Greenhouse Gas Price Scenarios for 2000-2012: Impact of Different Policy Regimes

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IWOe Discussion Paper No. 96

November 2001

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Acknowledgements:

The authors wish to thank the consortium partners for their valuable intellectual contributions. Financial support from the European Community under the specific programme for research, technological development and demonstration on "Energy, Environment and Sustainable Development" is gratefully acknowledged (contract no. EVK2-CT-2000-00076). The views expressed in this article are those of the authors, and do not necessarily reflect the pitions of those organizations with which the authors are affiliated nor those of the European Community. The Community is not responsible for any use that might be made of data appearing herein.

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Fifth Framework Programme
1998 - 2002

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Preface

The following paper, "Greenhouse Gas Price Scenarios for 2000-2012: Impact of Different Policy Regimes", is a component of the European research and development (R&D) project titled "Implementing the Kyoto Mechanisms: Contributions by Financial Institutions" (IMKYM-COFIN). The objective of this R&D project is to develop innovative financial products that are tailored to meet the needs of participants in emerging greenhouse gas (GHG) emission markets and prospective users of the Kyoto Mechanisms. Thus, it also aims at exploring how private-sector financial institutions may contribute to effective and efficient implementation of GHG emissions trading systems and the Kyoto Mechanisms. The project is co-financed by the European Commission, Research Directorate-General, and the Swiss Federal Office for Education and Science.

This paper is the primary output of the second of nine work-packages that collectively make up IMKYM-COFIN. This work-package was led by Natsource Tullett Europe (NTE), an international broker of energy and environmental commodities including GHG emissions based in London. NTE also provides strategic advisory services on environmental market development and entry. Other European project partners on IMKYM-COFIN include:

- **University of St. Gallen (HSG), Institute for Economy and the Environment (IWOe), Switzerland:** Research and advisory in the fields of environmental economics and management, with a special focus on emissions trading, Kyoto Mechanisms and climate policy. Scientific-technical co-ordinator of the project.
- **Gerling Sustainable Development Project (GSDP), Germany:** Project development company of Gerling Group of Insurance Companies, which is active in the fields of direct insurance (specialised in industry insurance), reinsurance and investment. Administrative-financial co-ordinator of the project.
- **SanPaolo IMI, Italy:** One of the largest Italian banks, active in the field of project finance.

Other components of the overall project include:

- Analysis of the scope for private-sector insurance against financial risks associated with GHG emissions trading and the Kyoto Mechanisms.
- Re-optimisation of project finance techniques applied to conventional projects, systematically taking into account potential financial implications of emissions trading and the Kyoto Mechanisms.
- Efficient risk diversification within portfolios of commercial climate protection projects.
- Design of a private-sector investment funds for commercial climate protection projects that generate marketable emission permits.
- Policy recommendations from the project's findings.

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Executive Summary

Policies to mitigate potentially harmful anthropogenic climate change may have significant economic consequences, including potential changes in absolute levels of wealth as well as transfers of existing wealth. Future greenhouse gas (GHG) permit prices will represent an important indicator of the economic impacts of climate policies that rely on emissions trading. Expectations about these prices already influence numerous decisions including those of policymakers designing climate policies, companies preparing for the onset of emissions restrictions, and developers of projects that reduce emissions. Expectations about future GHG prices are influenced significantly by results of emissions market models whose accuracy may be justly questioned. This paper seeks to revise future GHG price expectations by examining the results of a range of GHG market models and considering potential insights from several additional sources of information including analyses of variables not accounted for in most models, experience from SO2 market models and prices, and emerging prices in the nascent GHG market. The paper concludes with GHG price predictions for three time periods spanning 2000 to 2012.

Review of GHG Market Models

Modelers seeking to predict future GHG prices rely on a variety of modeling methodologies that differ primarily according to the range of economic sectors that are represented in detail and according to assumptions about the nature of interactions between those sectors. Most GHG market models of all methodological types have attempted to represent three basic policy scenarios including one which allows full international trading, one which restricts trading to industrialised countries, and one in which each country would be required to meet its entire international emissions limitation obligations through domestic measures.

Relying on the methodologies described above, along with numerous other projections and assumptions, GHG models have predicted permit prices ranging from EUR 1 to 25 per ton of carbon dioxide equivalent (CO2e) for the year 2010 under the full international trading policy scenario.[1] Nine of thirteen models surveyed project prices of EUR 9 or below. Projected prices for the Annex I trading scenario range from EUR 3 to 78 per ton CO2e, with seven of fifteen models projecting prices between EUR 18 and 25. Prices differ considerably under the scenario involving no international trading. Representative internal prices for European countries range from EUR 3 to 185. Prices in Japan range from EUR 92 to 274. US prices range from EUR 46 to 183. Much of the difference in results across the models can be attributed to diverging business-as-usual emission scenarios against which national reductions are quantified.

[1] All prices originally denominated in USD have been converted to EUR using the average 2001 exchange rate through October 24 (1 USD = 1.1169 EUR) calculated with data from the Federal Reserve Bank of New York.

Additional Variables

incompatibilities resulting Within the three broad policy scenarios described above, some differences in results can also be attributed to the representations of additional policy variables. These variables, such as the role of sinks, the number of regulated gases, and others, may have a significant impact on price. But they are represented in relatively few of the models, mostly for lack of reliable data. In addition, uncertainty surrounding some policy variables was clarified during recent international negotiations to further implementation of the 1997 Kyoto Protocol, an international agreement which would restrict GHG emissions and create an architecture for a global GHG market. Clarifications achieved during these recent negotiations are not reflected in most modelling efforts.

Drawing from experience in other emissions trading markets and on theoretical analysis, the report concludes that some policy variables not well-reflected in GHG models may produce outcomes that *raise* prices above the price levels that they predict. These outcomes include:

- inefficient trading system structures that raise transaction costs,
- limited sectoral coverage,
- restrictions on permit banking,
- discounting or elimination of surplus permits in economies in transition,
- exercise of market power,
- from failure to harmonise national trading systems,
- a compliance reserve,
- voluntary enforcement of supplementarity restrictions, and
- a tax on trades.

Other policy variables could produce outcomes that give reason to revise current predictions *downward*. These include:

- inclusion of multiple GHGs,
- low penalties for non-compliance,
- application of voluntary rather than mandatory regulations,
- crediting for GHG sinks, and
- limited US participation in the GHG market.

The net effect of these opposing forces will be determined by the unknown relative impact of each.

Several of the preceding variables will also impact permit price volatility. In particular, restrictions on banking and narrow sectoral coverage could amplify volatility relative to policy scenarios involving unrestricted banking and broad sectoral coverage.

Model Limitations

Modelers of what has become the worlds' most mature and best-known emissions trading programme, the US SO2 allowance programme, faced a set of uncertainties similar though smaller than that faced by modelers of future GHG markets. Various modelling efforts prior to implementation of the programme predicted that prices upon full implementation would be in the range of EUR 434 to 1122 per ton SO2. Actual prices since 1994 have not exceeded EUR 242.

Ex-post analyses reveal several factors that led to this overestimation of prices. These include:

- unexpected effects on fuel prices relating to rail deregulation,
- price expectation errors and the irreversibility of investments in abatement,
- political pressure to abate rather than trade,
- amortisation of 'end-of-pipe' abatement expenses,
- technological progress, and
- asymmetric corrections of faulty predictions.

Several of these factors apply also to the case of GHG trading and provide empirical justification for the view that GHG models too may overestimate future prices.

GHG Market Data

Though few governments have yet imposed binding GHG emissions limitations, a voluntary market for GHG emissions reductions has emerged in recent years. Prices for Verified Emissions Reductions (VERs), which carry only a possibility but not a guarantee of future governmental recognition, have traded between EUR 0.67 and 3.35 per ton of carbon dioxide equivalent (CO2e). Prices differ primarily according to vintage, the location of the reductions, and the likelihood that the reductions will earn future recognition. Compliance tools, or permits, which are issued by governments, are generally valued several dollars higher, though few have traded to date.

Besides revealing valuations of historical vintages, pre-compliance GHG trades provide information about current valuation of future vintages. Uncertainty about the usefulness of VERs suggests that their prices probably reflect a discount by buyers. However, other factors suggest that the onset of binding emissions restrictions will not necessarily lead to a significant price rise.

Price Scenarios

Based on the preceding analyses, and acknowledging that it is easier to criticise projections than to offer one's own, the authors offer "informed speculation" about GHG prices during three periods.

- During 2000 to 2004, prior to initiation of a possible EU-wide emissions trading programme, GHG markets are likely to remain either underdeveloped or separated by national boundaries. VER prices are likely to remain approximately at or below their current levels, as some demand shifts towards better-defined government-issued permits. The voluntary nature of the UK trading scheme and the relative permissiveness of its targets are likely to keep price at or below current market valuations of approximately EUR 8 per ton. Denmark's low non-compliance penalty will prevent prices from rising above approximately EUR 5.5 at least in the near term.
- An EU-wide trading programme may be in place during 2005-7 according to draft plans of the European Commission. Models of an EU-only trading programme for 2008-12 predict prices in the approximate range of EUR 33 to 49 per ton of CO2e. But targets are likely to be less restrictive prior to 2008, the programme may be voluntary, and additional supply may come from abroad if international trading rules can be agreed. These factors, along with possible overestimation of price by market models suggest that prices will be below EUR 10 per ton of CO2e.
- Models of the most plausible general policy assumptions predict prices of approximately EUR 10 to 20 per ton of CO2e. The significant impact of diminished or absent US participation in the market and the likely overestimation of prices by models suggest that prices during this period will remain below EUR 10 per ton.

Overall, our analysis leads to the conclusion that prices will remain on the low end of most projections throughout 2000-12. In the early years, transactions costs and inefficiencies will be greatest. But the voluntary nature of early trading programmes and the relative permissiveness of emissions targets in programmes' early years will keep prices low. As emissions targets grow tighter, potentially pushing prices higher, markets should begin to operate more efficiently across jurisdictions, thus preventing any major price rise.

Conclusion

Whether the various uncertainties surrounding the GHG market eventually result in prices that are lower or higher than our predictions, the identification and examination in this paper of a broad set of indicators that shed some light on future GHG prices will contribute at least to a better understanding of the bases on which price expectations ought to be constructed.

