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An Intertemporal Pricing Model for CO2 Allowances: The Impact of the Clean Development Mechanism.

SUMMARY

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SUMMARY

The increasing global attention to greenhouse emissions and the recent creation of EU Emission Trading Scheme has clearly suggested the need of consistent methods to value projects aimed to reduce gases. This need particularly concerns companies that have to find a way to both remain profitable and conform to new legal requirements.

The Kyoto protocol, signed in December 1997 in the homonymous Japanese city, established the basis for the global fight against carbon emissions. Not all countries in the world have signed it -- e.g. Afghanistan or Taiwan -, and some of the countries that subscribed the protocol haven't ratified it yet[1] - from now on Non-Annex I countries -[2] in opposition to those nations that have both signed and ratified it - from now on Annex I countries -. The original mechanisms introduced were mainly three:[3]

- International Emission Trading (IET): it permits the trade of CO2 allowances' credits - Assigned Amount Units (AAUs) - between Annex I countries;

- Joint Implementation (JI): it consists in projects implemented by an Annex I country into another Annex I country. Those projects give origins to carbon credit called Emission Reduction Units (ERUs) for the implementing country, while create carbon debits of AAUs that have to be deducted from the host country quota;

[1] See Borloo et al. (2008).

[2] The term Annex I countries is interchangeable with Annex B countries since it includes countries listed in Annex B of the Kyoto Protocol. Annex I is used just for simplicity but refers exactly to the same nations.

[3] See Carmona, Fehr and Hinz (2009).

- Clean Development Mechanism (CDM): it involves the enforcement of projects by Annex I countries into Non-Annex I countries. The plan under analysis allows the Annex I country to achieve carbon credits called Certified Emission Reduction Units (CERs) that will be added to its own endowment of carbon certificates.

The European Union has been one of the first to create a trading scheme system, the European Union Emission Trading System - EU ETS -, which is nowadays the most developed in the field.

Meanwhile lots of studies have been focused on the ways of optimizing this relatively new system. Environmental finance is a branch of finance that has an important role in this sort of works. Within it, an even more innovative research front is the so-called carbon finance, whose main goal is to understand price dynamics of carbon permits. Two types of factors that could influence the evolution of CO2 prices are currently under investigation:[4] short-term abatement measures and long-term abatement measures. The main difference between the two is the time the measure needs to become effective and reduce GHG emissions.

Short-term measures are typically the ones whose results occur rapidly, already starting from the first compliance period - the period at the end of which a company is required to comply with the cap and trade[5] system depending on CO2 emitted throughout the period -. They are mainly represented by fuel switching processes - e.g. switching machinery from coal to gas - or

[4] See Carmona, Fehr and Hinz (2009).

[5] The overall volume of GHG that can be emitted each year by the power plants, factories and other companies covered by the system is subject to a cap set at EU level. Within this Europe-wide cap, companies receive or buy emission allowances which they can trade if they wish, The EU-Emission Trading System (EU ETS) -- European Commission Factsheet, 2013.

production re-schedule.

Long-term measures, on the contrary, become effectively carbon profitable only some years after their inception: they require high initial investments - which can be considered fixed costs - that will be recovered over the time of workability of the plan through the carbon returns collected during the entire project's horizon. JI and CDM belong in all the effects to this category. They depend critically on the availability of a long term horizon in order to amortize their initial consistent cost. It has been observed[6] that the number of these projects sharply fell in the final part of Phase II: they have become less relevant in this pre-2013 period since their validity was conditioned to the fact that, even if registered before 2013, they would have started to generate carbon emission reduction from 2013 onwards.[7] However their number started to grow again in these first months of Phase III, and it is forecasted to reach maximum peaks in the actual Phase due to its major length.[8]

In this work project a two-scenario finite horizon, continuous-time model is built in order to reproduce the EU-ETS taking in consideration the environment with and without the presence of CDM, in both models short term abatement measures are present. We focus only on CDM since they are the most interesting instruments to lower carbon reduction. JIs are only mechanisms to reallocate credits within countries that ratified the Protocol and, actually, do not generate new carbon allowances. Possible extensions of the research could try to insert this additional

[6] See Kossoy and Guigon (2012).

[7] See Directive 2009/29/EC.

