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Economic Growth and Climate Change: Cap-And-Trade or Emission Tax?

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1. Introduction

Economic growth and the globalization of goods and capital flows led to an unsustainable level in the consumption of natural resources. This entailed a steady increase in pollution and climate change. The work of the Intergovernmental Panel of Climate Change (IPCC) was crucial in the dissemination of these findings and in the discussion leading to the Kyoto Protocol (IPCC, 2006, 2007). One of the controversial aspects of the protocol was the choice of policy instruments in the curbing of carbon emissions. Generally speaking, two approaches seem to be favored: "cap-and-trade" implying a trading of emission rights and "carbon tax" implying a taxation of emissions.

Many of the protagonists of the debate are evoking economic theory to offer guidance and support of their arguments. Our article tries to shed some light on the various theories, which attempt to explain the relationship between economic growth and climate change (especially Stern 2007, Nordhaus 2008, and Uzawa 2003), and to evaluate them critically along the ideas of intergenerational equity and economic externalities.

Given these theories, we want to explore what they have to say about the policy instruments of cap-and-trade schemes and a carbon tax. In line with recent IPCC reports, we argue that taxes are to be preferred over market oriented schemes as these are subject to many drawbacks such as their complicated institutional structure and implementation and their price volatility. In particular, given the recent stock market meltdown and volatility, the cap-and trade system presumably will not be very effective in providing sufficient incentives for reducing CO_2 emission.

The article has the following structure: in section 2 we discuss some empirical facts regarding the relationship, causes, and consequences of global warming. In section 3 we discuss economic theories of intergenerational equity and climate change and propose a multiple equilibria model of the interaction of growth and climate change. In section 4 this is followed by a historical investigation into the theories of economic externalities of Pigou and Coase. In section 5 we analyze which of the policy instruments mentioned above are preferable in the light of these theories. Section 6 presents the European experience with cap-and-trade schemes.

2. Growth and Climate Change: Empirical Facts

The globalization of economic activities since the 1980s and 1990s, accelerated through free trade agreements, liberalized capital markets and labor mobility, has, since the 1970s already, brought into focus the issues related to global growth, resources and environment. The industrialization in many countries in the last 100 years or more and the resource based industrial activities have used up resources, mostly produced by poor and less developed countries. The tremendous industrial growth in the world economy, in particular since World War II and strong economic growth in the last two decades in some regions of the world, for example in the US, Asia and some Latin American countries, have generated a high demand for specific inputs. Renewable as well as non-renewable resources had been in excess demand and they are threatened to be depleted. In particular the growing international demand for metals and energy derived from fossil fuels, as well as other natural resources, which are often extracted from developing countries, has significantly reduced the years to exhaustion for those resources. Although currently growth rates are declining and commodity prices falling the International Energy Agency estimates a further depletion of resources and price increases in the long run.

On the other hand the industrialization and resource based activities has had strong external effects by polluting and degrading the environment. Not only does the environmental pollution strongly affect current generation, but the environmental degradation affects also future generations. Since the conference and protocol of Kyoto in 1997 the global change of the climate has become an important issue for academics as well as politicians. Both the overuse of resources as well as the environmental pollution and climate change has brought into focus the issue of inequity.

Since the creation of the protocol of Kyoto in 1997, which in the mean time more than 170 countries have ratified, the topic of global climate change has gained growing attentions from academics and politicians. Especially within the academic realm of economics, the aspect of intergenerational inequity has been brought into focus. Basically global warming represents an unequal treatment of individuals across generations. Current generations extensively reap the gains of energy-intensive production which entails permanent damage to the environment and climate change while future generations have to bear the cost of these negative externalities in the form of lower quality of live and bio-diversity.