1. Introduction

Forecasting the economic consequences of new policy measures is a frustratingly difficult endeavour, as it requires one to make numerous assumptions about, among other things, the nature of the policy in question and the responses of actors and systems that the policy will affect. These and other complexities often confound even the most sophisticated attempts to accurately model future regulatory scenarios. Anecdotal evidence as well as more systematic academic reviews of such models' accuracy suggest that when it comes to predicting the future, regulatory analysts do not fare much better than weathermen.[2]

In the case of policies to reduce pollutant emissions, two of the most critical modelling assumptions concern what baseline level of emissions would occur in the absence of the policy and the costs of various technological abatement options. Beyond these basic assumptions, which are essential components of almost any ex-ante analysis of emissions-related policies, additional assumptions and data inputs necessary to carry out individual analyses may differ significantly according to the approach of the modelling team. For example, an energy systems model may require detailed information about the substitutability of various fuels, whereas a macroeconomic model might focus more on projections of economic growth. The type of policies under consideration also affects what assumptions must be made. For example, a model of a tax on consumption of energy would likely require information about consumers' elasticity of demand for energy, a model of a command-and-control policy might focus on the per-unit costs of a mandated abatement technology.

As the popularity of emissions trading has grown in recent years and that of alternative policy measures such as command-and-control measures and taxes has waned, the task of modellers has grown even more difficult. Emissions trading programmes provide affected sources with flexibility to choose from among more numerous compliance options than under alternative regulatory mechanisms. To accommodate this multiplication of compliance options, models must either grow more complex or adopt simplifying assumptions that gloss over a greater number of potentially significant details. In addition, models of emissions permit markets must attempt to translate information about abatement costs into the related but distinct issue of permit price. As this paper will discuss later in more detail, for these and other reasons, models of existing legislated emissions markets such as the US Sulfur Dioxide (SO2) allowance programme have generally failed to accurately predict permit prices.[3]

Yet despite the obvious shortcomings of ex-ante regulatory analyses, they remain an important source of information for policymakers who must choose between multiple

[2] For example, see Harrington et al. (1999).
[3] For example, see Farrell (2000) and Montero and Ellerman (1998).

courses of action and for emissions sources that would be affected by new regulations. After all, though such analyses often fail to predict accurately the economic impacts of policy measures, they generally provide a more reliable guide to future economic outcomes than mere intuition or plain guesswork. While ex-ante regulatory analyses may fail to predict future economic outcomes with any great precision, they do offer some basis for forming future expectations about those outcomes. For example, though predictive models may be unable to pinpoint whether a new water quality regulation will have a total cost of EUR 7 million, 10 million, or 12 million, models could provide reasonable certainty that the policy will cost less than EUR 1000 million and probably less than EUR 100 million. Even this most general of insights can help to refine observers' comparisons of competing policy choices. Moreover, apart from whatever models may tell us about the absolute level of economic impacts, predictive models also help clarify how those impacts may change relatively as a result of different policy choices.

1.1 Rationale

Greenhouse gases (GHGs), which are thought to be responsible for human-induced climatic change, are a by-product of numerous economic activities such as fossil fuel combustion, many types of manufacturing, and some agriculture. Restricting emissions would potentially mean curtailing or at least modifying many of these activities. For this reason, policies that would reduce GHG emissions in order to prevent global climate change are expected to have significant economic consequences, including potential changes in absolute levels of wealth as well as transfers of existing wealth. Recognizing this, negotiators of an international treaty to restrict GHG emissions from industrialized countries incorporated several emissions trading provisions into the treaty in order to minimize the cost of achieving its objectives. These "Kyoto Mechanisms" including Joint Implementation (JI), International Emissions Trading (IET), and the Clean Development Mechanism (CDM),[4] along with several other flexible provisions in the treaty such as its multi-year compliance period, partial inclusion of agricultural and forest sequestration, and coverage of a "basket" of six gases[5] aim to provide industrialized countries[6] with considerable flexibility in meeting their emissions limitation commitments.[7]

[4] For a description of these mechanisms and an analysis of how they might interact in the future, see Janssen (2000) or (2001).

[5] Annex A of the Kyoto Protocol lists the six types of gases that would be restricted by the agreement if it were to enter into force. These include carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6). As the paper will discuss later, expanding the Protocol's coverage from the single most important GHG, CO2, to these six gases is thought to reduce compliance costs by providing sources with a greater variety of processes from which to reduce emissions.

[6] In the jargon of the treaty negotiations, those 38 countries that would face binding emissions restrictions are known as Annex B countries. At other times, roughly the same set of countries are referred to as comprising "Annex I" of the UNFCCC. Because distinctions between the two terms are inconsequential to this paper's analysis, the terms are used synonymously throughout.

[7] For a thorough description and analysis of the treaty as a whole, see Grubb et al. (1998).

If the Kyoto Protocol were to enter into force, it would establish binding rules governing operation of the mechanisms. These rules collectively would form the architecture for an international GHG market that potentially would facilitate cross-border trades of a homogenous GHG emissions commodity. Some Annex B Parties would likely establish domestic emissions trading systems to operate within the bounds of this international system and would devolve trading rights to private entities within those countries' borders. Already Denmark and the United Kingdom have established such domestic systems, though it is not yet clear whether or how these will link to each other and to future domestic systems elsewhere in the absence of clear international trading rules. Domestic systems are also under consideration in a number of other countries,[8] and the European Union has publicized plans for an EU-wide GHG trading system that would begin operation in 2005.

The flexibilities provided to affected sources by these various emissions trading provisions have the potential to significantly reduce the cost of achieving the Kyoto Protocol's emissions limitation objectives. However, these flexibilities, along with the great breadth of economic activities that produce GHGs, make the task of modelling GHG markets enormously complex compared to previous emissions market modelling efforts. Given the poor track record of efforts to model earlier and simpler emissions markets, forecasts of economic impacts from more complex models of GHG markets should be treated with some scepticism.

In addition, most existing market models base their forecasts on permutations of the framework of flexibility provisions that were contained in the 1997 Kyoto Protocol, but were to be more fully elaborated in further negotiations. Most existing models do not yet take account of important decisions taken at the most recent round of treaty negotiations held in Bonn, Germany, during the latter part of July, 2001. There, almost all of the world's countries reached an important political agreement on key aspects of advancing implementation of the Protocol.[9] Besides reviving the nearly stalled negotiations, this compromise provided further details on some of the Protocol's features including the flexibility mechanisms, which makes many of the existing models' policy assumptions out-of-date. It also became clear during the Bonn negotiations that at least for the near future, the new presidential administration in the United States would stand by its rejection of the Protocol and refuse to accept an emissions limitation obligation. Because the United States produces such a significant share of Annex B emissions, its participation or lack thereof has significant consequences for the costs of the Protocol and for the GHG market. That most GHG models fail to reflect the new information resulting from the recent Bonn negotiations provides still another reason to question the accuracy of existing GHG models' economic forecasts.

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[8] Hasselknippe and Hoibye (2001).

[9] For a summary of the political compromise at Bonn, see International Institute for Sustainable Development (2001).

1.2 Objectives

As indicated by their continuing efforts to advance implementation of the Kyoto Protocol, political leaders around the world have expressed their intention to forge ahead with efforts to prevent the potentially catastrophic effects of climate change, even though these efforts may have considerable economic consequences. The potential enormity of these consequences makes it all the more important that environmental policy stakeholders understand the future impacts of the various policy choices they advocate.

Just as in previous emissions trading markets, forecasts from economic models significantly influence peoples' expectations about the costs of implementing GHG policies and the prices of GHG permits. As more market experience is gained, these analysts' projections will be replaced by true forward price curves that are developed using data from real transactions. However, until true price curves and other key information emerges, economic modelling projections about the *future* will continue to serve as one of the key bases for actions taken *now*. For example, many policymakers already use such assumptions to weigh the costs and benefits of different market design options. Sources likely to be affected by GHG regulations compare the possible future GHG permit price to their internal cost of abatement to determine whether they will be buyers or sellers in the market and to plan their operations accordingly. Entrepreneurs determine whether the anticipated revenue from sales of GHG reductions would justify investment in new emissions-reducing projects. And financial institutions need to have a clear understanding about the range of future prices of GHG permits in order to design new financial products and services that are tailored to meet the needs of participants in GHG markets.

Unfortunately, GHG model projections are not well understood by those who rely on them. People are naturally more likely to recall a headline price per-ton projection than the numerous assumptions and caveats that surround the projection. This natural tendency can lead to questionable choices or impressions that might have been prevented by a more thorough understanding of the projections. For example, studies such as that issued in 1998 by an economic consulting firm, Wharton Econometric Forecasting Associates (WEFA), projected that meeting Kyoto Protocol commitments would cost the United States as much EUR 402 per ton of carbon.[10] These and similar projections surely contributed to a vague perception among observers in the United States and elsewhere that meeting Kyoto's targets would be "costly", even though the projections rested on fairly rigid and unrealistic set of assumptions about how trading mechanisms would work.

[10] Note that in the rest of this report, prices are denominated in tons of carbon dioxide (CO2e) according to the convention established by participants in the nascent GHG market. It is notable that the particular price projection above is expressed in tons of carbon, because this yields a higher and therefore potentially more alarming figure.

Given the importance of GHG permit price expectations to current decision-making and the questionable accuracy of existing price forecasts, this paper attempts to refine GHG permit price forecasts, focusing on prices in the European Union during the years 2000 to 2012.

1.3 Methodology

The paper attempts to revise GHG price expectations by surveying existing price forecasts and considering additional sources of information that may shed light on the accuracy of these forecasts. This additional information includes a discussion of variables not reflected in most models, lessons from previous attempts to model emissions market behaviour, and real price data from the emerging GHG market.

Section 2 reviews existing GHG market models. The section describes the basic approaches and features of the models, drawing on previously published model surveys. Then it summarizes the outputs of these models under three basic policy scenarios in order to use these projections as a reference point against which to apply subsequent refinements. Section 3 discusses the likely relative price impacts of variables not captured in the broadly-defined policy scenarios run by most models and notes some of the changes in these variables resulting from the recent agreement in Bonn. Section 4 compares predictions and actual prices in the case of the US SO2 allowance market. This comparison is followed by a review and explanation of differences between predictions and actual prices. Then the paper discusses the extent to which the same shortcomings in SO2 allowance-price predictions may also apply to GHG permit-price predictions. Section 5 reviews price data from real GHG transactions. The section provides background on the nature of the emerging GHG market, describes some factors that have influenced prices in these early transactions, and discusses how these price data relate to future permit prices. Section 6 contains speculation about the possible level of future GHG prices based on information from the preceding sections including the various model critiques, GHG market data, and NTE's experience in other emissions permit markets. Section 7 contains overall conclusions.

1.4 Context

This work-package is among the first to be conducted in the IMKYM-COFIN project. The analyses and prices contained in this paper shall serve as inputs to subsequent work-packages on insurance, project finance, portfolio analysis, fund design, and policy recommendations.

