considerations to their fullest extent. To be fair some studies such as Edenhofer et al. (2010) do look at the annual cost profile and find that it varies considerably from one to another. Unfortunately they do not present the figures for the 450 PPM case, but the annual costs for the 400 and 550 PPM vary a lot across the models: for example for the year 2020 the costs can be as low as 0.2 % of GDP and as high as 0.8 % (i.e. a factor of 6). This is something that exercises the minds of politicians much more than the discounted present value cost to 2011. If we can throw some light on the reasons for the differences and possible implications for other key macroeconomic indicators we will have more influence on policy. This will be the more useful if we can find ways to keep the short term costs as low as possible, perhaps even if it means a slightly higher cost in the distant future. The issue of short term costs is especially important for developing countries where issue of higher energy prices and budgetary pressures is greatest.

There are models that have carried out such analysis and the present paper wishes to contribute to the discussion, by developing a dynamic economic-energy model that can simulate alternative and feasible policy options and that focuses on the relatively short and medium term costs of climate policies in a global setting, assessment in order to facilitate the current international negotiation debate.

In particular, since developing countries are considered as crucial for reaching effective abatement measures, we have specifically developed modelling choices in this direction. Since assessing alternative policy options is the core issue here scrutinized, our model should be as closest as possible to those developed and currently used by the international scientific community in order to provide comparable results by taking assumptions which are reasonably acceptable.
Much importantly, at the best of our knowledge there is no scientific contribution assessing the potential role played by the new and highly debated Green Climate Fund (GCF), which seems to represent the climate instrument where most developing countries are focusing on in order to reach consensus in the Post Kyoto negotiations. The GCF, when operational, would channel significant financial resources into adaptation and mitigation, potentially enhancing also the development of low-emission technologies in developing countries. By considering this gap in the scientific literature as crucial for depicting a clear assessment of alternative policy options and thus driving the negotiations, we propose an original modelling approach in order to partially fill this gap at least in some evaluation aspects.

2. **The Contribution of this Paper**

The aim of this paper is to contribute to the gap in the literature: that is to analyse the effects of starting on path that does not allow the world to exceed 450 PPM equivalent concentrations of GHGs by 2050, with a focus on the impacts of such policies as are necessary to achieve this target over the period to 2035. The aim is to identify those distributions of burdens of emissions reductions and those global policies that will make the adoption of the target likely in the coming years. In particular we look at how different ways of using the Global Carbon Fund can help reduce costs through promoting technological innovation as well as making participating in an agreement more attractive for developing countries.
For the purpose of this paper we have developed an energy-environmental version of GDyn (Dynamic GTAP Model), hereafter called as GDynE, which results from merging GDyn with GTAP-E. The latter is a computable general equilibrium model that is in turn an energy-environmental version of the standard GTAP static model, (GTAP, 2014), specifically designed to simulate CO_2 emission mitigation policies. It includes an explicit treatment of energy demand, the possibility of inter-factor and inter-fuel substitution, data on carbon dioxide emission accounting at sector and regional level and the possibility of introducing market-based policy instruments such as carbon taxes or emission trading.
The GDynE we have developed uses the last version of the GTAP-Database (GTAP-Database 8, updated to 2007), together with the latest version of the additional GTAP-Energy data on CO2 emissions along with the arrays in standard GTAP Data Base 8, in a format that can be readily used with the GDynE model. The last revised version of the GTAP-E model for the GTAP database 8, introduces a refined energy nest in private and government consumption with new parameters, including one representing government share of carbon tax payments/permits revenue.
In the GTAP-E model, substitution elasticity values between energy and capital are crucial when determining how the output in different sectors is affected by energy price changes. The values taken here are the average from two literature reviews (Stern, 2007, Koetse et al., 2008) where the authors reviewed several elasticities. They are in the last column of Table 1.

Table 1: Key Substitution Elasticities used in this Model

Elasticity	**Gdyn-E Standard**	**Hertel-Beckert**	**Stern/de Groot**
Capital and Energy	0.50	0.33	0.38
Energy sub-production	1.00	0.16	0.81
Non-electricity and Electricity	0.50	0.07	0.57
Non-Coal Energy Sources	1.00	0.25	0.41

We have developed a mechanism for funding a global carbon fund, as recently emphasized in the Post-Kyoto negotiation as a tool to foster the capacity of developing countries to contribute actively to achieving carbon emission abatement. The assumption is that a percentage of total carbon tax revenue gathered by governments of developed countries through either a carbon tax or an emissions trading scheme is collected in the GCF. This percentage value can be treated as an exogenous parameter according to a potential international agreement in the sense that all developed countries participating to Post Kyoto agree on drawing a “x %” from Carbon Tax Revenue (CTR). This means that when we use a portion of carbon tax revenue to finance GCF, the amount of investment paid by developed countries is subtracted from their Equivalent Variation (EV), resulting as an additional cost to abatement efforts. The “x %” of CTR is applied uniformly to all developed economies, meaning that it is decided during international negotiations. Further interesting issues may arise when the “x %” is endogenously given by some different criteria that should be negotiated (this could be an interesting future research issue to investigate). Given “x %” as exogenous, the higher the CTR value for one country, the higher its contribution to GCF. The amount of contribution to GCF is thus directly correlated with carbon tax. By construction, when an international emission trading is allowed, domestic carbon tax levels are all equalized to permits price. By considering abatement commitments as given, the size of the global carbon fund is directly correlated to permit price.