The role of such imperfect linkages between generations in economic growth and Greenhouse Gas (GHG) emission has become a major topic in economic research, as for example in the works of Uzawa (2003), Nordhaus (2008), Stern (2005), Heal (1998), Greiner and Semmler (2008) and the various reports of the IPCC (2006/7). The greatest concern with this respect in their work is CO_2 emissions. Since the beginning of the 19^{th} century yearly emissions have quadrupled with a 70% increase occurred within the past 30 years. The concentration of CO_2 in the atmosphere rose from 280 ppm in the year 1750 to 379 in the year 2005. At the same time, a warming of the global climate is unequivocal and can be observed in the increases in global average air and ocean temperatures. Since 1900 global temperature increased by roughly 0.7 degree Celsius. Figure 1 shows the global development of atmospheric CO_2 since 1750. The effects of such changes are drastic: Polar ice caps have been melting swelling global mean sea level and the likelihood and severance of extreme weather events increased.

Given current developments, scientific forecasts predict a likely temperature rise by the end of the century by 2-4 degree Celsius, sea levels are likely to rise by 28 – 43 cm, the Arctic sea ice is likely to disappear (in the second half of the century), and the probability of large parts of the world experiencing an increase in the number of heat waves, droughts, intensified tropical storms, and floods is high.

There are in fact two types of inequities. First, the overwhelming fraction of exhaustible resources, located in the South, are used up in the North, in the industrialized countries, and the North has become overwhelmingly the polluter of the global environment, in many recent studies seen as the cause for global warming. The second type of inequity comes from the unequal treatment across generations. Current generations extensively use up resources, pollute the environment and produce a global climate change. This produces negative externalities for future generations and future generations are treated unequally.

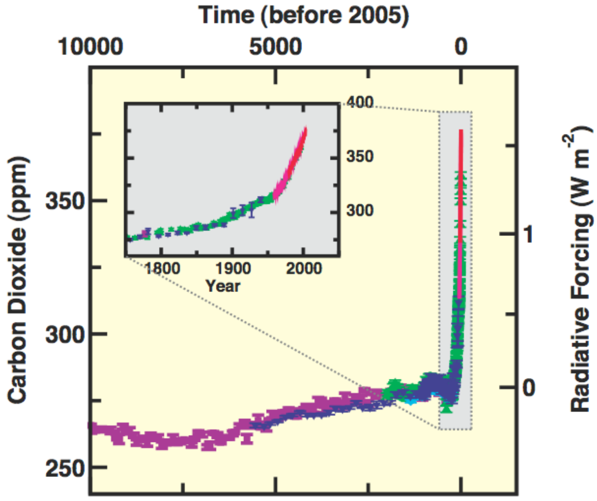

Figure 1: Atmospheric CO_2 over the last 10,000 years and since 1750, Source: IPCC (2007, p. 38)

Not only has average temperature increased by 0.7 degree Celsius since the end of the 19th century has roughly, but it is to be expected in the future that temperature will probably rise by 2-4° C by the end of the century, sea levels are likely to rise by 28-43cm, and arctic sea ice is likely to disappear (2nd half of the century). It is very likely that parts of the world will see an increase in the number of heat waves. Climate change is likely to lead to increased intensity of tropical storms (since the 1990s already heavy and extreme weather events).