[8] Phase III will be 8 years long, the longest Phase since the creation of the EU-ETS.

abatement measure in the model and study a more complete and realistic scenario. At the end a numerical simulation is implemented in order to verify the effects of the presence of CDM projects on carbon price.

An initial input for the body of literature today known as environmental finance has been given by Coase (1960) and Dales (1968). These authors were the first to propose the idea of tradable allowances as a way of endogenizing the social cost of pollution and make more effective the resolution of this increasingly analyzed environmental problem. After these publications a wide number of studies headed toward the search for the equilibrium price of emission allowances.

The topic was particularly deepened by Cronshaw and Kruse (1996) and Rubin (1996) who demonstrated the equality between such price at equilibrium and the marginal cost of the cheapest available abatement strategy for pollution. These results apply only to situations without uncertainty, so their real implementation is quite difficult and they remain confined as more theoretical findings. Nonetheless they represent the basis for the future developments in the field.

Carmona, Fehr and Hinz (2009) analyzed in a more realistic way the environmental problem, contextualizing the opportunity of reducing carbon emission in the newborn EU Emission Trading Scheme. They were the first to make a distinction between short-term and long-term abatement measures, available to firms after the implementation of the Kyoto Protocol to reduce carbon emissions. The paper suggests a model for pricing CO2 permits in case N firms decide to apply fuel switching, the cheapest short-term abatement process available. The analysis under consideration relates only to one trading period - in the case of EU ETS it is the year - that, even if divided in subperiods to account for within-period trading among firms, does not permit to

consider multiperiod abatement strategies such as JI or CDM, explicitly introduced by Kyoto Protocol. Evaluating only short-term measures is not representative of the real future possibilities available to firms since, even if in the present they are the cheapest procedures, in the near future they could be considered obsolete: when a firm already switches its technologies it becomes harder to find new profitable opportunities to switch them again.

Seifert et al. (2008) consider one representative agent/firm that can decide how to comply with the pollution restrictions either paying a penalty or reducing its emissions. The paper develops an interesting model that permits to analyze the spot price of CO2 allowances at the beginning of the compliance period. Starting from this equilibrium price a sensitivity analysis is conducted in order to understand which variables impact on this price. Like the previous paper also this one lacks a multiperiod view and is limited to short-term measures implemented in a compliance interval.

Chesney and Taschini (2012) re-elaborate the preceding works introducing asymmetric information between participants in the carbon market. The main finding is that the carbon price reflects the probability of not complying with the regulation at the end of the period. They introduce the problem of long-term abatement projects but only as a matter whose value can be influenced by the carbon price path. Actually they want to predict future carbon spot prices in order to understand what could be the actual value of these projects, while in this paper we want to understand which impact the availability of these schemes can have on the decision to implement them from the firms' and regulator's point of view.

We have identified a gap in the literature history mainly concerning the non-inclusion of long

term projects in decisions taken by firms relating to their emission schemes. Since we support the idea that those projects are an essential part of a company's decision making process, we want to include them in the analysis and see if their introduction is worth or not. Their presence should be profitable simultaneously[9] for the firms and the Policy Maker: a company in order to implement them should be better off, in terms of wealth, with their inclusion, while the Policy Maker should observe a diminution in the overall level of CO2 emitted in the environment. In order to control for those two effects we use dynamic programming instruments respectively for evaluating the firms' wealth, function of both the emission policy of every company and the rules imposed by the EU-ETS,[10] and the aggregate level of emissions in the air, function of the emission policies only.

Following the assumptions made by Seifert et al (2008), the model does not refer to the wealth-maximization of a single firm, but rather to a social wealth-maximization problem in which all firms that take part in the economic process are considered. Trading permits among firms is considered but it does not impact the maximization problem, since at an aggregate level trades cancel out – the number of permits bought is exactly equal to the number of permits sold in the economy -. [11]

The social planner is called to make a social-optimum choice about the aggregate emission rate,

[9] If only one part considers the project necessary it will not apport any positive effects in the world we are considering.

[10] In particular we will show that some EU-ETS's rules will impact directly on the level of emissions chosen by firms.

[11] For a clarification on the issue see Appendix B.

considering the level of emission - affected by the presence of CDM -, the costs linked with emission cut - affected by the cost of short-term abatement measure and the cost of CDM - and the cost of non-compliance with external rules - for example those rules imposed by the Scheme aimed to discourage emissions on a long run basis, as the penalty to be paid for every emission in excess -.