2. GHG Models

This section briefly reviews the methodologies and outputs of existing GHG models. The range of prices projected by these models will serve as a reference point against which to apply subsequent refinements. The review aims not to be comprehensive but rather representative of the range of existing model approaches. It draws on several model summaries published in recent years.[11]

2.1 Description

Described in general terms, emissions market models econometrically simulate the intersection of future supply and demand for emissions permits. Uncertainties about the behaviour of factors that will influence future supply and demand force modellers to make numerous simplifying assumptions. Springer (2001) usefully groups into three categories the type of assumptions involved in constructing GHG market models. These categories are discussed below.

2.1.1 Modelling Methodology

Model methodology refers to the way that the models represent economic interactions and to the scope of systems represented in the model. Published model summaries typically group model structures into three or four methodological categories. The categories described below are roughly based on Springer (2001), the most comprehensive and recent of the model summaries.[12] Note that some "hybrid" models bear characteristics of more than one of the model categories described below.

- **Energy System (ES)** models focus on interactions within the energy sector. They are often referred to as "bottom-up" models because they use disaggregated engineering data specific to individual technologies and other abatement options.
- **Computable General Equilibrium (CGE)** models describe interactions between multiple economic sectors based on statistical and theoretical principles such as the assumption of perfect competition. Because CGE models aggregate the activities of actors within sectors these are often referred to as "top-down" models.
- **Macroeconomic** models aggregate all economic sectors within a country or region and represent economic output as a function of labour and capital inputs.
- **Integrated Assessment (IA)** models encompass physical processes such as climatic and sea level change as well as economic processes. The economic components of such models are based on one of the three methodologies described above.

[11] See for example Edmonds et al. (1999), Grütter (2001), Springer (2001), Weyant (2000), Weyant and Hill (1999).
[12] See Appendix 1 for a table of the models summarized by Springer (2001).

2.1.2 Projections

To achieve compliance with an absolute emissions target, a policy must yield emissions reductions equal to the quantity of emissions that would have occurred in the absence of the policy ("business as usual" or BAU) and the quantity authorized by the target (such as 8% below 1990 levels in the case of the European Union). Hence, the higher the projected BAU emissions, the greater the required abatement, other things equal. Numerous other projections act as inputs to BAU projections. These include projections about population and productivity growth rates, improvements in energy efficiency, rates of technological innovation and diffusion, availability of fuels, etc.[13]

2.1.3 Assumptions

The Kyoto Protocol still contains only the broad outlines of what may eventually become more detailed rules governing international emissions trading. In order to project future prices, modellers must make assumptions about how such rules will evolve. These assumptions address questions such as whether limits will be placed on countries' use of the mechanisms, whether Parties will be prohibited from generating reductions from particular project types, whether trading of all six GHGs will be allowed, etc. Such assumptions affect transaction costs and the range of compliance options available to affected sources. This range of options is an important determinant of compliance costs and permit price.

2.2 Outputs

When examining different models' price projections, it is important to compare a consistent indicator from each model. Comparing one model's projection of prices for the year 2005 to another model's projection for prices in 2010, for example, would lead to faulty conclusions. Following the convention of most other model summaries, this paper compares prices for the year 2010 (regarded as representative of the Kyoto Protocol's 2008-2012 compliance period), denominated in EUR per ton carbon dioxide equivalent (CO2e).[14] Prices described in this way are summarized under three broad sets of policy assumptions that were adopted by most, though not all, existing models.

2.2.1 Full Global Trading

This scenario assumes that sources have unlimited access to the Kyoto Protocol's mechanisms. This implies that sources within Annex I may trade freely amongst themselves and may access reductions generated in non-Annex I countries via the CDM. Within this broad assumption, each individual model may contain differences concerning the role of transaction costs, banking of unused credits for future use, access to sinks offsets, etc. All of the projections cover CO2 only.

[13] Van der Mensbrugghe (1998).
[14] Prices denominated in EUR per ton of carbon were divided by 44/12 to yield EUR per ton carbon dioxide.

Table 1: Permit Prices under Full Global Trading

Model	Permit Price in 2010 (EUR per ton CO2e)
Rose	1
ZEW	3
ECN	4
RICE-98	6
POLES	7
G-Cubed	8
GREEN	8
EPPA	9
GEM-E3	9
MS-MRT	11
AIM	13
GRAPE	15
MERGE	25

Source: Adapted from Springer (2001).

Note: Prices have been converted from USD to EUR using the average 2001 exchange rate through October 23, 2001 (USD 1 = EUR 1.1169).

Table 1, adapted from Springer (2001) shows that under this scenario, models project prices in 2010 ranging from EUR 1 to 25. Note that nine of the thirteen models project prices of EUR 9 or below.

2.2.2 Annex I only

Under this scenario, all the previous conditions remain the same except that trading is restricted to countries in Annex I.

Table 2: Permit Prices under Annex I Trading only

Model	Permit Price in 2010 (EUR per ton CO2e)
Rose	3
Wage	4
ECN	6
WorldScan	7
GEM-E3	18
POLES	19
G-Cubed	20
GREEN	20
RICE-98	20
AIM	23
GRAPE	25
MS-MRT	32
GTEM	40
EPPA	49
Oxford	78

Source: Adapted from Springer (2001).

Under this scenario, with compliance options restricted relative to the global trading scenario, projected prices are higher. This implies that the modellers adopt optimistic assumptions about the capacity for the CDM to reduce compliance costs.

The overall range of price projections from models that ran this scenario, is wider too (i.e., EUR 3 to 78) compared to the global trading scenario (i.e., EUR 1 to 25). Within this range, eleven of the fifteen models project prices of EUR 25 or lower. Of these, four predicted prices of EUR 7 or less. Seven of the fifteen models that ran this scenario projected prices in the fairly narrow band of EUR 18 to 25.

2.2.3 Autarky

Under the autarkic scenario, each Party to the Kyoto Protocol would meet its national emissions limitation objective internally without trading emissions permits internationally (domestic trading is implicitly assumed in the models). No international GHG price would emerge since no cross-border trades would be allowed. Instead, each country would have different national permit prices (assuming they develop domestic trading programmes) depending on their internal marginal abatement costs. Grütter (2001) reports prices within individual European countries ranging from EUR 3 to 185. By comparison projected Japanese prices range from EUR 92 to 274. Projected US prices range from EUR 46 to 183.

2.3 Reasons for Differences

The wide range of price projections within each of the scenarios described above illustrates the point that forecasting is a difficult task whose results are sensitive to modellers' assumptions. Weyant and Hill (1999) caution that readers ought not interpret the range of results "as an expression of hapless ignorance on the part of the [modellers], but as a manifestation of the uncertainties inherent in projecting how the future will unfold with and without climate change policies." Edmonds et al. (1999) note also that while the models tend to disagree about the likely absolute level of future prices, they agree about the relative impact of most policy choices. For example, the models agree that more geographic trading flexibility reduces compliance costs.

Springer (2001) attributes much of the disagreement between models' absolute projections to their choices of BAU scenarios and to differences in modelling approaches. He notes, for example, that bottom-up models tend to assume that many "no-regrets" abatement options (i.e., those whose costs are negative) can be exploited. In general, this results in lower price estimates than from top-down models, which are less sanguine about the practical availability or utilization of such cheap abatement options.

Grütter (2001) also notes the importance of models' BAU assumptions. In addition, he attributes variations within scenarios to the models' treatment of variables such as the number of gases that may be traded, sinks, transaction costs, etc. Whereas most of existing models ran projections that correspond to the three broadly-defined scenarios described above, additional variables were not modelled consistently enough across the various models to enable a comparison similar to that contained above for the three broad scenarios. For example, few models simulated trading of all six Kyoto-defined gases. Most focused instead on CO2, for which the most reliable emissions data are available. So while it is possible to compare six-gas trading prices to CO2-only prices within those models that ran both scenarios, it is not possible to observe whether these results are consistent across numerous models since so few of them ran the six-gas scenario.

3. Additional Variables

This section attempts to refine GHG price projections summarized above by analysing the likely impact of additional variables not captured in the broadly-defined policy scenarios reviewed above. Those scenarios demonstrated that permit price projections vary inversely with the amount of geographical trading flexibility afforded to affected sources. This section draws on practical emissions market experience, economic theory, and model results to examine how additional variables may affect prices.

Using the taxonomy of uncertainties described in Section 2, the analysis in this section can be said to focus on "assumptions" rather than "projections" or "model methodology." The authors of this study do not claim any special insights into the accuracy of population projections, for example, or on the relative merits of various technical modelling approaches. But assumptions about how trading rules will unfold are open to revision on several grounds. First, few models explicitly attempt to simulate the impact of some emissions market design options such as the range of sectors covered by trading programmes, banking restrictions, supplementarity, etc. Also, political developments since the July international treaty negotiations in Bonn have further clarified the future shape of international GHG trading rules. These new developments are not captured in the existing models, whose forecasts were published prior to the July negotiations.

Because of emissions market models' inherent limitations (discussed in Section 4), this paper contains no attempt to integrate revised assumptions into a new model or some existing model to yield new absolute price forecasts. Rather, it contains a discussion of the relative price impacts of alternative assumptions. The impacts of these assumptions are weighed along with other factors in Section 6, containing speculation about possible future prices.

3.1 Pre-Bonn

Variables discussed in this section were addressed in a few of the models summarized above. Often, however, these variables were not included in models, perhaps because they were regarded as unnecessary details. Here we discuss these directly to identify which variables may impact price and how they may do so. Variables that were significantly affected by recent treaty negotiations in Bonn are addressed separately in Section 3.2.

3.1.1 Trading System Structure

Trading system structure concerns the regulatory framework in which emission permits would be tradable. Programmes such as the US SO2 allowance programme (described above), the northeastern US' NOx Budget programme, and southern California's Regional Clean Air Incentives Market (RECLAIM) programme exhibit a cap-and-trade structure. In such programmes, regulators start by defining an aggregate cap for a particular class of sources. Then they allocate portions of the cap (i.e., permits known as "allowances") to affected sources and allow sources to trade those portions. At the end of each specified compliance period, regulators assess compliance by determining whether individual sources' permit holdings exceed their actual emissions during that period. By contrast, in baseline-and-credit systems regulators assign a specific allowable quantity of emissions per unit of time (e.g. tons per year), input (e.g. tons per energy consumed), or output (e.g. tons per energy produced) that serves as a "baseline" against which actual performance of a specific source or project will be judged. At the end of a specified compliance period, sources whose emissions are below the baseline receive "credits" or permits that can be traded to other sources whose emissions exceed their baseline. Several state Discrete Emission Reduction (DER) programmes in the United States exhibit a baseline-and-credit structure. The Kyoto Protocol's project-based mechanisms, JI and CDM, would also operate according to a baseline-and-credit structure linked to the core cap of Annex B countries with absolute national emissions limitations.[15]

It is difficult to generalize about the relative merits of these two types of market structure because baseline-and-credit systems have not been implemented on a large scale comparable to that of the SO2 or NOx cap-and-trade programmes. But for several reasons it appears that cap-and-trade programmes tend to involve lower transactions costs, lower volatility, and higher liquidity than baseline-and-credit systems.