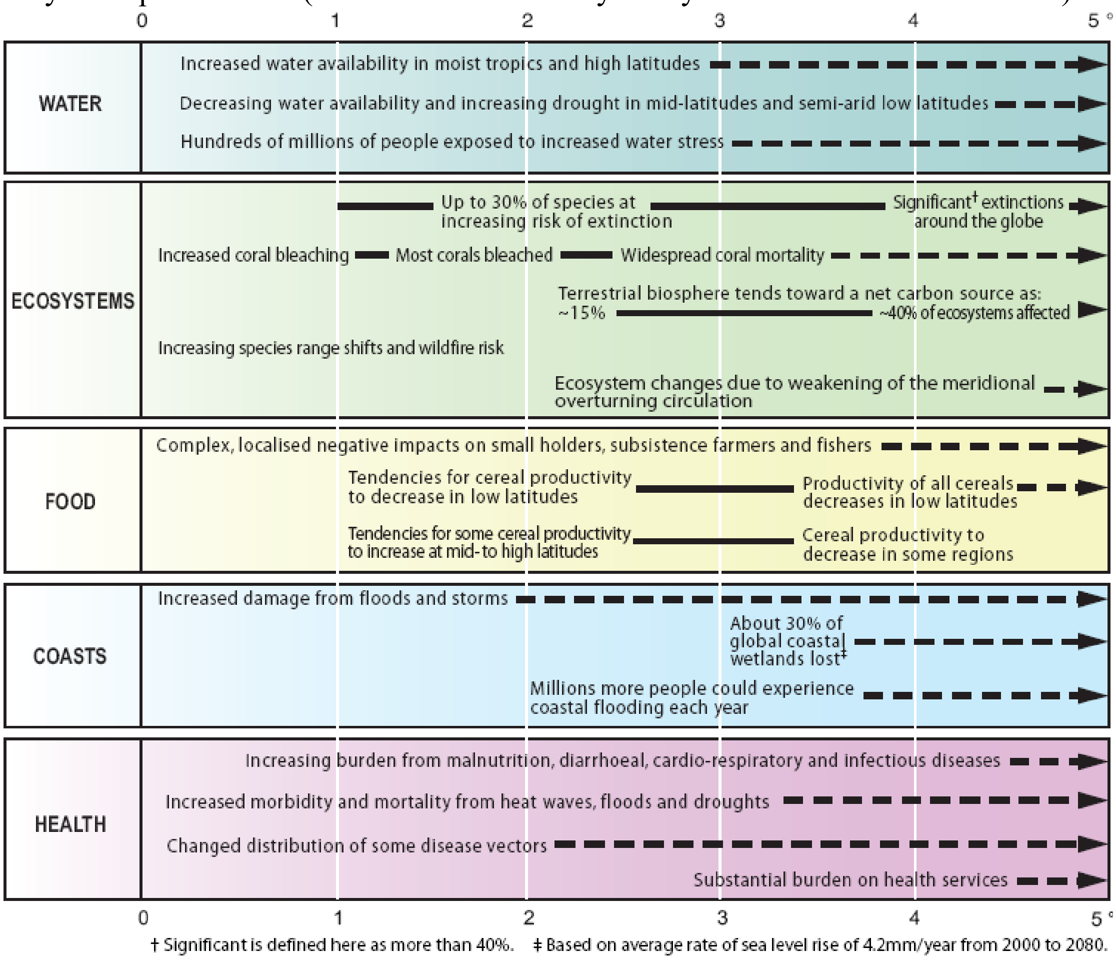

Table 1: Examples of impacts associated with global average temperature change, Source: IPCC (2007, p.51)

3. Growth and Climate Change: Theory and Modeling

Impacts of climate change will vary regionally but, aggregated and **discounted** to the present, they are likely to impose considerable future costs which will increase over time as global temperature increases. An extensive academic literature explores the issue of how to evaluate future damages as compared to current cost to avoid them. As pointed out above, due to the intergenerational aspect of the problem, preventing damages in the future requires efforts today. One direction to address this issue in economics is to employ the instruments of welfare analysis which weights future damages against their current cost. The crucial issue here is the discounting of the future: How much effort (current cost of change) should be undertaken depends on how we evaluate (**discount**) future damages. The degree of discounting is clearly a key in such an undertaking and varies widely in different studies. While Stern (2007) uses a very low discount rate of 1.4%, Nordhaus (2008) proposes to discount future welfare and damages by a discount rate of 5%. Weitzman (2008) proposes a discount rate of about 4%. In academia there exists a long standing debate on how exactly to take into account the welfare of future generations. While alternative approaches have been developed for valuating the future, see e.g. Heal (1998), overall there seems to be consensus that there exists a (rising) cost of future damages due to climate change. The calculation of such costs is yet more complex as potentially catastrophic losses, response lags, the treatment of risk, and non-economic impacts have to be included in the analysis.

Yet one also has to take into account:

- Impacts of **climate change will vary** regionally but, aggregated and **discounted** to the present, they are likely to impose considerable costs which will increase over time as global temperatures increase.