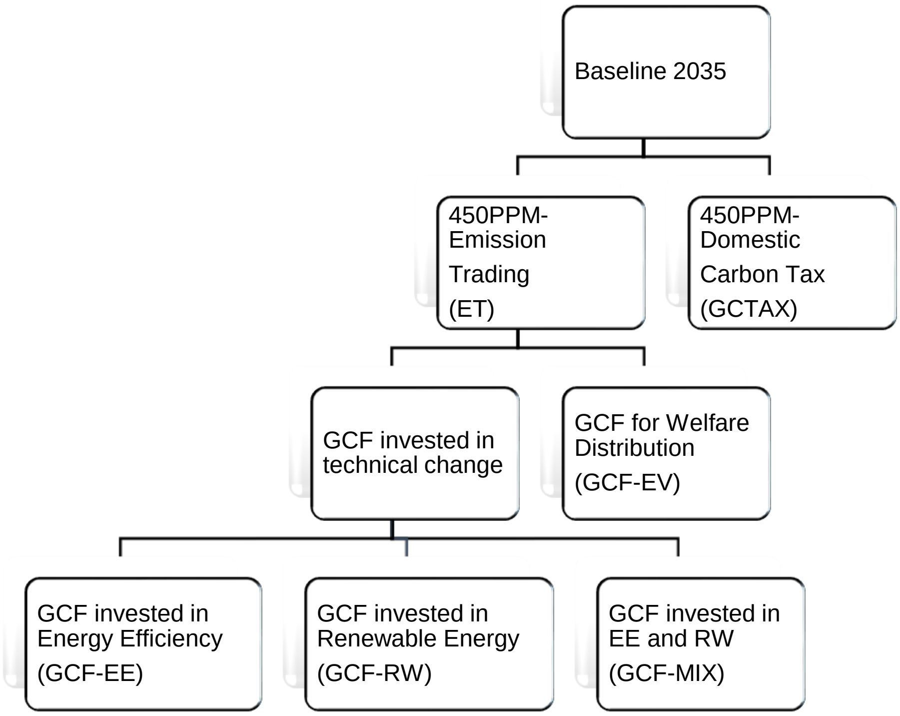

Figure 1: Scenarios Evaluated in the Paper

In terms of using the GCF we have hypothesized three alternative solutions, which can also be combined in a sort of policy mix strategy. The first is to use GCF only for redistributive purposes, so it is distributed to developing countries according to some exogenous criterion. The second option is to invest GCF in order to improve energy efficiency in developing countries. The third option is to use GCF to finance increasing production of renewable energies. While the first option does not modify the structure of the global markets since no impacts on prices arise, the other two options produce several impacts in terms of market prices for energy commodities, as well as resource efficiency in the production function and energy availability and mix. Even though all these changes occur only in developing countries, by working with a CGE it is possible to disentangle the indirect impacts on developed countries as well. In particular, what we would like to notice is that a sort of active policy adopted into developing countries thanks to financial assistance by GCF may produce benefits also to developed countries.

3. Simulation Design and Results with GDyn-E

We include in our simulation 17 regions with 10 developed regions (Canada, European Union, Former Soviet Union, Japan, Norway, United States, Rest of OECD), and 10 developing regions (Brazil, China, India, Indonesia, Mexico, Energy Exporters, Rest of Africa, Rest of America, Rest of Asia, Rest of Europe). The rationale behind the sector aggregation is to divide energy commodities from the rest of the economy as a first step, and to disentangle energy intensive industries from the rest of the economy as a second step. In order to reduce as much as possible computation problems due to excessive number of regions and sectors, we have adopted a final classification with 10 sectors: Agriculture, Energy Intensive Industries, Other Industries, Transport, Services, as a group of non-energy commodities; and Coal, Oil,