First, in cap-and-trade systems affected sources typically receive their entire allocation of allowances at the outset of a given compliance period. In fact, in the case of the US SO2 programme, sources know their allocations for the next thirty years, though future allowances cannot be used for current compliance. By contrast in baseline-and-credit systems, sources usually only receive their credits retrospectively, once their degree of over-performance against the baseline has been certified by the government. The resulting uncertainty and delay prevents some sources from offering permits for sale and may reduce interest on the part of potential investors or buyers. Further, the total quantity of permits that may be traded by a source is limited to the difference between actual performance and the baseline. In contrast, sources in cap-and-trade programmes may trade their entire allocation of allowances (though they must also take care to ensure that at some point before the conclusion of the compliance period they re-acquire enough allowances to cover their actual emissions).

Baseline-and-credit systems also tend to have higher transaction costs, which deters trading and raises overall compliance costs. Sources wishing to generate credits may have to undertake numerous administrative steps such as notifying their regulator of an intent to generate credits, developing and defending their baseline and monitoring procedures, and verifying their actual emissions. Each of these steps takes time, increases costs, and deters more active trading. Cap-and-trade systems tend to be more

[15] See Janssen (2000) or (2001).

costly to establish at the outset, but subsequently have more streamlined rules for participation and lower transaction costs.

Generally speaking, supply is relatively costly to generate under baseline-and-credit programmes. This suggests that at a given level of demand permit prices and overall compliance costs would both be higher and potentially more volatile under baseline-and-credit than under cap-and-trade programmes. Greater liquidity under the latter market structure would reduce volatility and costs, and keep permit prices closer to the marginal cost of abatement. Most GHG models assume that efficient permit markets will enable countries to undertake all available emissions abatement opportunities. So any increase in costs and decrease in trading that results from a particular type of market structure could have an upward impact on actual prices relative to current projections.

3.1.2 Sectoral Coverage

The range of economic sectors covered by emissions trading systems will have an impact on the assumption that economies can efficiently exercise all existing emissions-reducing options. If emissions trading systems cover only a few sectors, such as the Danish system that applies only to electricity generators, emissions-reduction opportunities in other sectors will either have to be captured by other, potentially less efficient policy measures such as taxes or mandates, or those options may simply not be exercised. This would require those sectors that are affected by emissions trading programmes to achieve a greater share of countries' national emissions reduction obligations. Conversely, inclusion of numerous sectors would allow countries to spread national reduction obligations more equitably and would create economic incentives for a greater variety of economic activities eligible to abate emissions.

Some sectors of the economy, such as transportation and housing, are generally not well-suited to emissions trading, except under relatively untested "up-stream" design approaches. However, this is not presently envisaged in the Commission's draft directive on emissions trading. So limited sectoral coverage seems most likely, and this may result in higher permit prices for those sectors involved in emissions trading.

3.1.3 Number of Gases

Manne and Richels (1998) note that data concerning emissions of non-CO2 GHGs and technological options for reducing those gases is scarce and unreliable. Some models such as MERGE address this issue by assuming that all gases are reduced proportionally. Most models ignore non-CO2 GHGs altogether. If all six Kyoto gases were included in GHG trading systems, this would probably lower prices by making available a greater diversity of abatement options. Grütter's meta-model approach, which uses several existing models' input data to determine forecasts' sensitivity to different policy scenarios, indicates that inclusion of all six GHGs would reduce prices roughly 30% below the CO2-only scenario.[16]

But for the same reason that other GHGs are difficult to model, they may also be difficult to regulate. Inadequate monitoring methodologies may explain why GHG programmes such as the proposed EU-wide trading system and Denmark's legislated trading system cover only CO2. If these methodological difficulties persist, the CO2-only assumption in many models will turn out to be accurate. On the other hand, it seems plausible to assume that the accuracy of monitoring other GHGs will improve over time, and that the cost-savings associated with their inclusion in emissions trading programmes will be made available and will push down permit prices relative to current forecasts.

3.1.4 Banking

Just as emissions trading can reduce compliance costs by allowing sources to choose the most efficient geographic locations for emissions reductions, banking of permits reduces compliance costs by providing sources with flexibility to choose the most efficient time to undertake emissions reduction activities. For example, some sources in the US SO2 allowance programme overcomplied in the programme's early years to prepare for compliance with more stringent emissions targets in the future. By contrast, the lack of banking forces sources to undertake emissions reductions within the timeframe prescribed by the trading authority, which can amplify price volatility. For example, in southern California's RECLAIM programme the inability to bank was partially responsible for a spike in prices that corresponded with the onset of more stringent annual emissions targets. Eventually prices rose so high that regulators revised the rules of the programme. In general, limitations on the banking of GHG permits may increase prices relative to current forecasts. Banking restrictions may also result in greater price volatility.

3.1.5 Penalties

In order for penalties to deter non-compliance with emissions restrictions, they must be set well above the likely market price for emissions permits. If penalties are set below the market price, sources may simply pay the penalty and continue emitting, which would erode much of an emissions trading programme's environmental benefits. Nevertheless, politicians may be inclined to set low penalties as a way of limiting industry's emissions trading compliance costs. The penalty for non-compliance with the Danish domestic CO2 programme, for example, is set at the relatively low level of DKK 40 (~ EUR 5.50), which may be insufficient to ensure full compliance with the programme's emissions restrictions.

In addition, if penalty levels are not harmonized, or at least are not all set well above the probable clearing price in each individual trading system, emissions sources will have an

[16] Grütter (2001), p. 20.

economic incentive to migrate to the jurisdiction with the least costly penalties rather than endure higher compliance costs in their home jurisdiction. The extent of this migration will depend on several factors including the size of the differential between compliance costs at home and abroad. If the savings from shifting production were small relative to other production inputs, the incentive to migrate may be small. In addition, migration will be limited to some extent by the nature of certain industries such as electricity generation, for example. Transmission losses would prevent electricity generators from migrating a great distance from their customer base. If any sources do pay non-compliance penalties to government in order to avoid having to reduce their emissions, the reduction in demand for permits will reduce prices relative to current forecasts, which assume full compliance.

3.1.6 Surplus Permits in Economies in Transition

"Hot air," or the surplus emissions permits accrued by several states of the former Soviet Union (known as Economies in Transition (EITs)) as a result of their economic contraction relative to the base year against which emissions limitations are measured, could potentially supply a substantial portion of anticipated emissions permit demand during the first compliance period. Some countries have argued that emissions targets for these countries should be reduced to reflect their new economic circumstances. Elimination of this potential supply would increase prices relative to current forecasts. Grütter (2001) estimates that under some scenarios, elimination of this surplus would increase permit price by as much as one third. It is unlikely, though, that these targets could be modified without re-opening the entire Kyoto Protocol to negotiation, something few Parties would like to do.

3.1.7 Market Power

Some observers have expressed concern that countries such as Russia, China, India, and some EITs may act as monopoly sellers in order to increase permit prices. If these countries were able to overcome all the challenges associated with establishing an OPEC-like emissions permit cartel, the international market for permits would resemble that described under the Annex-I only trading scenario described above. However the chances are low that these countries could coordinate their activities effectively enough to establish a cartel. In addition, many of the potential cartel countries are interested in using their permit surpluses to attract investment from the more industrialized countries. It would run counter to their investment interests to join a cartel that discouraged such investment. Rather than forego this investment and its attendant environmental benefits by attempting to manipulate the market, potential cartel countries may be more inclined to behave as normal price takers. Finally, facing an improbably effective cartel, industrialized countries could attempt to re-negotiate terms of the Kyoto Protocol either to break-up the cartel or to make it easier for Annex B countries to meet their targets through domestic action. This might involve a lowering of targets or an expansion in the range of activities that would qualify for emissions credits.

3.1.8 Nature of Obligation

Voluntary emissions trading programmes are likely to achieve lower levels of participation and abatement than programmes in which participation and compliance are mandatory. In voluntary programmes such as the domestic GHG trading programme in the UK, one would expect participation mainly by companies that anticipate receiving a generous allocation of permits relative to their anticipated actual emissions. Companies for whom participation would constitute a significant constraint on their emissions are likely to stay out of such a programme until it becomes mandatory, barring some external inducement such as strong financial incentives for participation. Indeed the UK Government has made GBP 215 million available as a financial incentive for companies to take on voluntary targets in its emissions trading programme. By contrast, in a mandatory system, companies expected to be short of allowances would be forced either to abate their emissions or to purchase permits from others, increasing demand and prices. Voluntary programmes such as that in the UK, and potentially the proposed EU-wide trading system, are usually intended as precursors to a subsequent mandatory programme. In this situation, one might expect low prices during the voluntary phase and a price rise during the mandatory phase.

The price spread between the two phases could be reduced to some extent if sources have the opportunity to bank unused permits from the voluntary period into the mandatory period. However, provision of this right makes it difficult for governments to determine the appropriate level for emissions caps in the mandatory phase, since the number of permits banked into the mandatory period will depend on the uncertain behaviour of numerous companies. If the mandatory caps are set too high or too many permits are banked into the mandatory period, the government may fail to stay within its national emissions limitation obligation. This possibility may prompt governments to propose limits on banking between voluntary and mandatory systems, which would preserve the anticipated jump in prices between phases. In the UK, for example, banking of certain allowances will be subject to a percentage-based cancellation rate beyond 2007. The Government reserves the right to determine the exact percentage limit when it is better placed to judge the size of the UK market and in light of progress towards achieving the country's Kyoto target.

3.1.9 Extent of Harmonization

Many of the Kyoto Protocol's original architects intended to establish a binding international framework for emissions trading prior to the development of domestic emissions trading systems in order to prevent cost-increasing incompatibilities between those domestic systems. The slow pace of international treaty negotiations has exposed this "top-down" approach as overly optimistic. Instead, the international response to climate change can now be said to be proceeding in a more "bottom-up" manner, with domestic trading systems coming into existence without benefit of clear international rules to which they can conform. The result of this less orderly policy development could be a proliferation of incompatibilities that limit the cost-savings associated with cross-border trading. Differences in the stringency of national monitoring procedures, the types of project-based activities deemed eligible for certification, and the range of gases covered may all cause governments to prohibit or limit import of foreign permits into their domestic systems. If sources do face difficulty executing cross border transactions, prices would be different in individual countries as described under the autarkic scenario in Section 2.