- How much effort (current cost of change) should be undertaken depends on how we evaluate (**discount**) future Damages. With Stern (2007), a very low discount rate of 1.4%, Nordhaus (2008), discount rate of 5% and Weitzman a discount rate of 4% this all would mean a different effort now. A low discount rate would mean a high effort now.

- The **range in costs** depends on the **inclusion of damages resulting** from potentially catastrophic losses, response lags, the treatment of risk, and economic and non-economic impacts.

- Future vulnerability depends not only on climate change but also on the **development path** (sustainable growth).

Yet, overall there are important feedback effects: as mitigation efforts (depending on the discount rate) and growth affect climate change so would also future growth depend on climate change.

A typical model where this interdependence of growth and climate change is treated in stylized way is the model by Greiner and Semmler (2008). Crucial for this approach is the albedo which is the fraction of incoming energy (energy from the sun) that is reflected back. On the other hand (1-albedo) is the fraction absorbed by the earth. As figure 2 shows the latter fraction rises with the temperature T (measured in Kelvin). This is, for example, due to the melting of arctic ice cap (for further positive feedback effects between current and future temperature, see Lovelock, 2006).

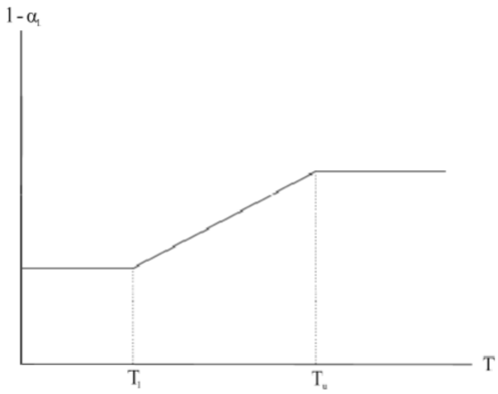

Figure 2: Absorbed Solar Energy (1-α) as a Function of Global Temperature, Source: Greiner and Semmler (2008)

The model by Greiner and Semmler (2008) shows that there are three possible long run growth rates associated with different temperature. The normal temperature measured in Kelvin, is T=288. This corresponds to 15 degree Celsius. The three possible growth rates are:

Scenario	1-α	Temp.	GDP Growth
I	0.2093	3.7°C ↑	2.6%
II		4.5°C ↑	2.3%
III	0.2171	6.2°C ↑	2.2%

Table 2: Results for Different Albedo Assumptions, Source: Greiner and Semmler (2008)

Table 2 illustrates the three different scenarios investigated in Semmler and Greiner. A stability analysis shows that only regime I and III are stable. Regime II is unstable and will not be realized in reality. The critical value of the middle case demonstrates the inherent effects of nonlinearity on the stability of possible growth paths. A small deviation around the lower equilibrium I causes no long run effects. If the critical value, which separates the two centers of attraction, is transgressed, however, there will be significant climate change with irreversible effects.

This means that if countries postpone the reduction of CO_2 emission, temperature through the albedo feedback may rise so much that only the low growth – high temperature growth path can be achieved. This makes climate policy urgent. The implementation of carbon reducing efforts by the governments into such a model with multiple equilibria shows that these efforts not only lower equilibrium temperature levels, but also increase economic growth. Thus the economy will be put on a superior growth path. The reduction of carbon emission could come from a carbon tax. The logic is that a higher emission tax will induce greater private abatement efforts**.**

Tax Level	Temp.	GDP Growth
0.11%	3.4°C ↑	2.60%
0.40%	0°C	2.80%
0.55%	0.8°C ↓	2.77%

Table 3: Effects of a carbon tax, Source: Greiner and Semmler (2008)

The considerations above have strong implications on the controversy about discount rates: Discount rates are not as much important as the danger of doing too little too late. Before we discuss this matter of an emission tax further, we want to give an overview on recent discussions on mitigation methods which were initiated by ICPP (2007).