Natural gas, Oil products, Electricity as energy commodities. As temporal horizon we have considered a period from 2010 to 2035 since GDyn-E is a top-down model where international economic relationships are very well designed while technology is exogenously given. As a standard modelling choice, periods here are shaped as a 5-year temporal structure.
Autonomous Energy Efficiency Improvement (AEEI) is modelled here as an input augmenting technical change with an approximate value corresponding to an increase in energy efficiency per year of 0.5.
We run several different scenarios: the 450 PPM scenario with Domestic Carbon Tax (GCTAX), the emissions quota assigned to each region is directly a proportion of the baseline values; The 450 PPM scenario with International Emission Trading (ET), In the case of emission trading, we adopt the same abatement commitments as in the GCTAX scenario, but in this case countries may trade permits in order to reach a higher policy efficiency (same environmental target at lower cost); The 450 PPM scenario with International Emission Trading and GCF for EV (GCF-EV) This scenario has been implemented with the aim of allocating a percentage value of CTR to the GCF in line with ongoing negotiations; The 450 PPM scenario with International Emission Trading and GCF used to finance technical change in energy efficiency (GCF-EE), In this scenario the percentage value of CTR is fixed by 8.00% but, considering that the permits price is endogenously determined in ET and that the investment of GCF in energy efficient technologies in developing countries would contribute to reduce equilibrium carbon tax level; The 450 PPM scenario with International Emission Trading and GCF used to finance production of Renewable Energy (GCF-RW), in this case capital investments go to capital availability to the electricity sector in order to increase production of renewable energies. The results are listed in Tables 2-4.

Table 2: Price of permits under different scenarios calibrated with WEO 450PPM Policies Scenario (IEA, 2012)

Scenarios	2015	2020	2025	2030	2035
GCTAX	15.34	32.74	106.51	194.98	383.99
ET	12.68	25.79	101.43	169.21	294.31
GCF-EV	12.68	25.79	101.43	169.21	294.31
GCF-EE	12.38	24.78	94.11	146.49	240.55
GCF-RW	8.80	20.62	84.03	148.13	261.22
GCF-MIX	8.75	20.41	82.34	140.83	242.58

Table 3: Cumulative Equivalent Variation under different scenarios (billions of $, 2010-2035) calibrated with WEO 450PPM Policies Scenario (IEA, 2012)

Regions	GCTAX	ET	GCF-EV	GCF-EE	GCF-RW	GCF-MIX
Developed countries	-3,125	-2,642	-3,096	-2,749	-2,758	-2,623
Developing countries	-3,668	-2,956	-2,504	870	-2,279	-541
World	-6,793	-5,599	-5,600	-1,879	-5,038	-3,163

Table 4: Global Carbon Fund under different scenarios (billions of $) calibrated with WEO 450PPM Policies Scenario (IEA, 2012)

Scenarios	2015	2020	2025	2030	2035	Average value 2015-2035	Cumulated value 2015-2035
GCF-EV	14.57	28.60	100.38	137.91	203.16	96.92	484.62
GCF-EE	14.22	27.48	93.06	119.61	165.42	83.96	419.80
GCF-RW	10.19	23.18	84.02	121.92	181.93	84.25	421.24
GCF-MIX	10.13	22.95	82.32	116.00	168.71	80.02	400.11

4. Conclusions

In this paper we have examined the options for a low carbon mitigation strategy for a global as well as a regional perspective using a new top down model (GDyn-E).
We have examined two options in detail: (a) a WEO scenario for meeting the 450 ppm target with national/ regional sub-targets that have to be met individually, with no international trading and (b) the same overall target to me met with a global carbon market. The latter is more efficient and reduces costs by about one per cent of GDP relative to the former. The global carbon market can, however, involve inter-country transfers that need further investigation but the ones considered in this analysis indicate some regions or countries can be losers relative to option (a).

The paper suggests that there are some reasons why the current consensus of low costs of mitigation to 450 ppm is not being taken up more enthusiastically by policy makers. The implied taxes or permit prices by 2035 are high and would entail significant courage on the part of governments to impose them. They also imply losses in GDP that would be hard to 'sell' to a sceptical public, especially in the face of other pressing challenges such as youth unemployment, ageing of the population and the like.

We suggest that one way of getting round the difficulty is to lower the costs of mitigation and to get greater buy in from developing countries. Indeed without such a buy in the whole venture is doomed and the 450 PPM target is infeasible. If carbon taxes can be used to fund a major low carbon program in developing countries it may have benefits for both the recipients and the funders. In particular the use of about 8 percent of a Green Carbon Fund, financed from a tax on the carbon tax receipts of developed countries and invested to increase energy efficiency in developing countries can have major benefits. It reduces the costs of meeting the global target of 450 PPM for both groups of countries and can even result in a small gain for developing countries. Thus this option is worth more careful consideration.

Further work that this paper has pointed to includes the following:

- The current model indicates that energy exporters will have a very strong resistance to the 450 PPM path unless there is a way of compensating them. The transfer of funds to energy exporters to compensate need to be considered.
- Other measures that allocate resources to R&D in developed countries, thereby lowering the cost of substituting fossil fuels over the next two decades should be examined
- Total costs will decline if we allow for some overshooting of the 450 PPM target so emissions go up initially to 2035 and then decline more later when the costs of switching are lower. Other researchers have found this and we need to evaluate it in our model.

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