To prevent these incompatibilities at a European level, the Commission has developed a proposed directive that would harmonize certain key emissions trading design elements across the Union. But national differences over the details of this proposal, and the difficulty of integrating pre-existing domestic programmes could slow implementation of the proposal, originally slated for 2005.

3.2 Post-Bonn

The political agreement reached amongst 178 nations at the most recent international climate change treaty negotiations in Bonn clarified several key features of the Kyoto Protocol. At present, few models have integrated these revised features into their forecasts of GHG prices. Below we discuss the potential price impacts of these decisions.

3.2.1 Sinks

Manne and Richels (1998) note that data concerning the potential supply of permits resulting from sinks is of poor quality. Moreover, inclusion of sinks was a particularly contentious political issue prior to Bonn, which created considerable uncertainty about the extent to which various activities would be eligible for credit. In the Bonn negotiations, several agreements were reached on the treatment of sinks. Parties agreed that afforestation (planting of new forests) and reforestation (replacing previously existing forests) would be eligible for credit under the CDM, and that use of sink-generated CDM credits for compliance by Annex B Parties will be limited to 1% of countries 1990 base year emissions during each of the first compliance period's five years (for a total of 5%). Projects that merely prevent deforestation would not be creditable. Changes in sinks since 1990 within the Annex B countries are to be fully accounted for, resulting either in a net debit or credit against countries' emissions limitation obligation. Countries facing a net debit would be allowed to offset this through domestic forest management activities within limits specified in a special Annex to the Protocol. The net effect of these various sinks provisions will be to make available relatively affordable, though limited, permit supply, easing the difficulty of meeting national emissions limitation obligations. Since the majority of models did not address the availability of permits generated by sinks, the Bonn decision on sinks suggests that projected prices should be revised downward.

3.2.2 Compliance Reserve

In order to prevent countries from overselling their emissions allocations, Parties in Bonn agreed that each country shall at all times be required to retain in their national registries either 90% of their annual emissions caps or five times its most recently reviewed national emission inventory, whichever is lowest. The practical effect of this may be to reduce the quantity of permits that may potentially be sold from some jurisdictions. The outcome may loosely resemble a baseline-and-credit system in which sellers must demonstrate that they have surplus to sell. As discussed above, typically these systems do not perform as efficiently as cap-and-trade systems that make the entire allocation available for trade up until the compliance deadline, when the final emissions goal must be met. To the extent that the international GHG market resembles a baseline-and-credit system, it will exhibit lower liquidity, potentially higher prices, and higher volatility than it otherwise might. However, this potential loss of efficiency must be weighed against the gain in integrity that will come with a strong compliance regime. In the absence of such measures, overselling could potentially threaten the programme's integrity along with its environmental benefits. On the other hand, alternative or supplementary compliance measures such as financial penalties could help to ensure environmental integrity without sacrificing liquidity.

3.2.3 Supplementarity

Leading up to the Bonn negotiations, several Parties including members of the European Union had advocated quantitative limits on Annex I Parties' use of the flexible mechanisms. This would have required those Parties to meet more of their emission reduction obligations through domestic activities. As a result, demand for international permits would decline along with price, and compliance costs would have increased. However, at the Bonn negotiations parties agreed only to a qualitative restriction which states that "…the use of the mechanisms shall be supplemental to domestic action and domestic action shall thus constitute a significant element of the effort made by each Party included in Annex I to meet its quantified emission limitation and reduction commitments."[17] The rejection of quantitative limits implicit in this compromise suggests that Parties will have considerable freedom to use the mechanisms as they deem appropriate. Individual countries or blocs of countries such as the EU may yet choose voluntarily to observe supplementarity limits. But because this would disadvantage those countries' sources by artificially raising their compliance costs, implementing such limits could be politically difficult. Unless these targets are set aggressively and enforced firmly, the net impact on prices is likely to be small.

3.2.4 Tax on Trades

Parties agreed that two percent of the credits issued for CDM projects shall be used to provide financing for a fund to help developing countries adapt to climate change. It is not clear yet what body would bear responsibility for monetising credits that accumulate as a result of this provision. The effect of the provision will be to marginally increase

[17] Bonn agreement in Natsource (2001).

the cost-per ton of CDM projects and potentially also the international permit price. Those analysts that have simulated a similar tax, such as Grütter (2001) have shown that the impact of this measure would be minimal.

3.2.5 US Participation

Prior to the Bonn negotiations, the new presidential administration in the United States indicated that it would not pursue ratification of the Kyoto Protocol and would only participate in future Protocol negotiations to prevent other Parties from adopting positions that would threaten US interests. The US delegation in Bonn maintained this position throughout the recent negotiations even as the rest of the world's countries achieved consensus. This development leaves the United States outside of the primary international effort to reduce GHG emissions. If the situation persists through the first compliance period, demand for permits will be dramatically reduced, as most models indicated that the United States would be a large net purchaser of emissions. An analysis by CICERO projects that without US participation prices would drop by roughly two-thirds, falling from EUR 16 to 5 under one scenario.

In reality, it is unlikely that the United States will take no action against climate change in the next decade. Political inclinations shift with elections, and already the current Bush administration faces significant domestic pressure to re-engage in international treaty negotiations and to reconsider a broken pledge to impose CO2 limitations on electricity generators as part of a "four-pollutant" regulatory approach that would also cover SO2, NOx, and mercury. If the United States establishes a separate domestic trading programme outside of the Kyoto Protocol framework, US sources are likely to insist on the ability to use international reductions in meeting their commitments. They may compete with sources from the rest of the world to buy reductions generated in non-Annex I countries that do not face emissions caps. This would boost demand, at least for CDM-generated reductions, relative to a situation with no US participation. Sales to the United States by countries within Annex I would raise accounting questions about how to ensure that those sales are not used for compliance in both the Kyoto Protocol and the US system. Moreover, it is questionable whether the Parties to the Protocol will exert pressure on sellers to trade only with countries attempting to meet their Protocol obligations. Even if such transactions were somehow made possible, the United States is unlikely to demand the same quantity of permits that it would have within the framework of the Protocol, since US politicians have argued that the country's targets are unfairly stringent. Even with a domestic emissions trading system, the aggregate national target would most probably be considerably less aggressive than the target of 7% below 1990 levels specified in the Kyoto Protocol. Thus, under almost any plausible scenario, US demand will be less than projected under models that assume full US compliance with Kyoto Protocol restrictions.

It is also theoretically possible, though unrealistic, that the US will rejoin the Kyoto Protocol in time for the first compliance period. But even under this unlikely scenario, the United States would probably have negotiated a less stringent national target as a condition of its re-engagement. This too would result in lower demand than predicted under current forecasts.

3.3 Price Volatility

In addition to preceding variables' impacts on price levels, it is useful also to mention briefly how some variables may impact price volatility. Generally, it is considered desirable for emissions markets to exhibit a moderate level of volatility such that permit prices fluctuate within a range narrow enough to allow sources to plan for the future and rely on existence of an external supply of permits at more or less predictable prices. The level of volatility will affect the price of options as well as the role that revenues from sales of GHG emissions permits play in project finance, among other things.[18]

As indicated above, banking restrictions can potentially amplify volatility by constraining sources' compliance flexibility and by causing a period drop in permit prices as particular vintages near their date of expiration. Broad sectoral coverage helps to reduce permit price impacts resulting from external shocks to any given sector. For example, in a trading programme that applied only to electricity generators, a spike in demand for electricity would also likely cause a rise in permit price, as generators burn more fuel and generate more emissions. By contrast, such a price impact would be muted in a programme that covered a wider range of sectors. Finally, regulatory uncertainty with regard to all of the preceding variables contributes to volatility, as each new announcement of a development in trading rules may force market participants to reconsider their estimates of permit valuations.

[18] The impact of GHG emissions trading on project finance is dealt with in another work-package of this project.

4. Model Limitations: Experience from the US SO2 Programme

The US SO2 allowance programme has created the best-known and most mature legislated emissions market in the world. Because it has contributed to significant reductions of acid rain-causing SO2 emissions at what is perceived to be relatively low cost, the programme is often cited as an example to be emulated by designers of other emissions trading programmes. This section compares price projections for this programme to actual prices recorded in the SO2 allowance market. Then it reviews explanations for apparently lower-than-expected prices and considers whether some of the factors that contributed to inflated price expectations in the case of SO2 might apply also to projections of GHG permit prices. The section begins with a brief description of the SO2 programme's features.

4.1 Description[19]

Title IV of the 1990 Clean Air Act Amendments requires large stationary sources to reduce their SO2 emissions by 10 million tons below 1980 levels. This goal is to be achieved through a two-phase tightening of emissions restrictions on fossil fuel-fired electric power plants.

Phase I, which began in 1995, imposed emissions restrictions on 445 large, mostly coal-burning electric utilities located in 21 eastern and midwestern states. Phase II, which began in 2000, tightened emissions restriction on Phase I units and extended emissions restrictions to additional emissions sources throughout the nation, bringing the total number of affected sources to around 2000. Affected sources now include existing electricity generators with an output capacity of greater than 25 megawatts, as well as all new utility units.

Allowances are the currency by which compliance with the SO2 emissions requirements is measured. An allowance authorizes a unit within a utility or industrial source to emit one ton of SO2 during a given year or any year thereafter. Affected utility units were allocated allowances based on their historic fuel consumption and a specific allowed emissions rate. After they have been allocated, they may be bought, sold, traded, or banked for use in future years. During Phase II of the programme, the allowance allocations to utilities are capped permanently 8.95 million tons per year.

For each ton of SO2 discharged in a given year, one allowance is consumed, meaning that it can no longer be used. Sources whose annual emissions exceed their allowance

[19] Adapted from Natsource (2000).

holdings would face a penalty of over EUR 2000 per ton of excess. However, no sources have yet incurred this penalty.

4.2 Projections and Prices

Numerous descriptions of the SO2 allowance programme claim that sources have overcomplied with emissions restrictions at substantially lower prices than were projected prior to its implementation. Some of these accounts claim that actual prices are less than a tenth of the level projected. For example, a former US Environmental Protection Agency (EPA) Administrator testified to Congress that: "…during the 1990 debates on the Clean Air Act's acid rain programme, industry initially projected the costs of an emission allowance...to be approximately USD 1,500 (EUR 1675) … Today those allowances are selling for less than USD 100 (EUR 112)."[20] Though most analysts agree that allowance prices are, in fact, lower than projected, the extent to which prices were overestimated is often exaggerated.

The following table shows price projection ranging from EUR 427 to EUR 1102 per ton.