4. The History of Regulating Economic Externalities: Pigou versus Coase

Uzawa (2003), Nordhaus (2008), and Greiner and Semmler (2008) suggest emissions taxes to reduce emissions of greenhouse gases. This idea of regulating economic externalities originates in Pigou (1932). Other economists follow a market approach based on Coase (1960) who suggested creating and trading emission rights in order to internalize an economic externality. In this section we give a brief overview on the long standing controversy between those two approaches and evaluate their applicability to global warming.

Marshall is usually associated with the development of supply and demand and their clearing in markets. Soon after his theorizing, however, it was discovered that there exist cases where a substantial economic impact, positive or negative, was delivered through the market mechanism, but nevertheless lay in a sense outside of the process of supply and demand. That is, although economic agents were benefited or harmed in regard to their income or wealth, the actions that impacted them were not driven by the motive to do so, nor were the agents themselves obliged to pay for the benefits, or able to escape the harm by making payments.

Pigou, Marshall's successor in the Professorship at Cambridge, proposed in The Economics of Welfare to deal with this by a system of taxes and subsidies. Activities that led to negative externalities should be taxed; the proceeds could be devoted to compensating those injured, or rectifying the situation. But the tax itself would reduce the amount of the activity. Activities with positive externalities should be subsidized, thereby increasing the amount provided, so as to ensure that the full social benefits would be achieved – social marginal rewards should be equated to social marginal costs.[1] By doing so, an optimal position will be reached. The strength of this approach is that it reaches clear and definite conclusions about policy. Arguing from conventional assumptions it shows that Government intervention can correct the problem of externalities.

However some important reservations should be noted. First, the approach is normally set out in the form of a static equilibrium model (as described in the footnote.) Modern economies are not static; both the economies and the problems are growing, and one major concern is that climate problems are growing faster than our economies. A static framework cannot deal with this. The fact that it is also an equilibrium framework just adds a further note of unreality. Actual growing economies are in flux; the composition of output and the distribution of income and the technologies and organization of production are all changing. They are not in equilibrium, and the problems of emissions have to be dealt with in conditions that may include change and disorder.

It is not just that actual economies are dynamic, and seldom exhibit equilibrium; we know now that markets can be systematically unstable and volatile, often within definable limits, and operating in ways that lead to dynamic patterns of change. Markets are not characterized by easily defined and unique stable equilibrium positions. They are more complex, and more

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[1] Economists following Pigou have set this out in simple neo-Classical models, in which consumer utility depends positively on output, negatively on pollution, output depends positively on inputs of labor and capital, but also on the production of waste (curbing waste will reduce output). (Output may also be reduced by pollution.) Pollution, in turn, depends positively on waste products. This gives rise to a simple maximizing problem with the usual first and second order conditions. The model can be extended to include defensive activities by households, trying at their own expense to defend themselves from pollution. Maximizing consumer utility will lead to the result that firms should produce to the point where the marginal product of their waste emissions just equals the marginal damages those waste emissions do to consumers. And THIS is the level of the Pigouvian tax or 'effluent fee' that the government should impose directly on waste emissions. This tax will produce an optimal result. In this model there is no room for compensation of victims.

fragile, than their advocates have understood. They generate powerful forces for innovation, but for just that reason, their movements can be unsettling.

This leads to the second point: the Pigouvian framework is too simple in another way; the models generally can be solved pretty easily for unique solutions. This is very unlikely in a dynamic framework, and it is probably a mistake to be looking for a unique policy that will provide the clearly defined 'best' outcome. Instead we should expect to find a number of policies that will most likely improve the situation, but that it will not usually be possible to demonstrate that one of them is the 'best'.

In contrast to the Pigouvian tradition Coase (1969) argued in "The Problem of Social Costs" that rather than intervening with taxes, governments working with the parties affected by externalities should find ways of changing the liabilities and the property rights, if possible in ways that will permit market incentives to drive the system to a superior position. Coase did not propose specific models, but his followers have developed them. 'Cap-and-trade" is certainly in that tradition.