The framework in which the model has been inserted is a finite horizon one, with T representing the final period under analysis. We assumed T to be the duration of an EU-ETS Phase – presently it is equal to 8 years -. Using dynamic programming tools, we have derived the intertemporal choices of the social planner about the firms' emission processes. We derived such an intertemporal analysis for both the cases in which CDM projects were present or not. The dynamic problem was solved for a 2-period scenario that allowed for a simpler manual resolution, but it can be extended to whichever Phase's length with the help of specific mathematical software.

At the end of the paper we elaborated a numerical simulation showing under which conditions the presence of long term projects is relevant. We concluded that the presence of long term projects is justified and can be exploited, as a policy-making instrument, at most in the cases where the regulation parameters reflect a punishment mechanism that penalizes more emissions at the end of the Phase than the ones at the beginning. We strongly think that such a structure mirrors the one actually in use in the EU-ETS, therefore we consider this conclusion valid and applicable to the European reality.

Recently the European Trading Scheme has faced some challenges relating to the drop of carbon

price. In April 2013 this price reached a minimum peak of 3.05 euro, putting in danger the very survival of the overall System. In fact if the price would continue to decrease, reaching the minimum admissible threshold of 0, there will be no more need of a carbon market: every market is useless if the good traded does not have a price. It is now clear that the Policy Maker should find new and more effective ways to influence the carbon price and take under control the market's tendencies.

Following the results of our study we recommend the Regulator to take in consideration CDM projects as a way of directly influencing the aforementioned variables. Our feeling is that those projects have been disregarded in the previous Phases of the Scheme, a fact that could be explained by the short duration of such Phases and the consequent complexity in developing complete projects. However, due to the length of the actual Phase, we consider the reappraisal of CDM projects and macro-policies, related to them, as a fundamental and unavoidable choice for the Policy Maker. All throughout the paper we underlined diverse factors that can be manipulated in order to achieve predefined goals: the use of the conversion rate between permits originated in a project and permits accepted in the market - the so called α-variable -; the cost of the CDM project; the recognized carbon returns of the project - strictly related to the α-policy -. Appraising these instruments could be a possible way of escaping the actual unwanted situation, bringing the Scheme back to a healthier and more effective functioning.

References

Borloo, J.L., Lagarde, C., Idrac, A.M. 2008. *Developing a CDM or JI project to reduce greenhouse emissions*. Ministry for the Economy, Industry and Employment. Paris.

Carmona, R., Fehr, M. and Hinz, J. 2009. "Optimal stochastic control and carbon price formation" *Siam J. Control Optim.*, 48(4): pp. 2168-2190.

Chesney, M. and Taschini, L. 2012. "The Endogenous Price Dynamics of Emission Allowances and an Application to CO2 Option Pricing" *Applied Mathematical Finance*, 19(5): pp. 447-475.

Coase, Ronald. 1960. "The problem of social cost" *Journal of Law and Economic*, 3(1): pp. 1-44.

Cronshaw, M. B. and Kruse, J. B. 1996. "Regulated firms in pollution permit markets with banking" *Journal of Regulatory Economics*, 9(2): pp. 179-189.

Dales, JH. 1968. *Pollution Property and Prices*. Toronto: University of Toronto Press.

Directive 2009/29/EC of the European Parliament and of the Council. 2009. Official Journal of the European Union.

Gozzi, Fausto. 2011. "Short Course of Dynamic Programming" *Luiss University*, pp 1-59.

Kossoy, A., Guigon, P. 2012. *State and trends of the carbon market 2012*. Washington DC: Carbon Finance at the World Bank.

Metz, B., Davidson, O.R, Bosch, P.R., Dave, R., Meyer, L.A., 2007. "Fourth Assessment Report. Contribution from Working Group III" *IPCC*. Cambridge: Cambridge University Press.

Rubin, J. D. 1996. "A model of intertemporal emission trading, banking and borrowing" *Journal of Environmental Economics and Managements*, 31(3): pp. 269-286.

Seifert, J., Uhrig-Homburg, M. and Wagner, M. 2008. "Dynamic behavior of CO2 spot prices" *Journal of Environmental Economics and Managements*, 56(2): pp. 180-194.

European Commission. 2009. "Il sistema per lo scambio di quote di emissioni dell'UE (EU ETS)" *L'azione dell'UE contro il cambiamento climatico*.