Table 3: Pre-Implementation SO2 Allowance Price Estimates

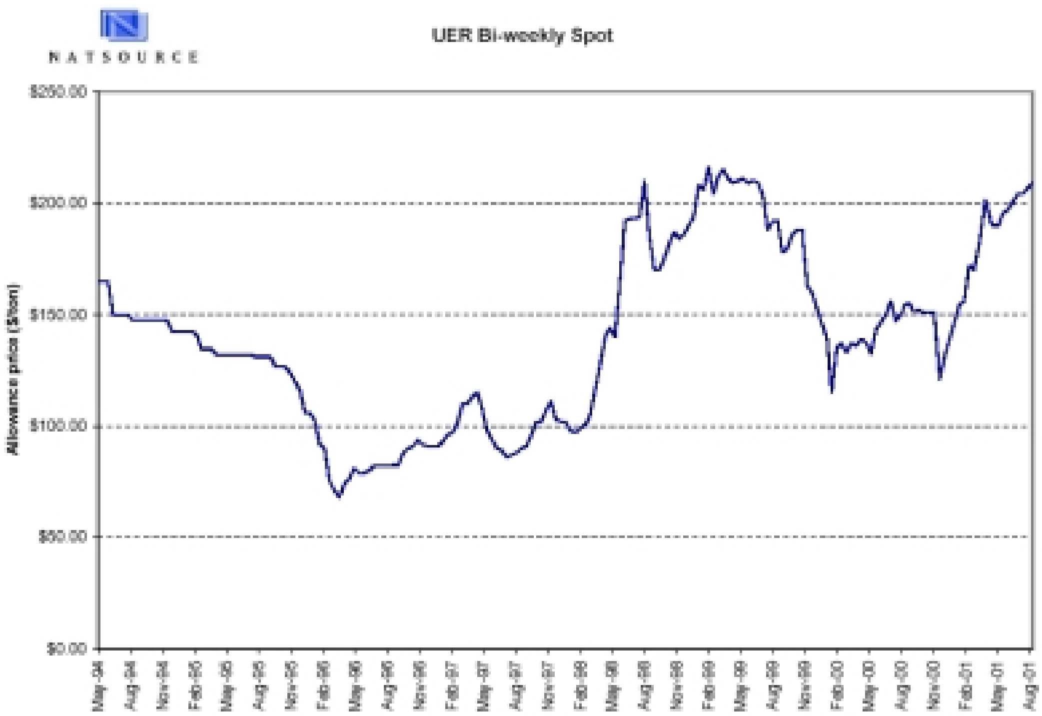
Source (year)	Price (1995 USD per ton)
ICF (1989)	722-1005
ICF (1990)	564-740
NAPAP (1990)	603-881
EPRI (1992-3)	516
EPRI (1994-5)	389-566
ICF (1994-5)	533

Source: Data from sources indicated above, compiled in Smith et al. (1998).

The USD 1,500 per ton figure mentioned above, which is often cited as an example of the high-end price forecasts, is actually not a forecast. Instead, it is a reserve price at which the government would sell allowances in the case of hoarding.[21]

[20] Browner (1997).
[21] Richard Schmalensee, personal communication cited in Smith et al. (1998).

Figure 1: Historical SO2 Allowance Prices



Source: Utility Environment Report biweekly reports of spot price, compiled by Natsource

By contrast, Figure 1 shows actual allowance prices over the course of the SO2 market's existence.

Figure 1 shows that SO2 allowance prices have ranged between a low of about EUR 78 per ton around March of 1996 to the current price (as of August 28, 2001) and historical high of approximately EUR 242.

Smith et al. (1998) point out that prices in contained in Table 3 are for the point of "full implementation," meaning that the accumulated bank of unused allowances would be mostly depleted and sources would be collectively be forced to restrict their emissions to the total annual allocations. Comparisons of these projections to current prices is thus somewhat spurious, since sources in the programme still benefit from a large bank of unused allowances that have been accumulated during the programme's early years in which emissions targets were relatively unrestrictive. For example, in the programme's first year, affected sources emitted only 5.3 million tons of an 8.7 million-ton cap.[22] Nevertheless, Smith et al. (1998) concede that the bank of unused allowances is

[22] Ellerman and Schmallensee (1997).

considerably larger than anticipated and acknowledge that the programme has achieved unexpected cost savings.

4.3 Factors

Several authors have attempted to explain the discrepancy between projected and observed SO2 prices and the programme's unexpected cost savings. Some of these are reviewed below.

♦ Rail Deregulation and Low-Sulfur Coal

One of the most common explanations for low prices relates to an unexpected development that affected the SO2 programme indirectly. Railroad deregulation during Phase I of the SO2 programme made it economical to transport the cheapest and lowest-sulfur coal in America from mines in the Powder River Basin (PRB) of Wyoming and Montana in the western United States to power plants in the midwest.[23] High transportation costs prior to deregulation forced these plants to rely on locally-mined coal with higher sulfur content. The availability of PRB coal reduced many utilities' demand for SO2 allowances. Despite the seemingly unexpected nature of this non-SO2-policy development, it is important to note that fundamentally, this was still a modelling failure: railroad deregulation had passed several years before the acid rain programme, and modellers were unable to accurately forecast the benefits of rail competition. They also failed to reflect the way in which these developments helped to drive down scrubber costs as manufacturers strove to maintain their cost-competitiveness with other cheap compliance options.

♦ Expectation Errors and Irreversibility

Another interesting explanation for low allowance prices relates to the nature of investments in abatement equipment and the role of price expectations. In theory, the price of allowances should reflect the marginal cost of abatement. One would expect sources to install and operate emissions abatement equipment as long as the cost of doing so is lower than the price of allowances. If the cost of the price of allowances fell below this cost, sources would be expected to stop operating abatement equipment in favour of allowance purchases.

But this explanation overlooks two key features of investments in abatement equipment. Scrubbers, one of the main technical compliance options available to sources affected by the SO2 programme, are both capital-intensive and can take up to three years to become operational once the decision has been made to begin their installation.[24]

[23] Ellerman and Montero (1998).
[24] Montero and Ellerman (1998).

So those sources facing a choice of whether to comply by between installation of scrubbers or by allowance purchases focused not so much on present allowance prices, but rather on expected allowance prices at the time the scrubbers would be operational. A survey conducted by researchers at MIT indicated that expectations of allowance prices of USD 300 (EUR 335) to USD 400 (EUR 447) were "very important" in many plant operators' decisions about whether to scrub.[25] Furthermore, sources were unfamiliar with the new emissions trading system and may have regarded installation of scrubbers as safer than subjecting themselves to the potentially volatile costs of reliance on allowance purchases. Once installed, scrubbers will remain in operation even if the plant operators' price expectations were too high, since most of the scrubbers total costs are sunk in initial construction. As long as the short-term costs of maintenance and operation are less than the price of allowances, it remains economical to continue running the scrubbers.

As a result of erroneous price expectations and the irreversibility of scrubber investments, sources abated more than was anticipated. Montero and Ellerman note that some other compliance options, such as purchase of long-term low-sulfur coal contracts, have similar characteristics of irreversibility, and may also have contributed to over-abatement. Together, these choices reduced demand for allowances and resulted in lower-than-expected prices.

♦ Pressure to Abate

Bohi and Burtraw (1997) point out that some states governments pressured their sources to install abatement equipment rather than rely on allowance purchases. Ellerman et al. (1997) note that this may have been intended to ensure some utilities' continued consumption of locally-mined high-sulfur coal, thus protecting local businesses and jobs, even though the resulting installation of scrubbers may have been uneconomical. As explained above, these irreversible investments place downward pressure on allowance prices by reducing demand.

♦ Amortization

Compliance options that involve modifications to old capital stock can become more expensive as the decision of whether to invest is delayed. Installation of a scrubber or upgrading the efficiency of an existing generator involves modifications to a piece of equipment with a limited lifetime. Deferring such modifications shortens the period over which their costs can be amortized, since the equipment being modified will be nearer to the end of its useful life.[26] This creates an incentive for early over-compliance which reduces allowance demand.

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[25] Ellerman et al. (1997).
[26] Morel et al. (2000).

♦ **Technological progress**

Economic theory predicts that the opportunity to earn revenue by selling unneeded allowances should spur technological progress in search of new and more efficient ways to reduce emissions. Harrington et al. (1999) note that in the case of SO2, scrubbing has turned out to be more efficient and reliable than anticipated. Experiments and modifications to existing plants have also yielded greater than expected opportunities to use lower sulfur coal and new coal blends, both of which reduce emissions.

♦ **Asymmetric Corrections**

In their review of numerous pre-implementation cost estimates, Harrington et al. (1999) argue that gross underestimates of compliance costs are more likely to be brought to the attention of regulators by worried members of the regulated community than are overestimates. This asymmetric correction of cost estimates leads to inflated price expectations.

4.4 Relevance to GHG Market

In a sense, some of the factors described above are unique to the case of SO2 allowances. For example, the availability of cheap low-sulfur coal should not affect the international GHG market in a direct or significant way. But in a more general sense, several of the factors above provide some empirical justification for the expectation that other emissions market models, such as those for GHGs, may also overestimate future prices.

Unexpected but related developments, such as the rail deregulation that made low-sulfur coal affordable to transport, may also occur in the case of GHG reductions. In fact, GHG emission limitations would affect so many economic sectors that the probability of cost-affecting unexpected developments seems greater than in the case of SO2 market, in which only one class of emissions sources (i.e., large power plants) with limited technological abatement options (e.g., scrubbing, fuel switching) was affected by emissions limitations. However, while the probability of any major cost-changing development may be high, there appears to be little basis on which to expect that such developments will necessarily be of the cost-reducing sort. It may be equally likely that unexpected developments will increase prices. All that can be surmised from this particular factor in the case of SO2 is that emissions permit price estimates are subject to great uncertainty, some of which cannot be anticipated or quantified.

Similarly, the uncertain pace of technological development could ultimately cause price estimates to be either too high or too low. It is possible, for example, that current GHG models overestimate the pace of future technological progress. But it seems more likely that in the wide range of economic activities that could potentially reduce GHG emission reductions, estimates of technological abatement options will have failed to anticipate at least a few efficiency-enhancing developments.

Expectation errors and irreversibility provide a significant reason to revise GHG price forecasts downward. With such a wide variety of potential abatement options, not all GHG abatement investments will be irreversible. Nevertheless, a large proportion of abatement options exist in sectors such as electricity generation, manufacturing, and other industrial processes that often do make large capital investments which will essentially be irreversible once in place. These investments will put downward pressure on GHG prices. Moreover, if it is the case that GHG price expectations overestimate future prices, more of these irreversible investments will occur. In addition, emissions sources in Europe are mostly unfamiliar with emissions trading. If some of these sources respond to this unfamiliarity by choosing the safe compliance option of abatement over the seemingly riskier option of purchasing permits, even though the latter option might be more cost-effective, demand for permits and permit prices will fall below the level that marginal abatement costs would imply. The effect of amortization may also have a similar affect, though its magnitude depends on what proportion of technological abatement options involve retrofits of existing equipment.