The idea is that by redefining property rights governments can make use of market forces to accomplish their goals, rather than establishing a bureaucracy to force businesses to follow costly rules. Governments must find ways to make businesses feel the responsibility for things which are currently considered outside of their interests, such as air quality and climate change. Markets can be used to settle how to distribute the costs of reducing air pollution, or excess carbon emission, and the burdens of bearing it. The desired or acceptable level of pollution is decided by Government, and then 'rights to pollute', adding up to that amount, are distributed among those who benefit from the activity causing the pollution. These rights can be bought and sold. A firm that needs to pollute more can buy the rights from firms that can easily reduce their pollution. If the neighbors of a polluter can't stand it, they can bid for that polluter's rights, thereby compensating the firm for the cost of reducing pollution. The idea is to keep government out of the details - bureaucrats are likely to tangle things in red tape. Instead of micro-managing, the government should create property and other rights that will give rise to tradable claims.

Coase starts from very realistic examples – a train running through farmland casing uncompensated damage, a noisy shop next to a doctor's office, cattle farmers and wheat farmers – in each of which the normal activity of one party damages the normal activity of the other. He carefully parses the ways in which rights might be assigned, determining who bears the burden of liability, comparing the possible economic results. It is clear that the set of possible outcomes is far larger than imagined by Pigou, but Coase also accepts a very simple and standard account of prices and markets – essentially Pigou's. Neither appreciates the importance of market dynamics, multiple equilibria and market instability, nor do they consider the problem of externalities in a growing economy.

Interestingly, Coase, unlike his pro-market followers, did not contend that a reassignment of rights was always the best way to go. He accepted that a system of taxes and subsidies might well do the job (Coase, 1969). The more or less standard view of Coase's argument – surely at least partly justified - is that he proposed that we should always consider the possible ways to re-assign property rights in cases of externalities. If such reassignment could effectively internalize those externalities, the market could simply go ahead and work its magic. (In the US such a system reduced acid rain and basically brought about the removal of lead from gasoline. 'Cap-and-Trade' proposes to do this for carbon.) But there is more to Coase than that. First, he redefines 'factors of production' as rights, rights to carry out certain kinds of activities. These rights can be redefined, and the question is, which bundle of rights, assigned which way, will be the best. He sees a close connection between technology and the legal system, a connection that can affect the direction of innovation. But he does not assume that the present arrangement is best, nor does he necessarily argue against government intervention or taxation. Re-assigning rights, redesigning the bundles, is most certainly intervention. His chief point is that there are many possibilities. He also recognizes in his examples, though he doesn't stress it in theoretical discussions, that the burden of liability – and of taxation -can also provide a stimulus to innovation. This point is neglected by many of his followers.

Regulation, and government intervention generally, is indeed very powerful and the impacts will set off responses, that will develop over time through market processes. In potentially unstable markets, and in dynamic conditions, the results may be very far from those **desired**.[2] Indeed in the case of 'Cap-and-Trade' the chief effect of market instability and price volatility may be to create problems rather than to provide incentives to desirable behavior. It might be best to design a simpler system that would lead to market responses which would reliably bring about responses in the right directions; taxation properly designed can do this. Any taxes, even very light ones, will be likely to trigger responses. After all they affect the earning and spending of money. But if we think the program through carefully, we can develop a system of taxes that should generate desirable responses, moving the market in the directions we want. And providing incentives to innovate in the most desirable ways. As we shall see the better and more reliable course is to depend on the strong and direct incentives created by taxes.

5. Cap-and-Trade or Carbon Taxes?

The most debated and important of these policy measures are emission trading and tax policies --- best known as "cap-and-trade" and "carbon tax". For many economists (Uzawa, 2003, Nordhaus, 2008, Mankiw, 2007, IPCC, 2007) an emission – or carbon – tax is preferable to a cap-and-trade system. This is due to advantages of the former and shortcomings of the latter:

Tradable permits (Cap-and-trade system) require that the actual polluter can be identified, for example firms. Enforcement of the cap is difficult and trading of emission certificates are exposed to speculative investments, generating a high volatility of the carbon price as the European example shows, see section 7.