European GHG sources may also face political pressure to engage in uneconomical abatement. Though the European Union was ultimately unsuccessful in its attempts to impose a quantitative limit on Parties' use of the Kyoto Mechanisms, Member States may yet enforce similar limits on sources within their countries. The effect of this would be to drive up compliance costs and push down permit prices.

In summary, the factors that caused SO2 allowance prices to remain below pre-implementation forecasts give cause for considerable scepticism about the accuracy of GHG price forecasts. While some of these factors could push actual GHG prices in either direction of forecasts, many are likely to push prices in a downward direction. The net effect of these opposing forces will naturally be determined by the relative magnitudes of each. However, given that the cumulative effect of these factors produced overestimation in the case of the world's largest and most mature emissions market, that for US SO2 allowances, we are inclined to expect that the same may hold true in this case.

5. GHG Market Data

Though few governments have yet imposed binding GHG emissions limitations, a voluntary market for GHG emissions reductions has emerged in recent years. Motivated by a variety of factors, participants in this market have begun to explore the practical challenges and benefits of GHG trading even as the regulations that will eventually govern the GHG market remain under development. Because early GHG trades occur outside a formal regulatory framework, they are not directly comparable to the sort of compliance-motivated trading that will occur once governments put in place binding emissions limitations and trading rules. Nevertheless, early trades involve real transfers of funds in return for various GHG commodities, and the features of these trades provide some insight into the nature of a future compliance-based GHG market. This section describes the motivations of early GHG market participants, summarizes the features of the current GHG market, and considers what these features might foretell about future GHG prices.

5.1 Participant Motivations

Buyers believe that providing financial support for emissions-reducing activities within this emerging policy framework demonstrates leadership in addressing an issue that concerns the public, i.e., climate change. They also use early trades to demonstrate the advantages of emissions trading vis-à-vis other regulatory means of enforcing emissions limitations such as taxes and mandates. In anticipation of such emissions limitations and the potentially high costs of complying with them, acquisition of rights to GHG emissions reductions that may eventually be recognized as a credit helps buyers to hedge regulatory risk. Participation in the emerging GHG market also provides buyers with valuable first-hand trading experience that may create an advantage over their less-experienced competitors.

Like buyers, sellers too seek to demonstrate leadership and the viability of emissions trading as a tool for achieving environmental protection. Sellers also hope to boost the returns of environmentally beneficial projects by earning revenue from the sale of a good, GHG emissions reductions, that previously carried no monetary value.

5.2 What is Traded

In legislated emissions markets such as the SO2 allowance programme or the NOx Budget programme, participants trade government-sanctioned permits that authorize their owner to emit a specific quantity of emissions. But few governments have yet established binding GHG emissions restrictions or permits that could used to demonstrate compliance with those restrictions. This means that until very recently, GHG traders were unable to exchange permits. Instead, they exchange commodities whose features are determined by negotiation between the two parties involved in the transaction, usually without any explicit participation by government regulators.

The outcome of these negotiations is different in each case, depending on a variety of factors including the unique interests of the buyer and seller. Consequently, there is no single, standardized commodity that changes hands in the pre-compliance GHG market. Despite these differences, the products that change hands in most GHG trades typically include a common set of characteristics that allows for some generalized description of the tradable commodity.

Most GHG trades to date have involved **Verified Emissions Reductions (VERs)**. In essence, these represent a quantifiable change in emissions that result from a specific activity, verifiable by a third party (i.e., external to the buyer and seller), surplus (or "additional") to legal emissions reduction requirements, that may constitute a claim against future compliance requirements. It is important to be clear that VERs carry only the possibility, but not a guarantee, of future government recognition as a credit that can be utilized for compliance with an emissions limitation. Despite adhering to the preceding definition of a VER, many will expire valueless if governments determine that the reductions failed to meet whatever crediting rules are established in the design of domestic and international programmes.

Less commonly, participants trade **Emissions Reductions (ERs)**, which have not be verified by an a third party.

With the advent of domestic trading systems in Denmark and the UK, market participants may also trade government-issued **permits** that authorize a specific quantity of emissions. At present few permit trades have occurred.

5.3 Prices

To some extent, different prices paid in the GHG market to-date can be attributed to different features of the commodities exchanged such as vintage, geographic location, environmental integrity, etc. For example, one would expect more rigorously-scrutinized reductions to command higher prices than reductions of questionable environmental integrity. However, at present the market is not yet mature enough to fully reflect differences in these features. Instead, prices are driven to an equal or even greater extent by the unique circumstances of each individual trade. For example, the Dutch government paid higher-than-usual prices through its Emissions Reduction Unit Procurement Tender (ERU-Pt) process in part because the tender procedure did not allow for negotiation of price once formal sale offers had been submitted, even though the emissions commodity procured was in many ways similar in character to that exchanged in company-to-company transactions at much lower prices.

NTE estimates that approximately 55 million tons of carbon dioxide equivalent (CO2e) have been exchanged since the market's first trades in 1996-7. This estimate excludes trades of less than approximately 1,000 tons and trades within companies such as trades in BP's and Shell's internal trading systems.

Table 3 below shows GHG commodity price ranges in nominal US dollars differentiated by commodity type and vintage for market activity since 1996-7.

Table 4: GHG Prices by Commodity and Vintage (USD per ton CO2e)

Commodity Type	Vintage Year	Price per ton CO2e (USD)
VERs		
Annex B VERs	1991-2007	\$0.60-\$1.50
Annex B VERs	2008-2012	\$1.65-\$3.00
CDM VERs	2000-2001	\$1.75-\$3.00
ERs		
ERs	1996-2012	\$1.00-\$2.70
Compliance Tools		
Dutch ERUs	2008-2012	\$4.40-\$7.99
Danish Allowances - Bid/Offer	2001-2003	\$3.55-\$4.14
UK Permits - Bid/Offer	2002	\$6.50-\$9.15
UK Permit Call Option - Bid	2002 (expiration Feb. or Mar. 2003)	\$12.03 (strike), \$0.86 (premium)

Source: Natsource. Prices updated August 21, 2001.

VERs as a group have traded between about EUR 0.67 (USD 0.60) and 3.35 (3.00) per ton CO2e. Prices are segmented by vintage and location mainly because of expectations about future crediting rules. In particular, reductions undertaken after the base year for Kyoto commitments (1990), and before the first commitment period, and that occur within Annex B countries are presumed to stand a lower chance of earning credit than reductions undertaken during the first commitment period. By then many countries are likely to have put in place binding emissions restrictions for which vintage 2008-12 VERs might be usable for compliance. So these trade at a slight premium over earlier vintages. Nevertheless, buyers still ascribe a value to pre-2008 VERs because they may be usable to meet voluntary commitments or binding commitments in domestic trading systems that emerge prior to 2008.

VERs generated in non-Annex B countries trade roughly at parity with vintage 2008-12 Annex B reductions. Prices are not segmented by vintage, since the CDM as envisioned in the Kyoto Protocol would allow project developers to earn credits for reductions after 1999, and those credits could be banked for use during the compliance years. So both vintage 2008-12 Annex B reductions and post-1999 non-Annex B reductions are assumed to have a similar probability of being usable for compliance with future emissions restrictions.

Compared to VERs, relatively few ERs have traded. Buyers probably prefer VERs because it is anticipated that verification will be required in order to earn government-recognized credits in the future. Despite this lesser demand for ERs, they are not necessarily cheaper than VERs. Although such reductions incur no verification costs, other required qualities may raise their costs back to parity with VERs. For example, ERs purchased by the Oregon Climate Trust must be "financially additional", meaning that their projects would not have been financially feasible but for the revenues generated by sale of the GHG emissions reductions. This requirement narrows the pool of potential sellers, and in so doing, excludes some who might have offered cheap reductions.

Compliance tools (or "permits"), such as UK permits, are valued more highly than VERs because permits are by definition usable for compliance in at least one market. By contrast, VERs carry only the possibility of future government recognition. Government permits are also relatively more valuable than VERs because they are more likely to be transferable into other jurisdictions. So the pool of companies willing to purchase UK domestic allowances, for example, will undoubtedly extend to companies located beyond the UK, based on the expectation that such allowances represent a superior compliance hedging tool even in non-UK domestic markets compared to VERs.

Dutch ERUs are placed in the category of compliance tools for several reasons. First, the trades involve the type of emissions credit that will result from JI projects as defined under the Kyoto Protocol (ERUs). In addition, the contracts are unique because the Dutch government instead of a private company acted as the buyer. In the course of playing this role, the government established a high quality standard for generation of the reductions and negotiated legal agreements between the host-country governments and itself that will effect the transfer of ERUs at the appropriate time. Finally, the government appeared to be willing to pay a somewhat higher price than for mere VERs, suggesting that the government itself perceived that it was acquiring a more valuable commodity. On the other hand, the transactions resemble those for VERs in the sense that transfer of the commodities is contingent on entry into force of a still-uncertain regulatory framework, in this case the Kyoto Protocol. By contrast, in trades for other so-called compliance tools such as UK or Danish permits a regulatory framework and legally binding emissions restrictions are already in place, making such (potential) transactions less tenuous than those for Dutch ERUs.

The World Bank's Prototype Carbon Fund's (PCF) purchase of reductions from a landfill in Latvia is another transaction whose unique features defy simple categorization.[27] PCF

[27] Inclusion of this purchase in Table 3 would have obscured the segmentation by vintage and location apparent VER transactions. Instead its unique features are described separately in this paragraph.

paid ~EUR 3.91 per ton for reductions generated over the years 2002-2012. As a CDM transaction, this would be only a slightly higher price than that paid in similar previous transactions. But since Latvia is an Annex B country, project-based reductions generated there would fall under JI guidelines. For Kyoto Protocol compliance purposes, only JI reductions generated during the first compliance period (2008-12) and potentially onwards would be creditable. Reductions generated during pre-2008 would seemingly have a lower value in light of this fact. NTE's communications with PCF indicates that they were aware of this when they did the deal and took this approach purposefully. Though PCF has not been explicit about their motivations for this anomalous approach, some indications suggest that they sought to balance a low per-ton price with a desire for their injection of revenue to impact the financial viability of the project. That is, for PCF to make a significant financial impact by buying only the 2008-12 vintage reductions, they would have had to pay a per-ton price well above their stated purchase price targets. Instead they chose to spread their purchase over a greater number of years. Like many VER transactions (but also like the Dutch ERU transactions), transfer of actual credits is contingent upon elaboration of an emissions trading regulatory framework.