Carbon Tax, on the other hand, allows for a broader application, including energy supply, major polluting industries, the service sector, transport system and households. Furthermore, the generated tax revenue can be used to reduce other taxes and tax funds, can to be used to compensate developing economies, or can be used to induce climate-friendly investment behavior (see Uzawa, 2003).

Although more and more economists seem to lean toward a carbon tax, policy makers appear to tend toward the market-based cap-and trade system. Overall, we obtain in our model similar results as in the growth literature regarding government actions. A zero emission tax is

[2] We see this in the case of illegal drugs, for example. Making drugs illegal has an impact, a very important impact, but not the desired one of eliminating the market. Instead it drives up the price and makes drugs more profitable for the successful cartels. Police work also tends to eliminate competition, and block entry, making life easier for the established 'firms'.

not necessarily welfare improving (Greiner and Semmler, 2008). For many economists (Uzawa, 2003, Nordhaus, 2008, Mankiw, 2007, IPCC, 2007) emission tax – or carbon tax – is preferable to a cap-and-trade system. On the other hand, Tradable permits (Cap-and-trade) require that the actual polluter can be identified, for example firms. As above mentioned permits are open to speculative investments and exhibit a high volatility of carbon price. On the other hand, a carbon tax allows for a broader application: energy supply, industry, service sector, transport system and households. The tax revenue can be used to reduce other taxes and tax funds to be used to compensate developing economies

6. European Efforts and Experiences: The high Volatility of the Carbon Price

Europe has been leading in the implementation of the Kyoto protocol. As instrument for reducing GHG the European Union has implemented the cap-and-trade system since 2005. The experience of the cap-and-trade system in the EU showed that, in practice, the cap-and trade system does not work efficiently. In addition to the disadvantages of tradable permits mentioned above, poor implementation practices worsened the system's performance: permits were granted rather than auctioned off which entailed windfall profits for the holders, costs have been passed on, too many industries and activities have been left out, and sometimes the carbon price crashed, due to ill-timed permit issuance. The crucial appoint is the volatility of the carbon price.

Already before the introduction of emission trading several critics argued that the price per tonne CO_2 would be too volatile in order to send correct signals to market participants regarding the true cots of emissions and the appropriate level of abatement. Figure 3 and 4 show the development of the European stock market (represented by the Eurostoxx Index) since September 04 and the price of CO_2 since September 2005 (the starting point of emission trading in Europe). Both time series end on March 20^{th}, 2008.

Figure 3: Eurostoxx (10/03/05 – 20/03/08, week days only), Source: Bloomberg

Figure 4: Carbon Price €/t (10/03/05-20/03/08, week days only), Source: Bloomberg

Mere inspection of both graphs shows that the carbon price is much more volatile and unstable than the stock market index Eurostoxx. To get a more precise picture of the volatility, table 4 summarizes the standard deviations for various real and financial variables in Euroland. The standard deviation of employment is the lowest for employment with 0.32% followed by consumption and GDP with volatility in the 0.60%s. Return on short term government debt has a standard deviation of 0.89% and investment fluctuates with 1.4% of its mean. Return on equity (in our case Eurostoxx) has a volatility which is more than 10 times GDP's with 3%. The standard deviation of the return on the emission price is much higher with 11% for the forward and more than 10 times the one of equity with 37% for the spot price.

Variable	Standard Deviation (in %)
Employment	0.32 %
Consumption	0.61 %
GDP	0.65 %
Return on Government Debt (Short term)	0.89 %
Investment	1.4 %
Return on Equity	3 %
Return on Emission Price (Forward)	11 %
Return on Emission Price (Spot)	37%

Table 4: Volatility of selected variables (quarterly data for EU countries from 1970-1997), Source: Data on Emission Price Bloomberg, all other Semmler (2006)

The high volatility on the return, due to the tremendous fluctuations of the emission price, poses considerable uncertainty for firms in their investment decisions. Moreover, when the carbon price becomes too low, efforts to reduce CO_2 will rapidly fall.

Recently new proposals to further reductions in GHG have been passed (EU decisions, January and December, 2008).The above-mentioned further reduction aim in the new EU guidelines strive for a reduction of CO_2 emission by 20% from their 1990 level by 2020 and an increase in alternative energy usage to 20% of total energy supply. While these aims are ambitious, they are still mostly pursued through the permits system (though the introduction of an auction system is now planned). On the other hand, the EU is also aiming to reduce CO_2 through a carbon tax, in particular on imported goods. Overall, given the European experience the carbon tax appears to be a better solution as the above volatility study has shown.

7. Conclusions

Given the recently published scientific evidence on global warming and its damages, such as the numerous reports by the IPCC, the importance of climate mitigation has been sufficiently demonstrated. The urgency on climate actions becomes particularly true if the positive feedback effect of “temperature on temperature” through the endogenous albedo effect holds true. This produces the danger of doing “too little too late.” Our multiple equilibria model motivates this urgency. As shown, our considerations have strong implications on the controversy about discount rates: Discount rates are not as much important as the danger of delaying actions. The last report by the IPCC (4th Assessment Report) has urgently suggested a broad range of mitigation policy measures, such as integrating climate policies, broader development policies, regulations and standards, financial incentives, voluntary agreements, and information instruments to control and reduce Greenhouse Gas (GHG) emission.

It also emphasizes the role of technology policies to achieve lower CO_2 stabilization levels, a greater need for more efficient R&D efforts, and higher investment in new technologies during the next few decades (for achieving stabilization and reducing costs). Further recommendations include government initiatives for funding or subsidizing alternative energy sources (solar energy, ocean power, windmills, biomass, and nuclear fusion).

Moreover, it is needed, as the IPCC requests, to integrate climate policies in broader development policies, regulations and standards, for example taxes and charges, financial incentives, voluntary agreements and information instruments. Overall the IPCC stresses the fact that the effectiveness of such policies ultimately depends on national circumstances, their design, interaction, stringency and implementation. Yet, the major instruments that the IPCC and numerous well-respected economists propose are two specific tools to reduce GHG in order to fulfill the agreements of the Kyoto protocol. These two tools – decentralized market trading of emission right and carbon taxation – were the subject of our article. Both measures have a long standing history in economic theory originating in the works of Pigou and Coase.

The experience of the European Union with emission trading and recent economic models demonstrate that there is a clear advantage in choosing carbon taxes over carbon trading schemes. The advantages are the universal applicability, better efficacy, and lower set-up costs due to existing administrative institutions. The disadvantages of carbon trading are the arbitrary distribution of rights to special interest groups (rather than auctioning them off) and the disproportionate volatility of the emission price due to uncertainty in the overall quota and financial speculation. Hence, revising the existing, ill-conceived trading scheme in Europe and the introduction of carbon taxes in the developed countries is a necessary condition for meeting the commitments of the Kyoto protocol and the ambitious goals of the European Union and for ultimately obviating further increases in CO_2 emissions.

For the US it seems to hold that the effort to be undertaken to reduce CO_2 emission should be even higher than for Europe. The US had much higher growth rates than Europe since 1990 and lower energy efficiency improvements, and thus higher CO_2 emission than Europe. The reduction by 20% of CO_2 emission as compared to the 1990 level (as required by the Kyoto protocol) means now in effect a reduction of the CO_2 by more than 30% of the 1990 level, according to some experts. In what steps this will be achieved by the Obama administration and the new congress is to be seen.

Overall, in line with recent IPCC reports, we have argue that taxes are to be preferred over the cap-and trade system as the latter is subject to many drawbacks such as their complicated institutional structure, the lack of its general implementability, and the volatility of the carbon price. As we have shown, in particular, given the recent stock market meltdown and volatility, the cap-and trade system presumably will not be very effective in providing sufficient incentives for reducing CO_2 emission.

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