5.4 Impact on Price Scenarios 2000-2012

Trades described above for VERs and ERs generated between 2000 and the present represent the only known GHG market activity for those vintage years. Hence, no forecasts or further analysis are needed to ascertain those particular prices. Besides revealing valuations of historical vintages, pre-compliance GHG trades also provide information about current valuations of future vintages. As indicated above, buyers are currently willing to pay the most for reductions that will be generated during the first Kyoto compliance period. So far there has been little if any differentiation between VER vintages 2000 to 2007.

The absolute level of per-ton prices in the pre-compliance GHG market is generally on the extreme low end of model projections under the most flexible policy scenario, which assumes full international trading. Because this trading occurs outside of a legislated regulatory framework, it is not directly comparable to the market that regulatory analysts have attempted to model, nor to the actual market that is likely to develop over the next decade.

On one hand, the many uncertainties involved in voluntary pre-compliance GHG trading seem to indicate that prices from this market probably underestimate actual future prices under legislated emissions trading. In particular, there is considerable uncertainty whether any given reduction, no matter how rigorously quantified and monitored, will eventually earn certification under government rules that have not yet been developed. So buyers would be expected to reduce their willingness to pay as a way of reflecting the uncertain usefulness of the pre-compliance GHG commodity. In addition, most buyers act voluntarily and would likely curtail their purchases if the cost of acquiring reductions were considerably higher than it is now. By contrast, binding emissions restrictions would create a natural source of demand from those companies for whom meeting the restriction internally would be expensive. For these reasons, current GHG prices may be below those that will eventually emerge once governments establish formal emissions restrictions and trading rules.

On the other hand, there is reason to question whether this price rise will materialize. Once the rules for generating permits have been made clear, project developers and affected sources alike will perceive a clearer, stronger economic incentive to curtail their emissions. This will prompt the private sector to seek out innovative and cost-effective ways of reducing emissions. Moreover, the establishment of rules will reduce the transactions costs incurred by developers in navigating some of the uncertainty surrounding credit creation. For example, project developers currently incur significant expense calculating their reductions against baselines whose methodologies have not been provided or endorsed by governments. Developers also usually require considerable legal services to develop contracts that minimize their liability under unforeseen future outcomes. Reduction of these and other transaction costs will make it easier for developers to generate additional permit supply. At the very least, despite its differences from compliance-motivated trading, pre-compliance GHG prices offer a useful indicator of future permit valuations.

6. Price Scenarios

Acknowledging that it is easier to criticize others' projections than to offer one's own, it is with appropriate humility that the authors of this research effort now speculate about possible future GHG prices. The following predictions are based on the analyses of the preceding sections which covered GHG model price forecasts, impacts of additional policy variables, comparisons of other emissions market predictions to actual prices, and GHG prices from pre-compliance trading.

This paper's stated purpose is to present price scenarios covering vintages 2000 to 2012. At this time of advancing policy development, considering the entire period as a homogeneous whole would overlook probable differences in the characteristics of developing GHG markets. In order to make our analysis more precise we offer possible GHG prices in three time segments whose boundaries are delineated by major anticipated European and international policy developments. The first of these time segments ranges from 2000 to 2004, after which it is anticipated that the European Commission may have established an EU-wide trading system. The second time segment covers the first years of the proposed EU-wide trading system, 2005 to 2007. The Kyoto Protocol's planned first compliance period lasting 2008 to 2012 is the third and final segment considered in the following section. For each time segment we offer what we consider the most probable range of prices. Then we describe possible circumstances under which prices would be either higher or lower, and the likelihood that such circumstances will occur.

6.1 2000 to 2004

During this period, in which the Kyoto Protocol remains under negotiation and most national governments are still considering how to respond to climate change, GHG markets are likely to remain either underdeveloped or separated by national boundaries. Now that the European Commission has announced its plans for a European GHG trading system, some member states may await the details of these plans instead of developing a national system that would later have to be integrated into the EU system. Denmark and the UK at least will have national trading systems in operation for part of this period. At present these contain no provisions for mutual recognition of each others' permits. So market prices will probably be driven by factors unique to each independent national market and to what remains of the market for VERs. Consequently, in this period there is likely to be no single GHG permit price. Rather, each distinct market will have its own price.

6.1.1 VERs

With the beginning of the two national legislated trading systems, companies around the world can now purchase government-issued permits rather than VERs whose compliance value is highly uncertain. Permits are generally regarded as a superior risk-hedging tool for foreign companies, since permits from one jurisdiction seem to stand a greater chance of being transferable into other jurisdictions than do VERs, which carry no government's endorsement. Consequently some demand for VERs will shift to permits, potentially reducing VER prices from their already low levels.

Nevertheless, some VER demand may remain since early-vintage permits will not be fully bankable into the Kyoto compliance period. Despite permits' superior credibility, some buyers that are most concerned about the Kyoto compliance period may prefer to pay low prices of VERs of 2008-12 vintage rather than potentially higher prices for earlier vintage permits that may not bank into 2008-12. In fact, as the likelihood of binding GHG regulations grows, demand for VERs may also grow, as more companies perceive the need to avoid potentially high compliance costs. Further, since even the most advanced of the national trading systems do not yet include detailed rules for importing foreign project-generated reductions, VERs remain the only available commodity to buyers interested in acquiring CDM-style and JI-style reductions. In light of these considerations, we expect that during this period, the VER market will continue to trade sporadically at its current levels below EUR 5 per ton.

If a significant number of other countries establish emissions trading systems in the near future, opportunities to acquire permits rather than VERs will be greater. Further, if these permits are bankable into the Kyoto compliance period, they will be more attractive than VERs. These would further reduce demand for VERs and push prices even lower than their current levels. Establishment of crediting rules for international projects would also reduce VER demand.

However, these rules will generally be subject to international rather than national authority, which suggests that it may still be some time before rules are elaborated. We do not expect many new domestic emissions trading programmes in Europe to be established before 2005 since these would have to undergo a difficult integration into the planned EU trading system. It is more likely that member states will await guidance from the Commission about how to harmonize their domestic systems during the design stage, or that they will decline to establish specifically domestic systems and engage only in EU-wide trading. Governments will probably restrict the extent to which permits can be banked into the Kyoto compliance period in order to ensure that Europe as a whole is able to stay within its Kyoto-defined emissions limitations.

VERs could increase in value for a short period if a significant number of governments signal their intention to regulate GHG emissions in the future but do not quickly establish emissions trading rules. In the meantime, risk-averse companies might take greater interest in VERs. However, as legislated markets develop, we would expect to see interest shift to permits.

6.1.2 UK

Projecting market behaviour in the UK trading system is complicated by the fact that its design combines a cap-and-trade structure (known in the UK as the "absolute" sector) with two baseline-and-credit elements (known as the "unit" and "project" sectors). Companies that enter into the trading programme via Climate Change Agreements (CCAs) with the Government may opt for either absolute or relative (i.e., unit) emissions targets. To date, the majority have chosen the latter.

Unrestricted trading can occur within each sector and from the absolute to relative sector. But trading from the relative to the absolute sector is restricted by a "gateway" mechanism. The gateway will only be open, allowing transfer of relative permits into the absolute sector, when there has been a net flow of allowances into the relative sector. This mechanism will probably result in different valuations for unit- and absolute-sector permits. It is expected that the gateway will rarely open and hence the price of permits from the absolute sector is likely to be higher than those from the unit sector. It is not yet clear what restrictions will be placed on the use of project-sector permits or how these might affect their value.

According to Table 3, current bids and offers for vintage 2002 UK absolute-sector permits suggest a mid-market price of approximately EUR 8 (GBP 5.2). This level will probably change once the first compliance period begins in 2002 and actual trades occur, providing clearer price information to market participants. The market's voluntary nature suggests that in its early years, prices will remain mostly at or below this level. Since sources are not currently required to participate in the programme, only those companies who stand to benefit are likely to join it. Companies who anticipate that participation would be costly are not likely to join the programme. Yet these are the same companies who would provide significant demand. Thus the market may be oversupplied in the early years.

Prices could rise above current levels if a significant number of foreign buyers acquire UK permits as a hedging tool that might be transferable into domestic markets elsewhere. Yet the extent of this strategy looks to be limited in the short term by the failure of governments so far to develop trading rules that would allow for international transfers. International fungibility may not occur until rules are purposefully harmonized by international agreement either via the Kyoto Protocol or at the European level by the Commission. UK prices might also rise if the government signals its intention to impose mandatory regulations in the future and that current vintage allowances will be bankable into that period. This would encourage more companies to join during the early years in which emissions restrictions are relatively permissive. Banking permits during these years would reduce the cost of complying with more restrictive future emissions limitations. However, since the UK system will eventually have to integrate with a European one, there is considerable uncertainty on the question of how UK allowances may be banked forward from earlier vintage years characterized by voluntary participation into later vintages that are characterized by mandatory compliance with EU standards.

6.1.3 Denmark

According to Table 3, current bids and offers for Danish CO2 allowances suggest a mid-market price of approximately EUR 4. Danish legislators capped the price of their CO2 allowances at approximately EUR 5.50. Thus, in the near term, prices will remain at or below this level. Eventually Denmark will have to consider how to make its national trading programme compatible with evolving plans for an EU trading system. Among other changes necessary to undertake this integration, Denmark will have to increase the level of its penalty nearer to the level currently under consideration by the Commission, EUR 50. With a higher penalty, Danish prices would be free to rise above the current cap. Projections by participant companies in the Danish programme indicate that while permit allocations tend to cover probable emissions for 2001 and 2002, in 2003 actual emissions are likely to exceed permit supply, pushing up demand and prices.

6.2 2005 to 2007

In June of this year, the European Commission announced its intention to issue a directive before the end of the year that would create an EU-wide GHG emissions trading scheme. Initially the proposed cap-and-trade scheme would be mandatory and cover only CO2 emissions from industries including electricity generation, oil refining, metal smelting, and production of cement, glass, ceramics, pulp, and paper. The commission intended for the directive to be negotiated and adopted by members states during 2002 and 2003, then implemented in 2004. The scheme's compliance periods are to run from 2005 to 2007. These years mark the boundaries of the period discussed in this section.

In July, however, the Commission announced that it would delay its proposal to allow for additional consultation with member states. It is not clear whether this will affect the proposed timetable for implementation and compliance. Recent stakeholder discussions with the EC indicate that the Commission may consider an introductory period of voluntary participation 2005-2007 with a clear commitment to mandatory implementation from 2008 onwards.

Model projections provide a starting point for thinking about possible prices under an EU trading system. The POLES[28] and PRIMES models project prices of EUR 49 and 33 under EU-only trading scenarios for 2010. Even if the programme were to remain

[28] See IPTS (2000) and Capros and Mantzos (2000).

mandatory, there are several reasons to expect prices during 2005-7 to be lower. First, there is the possibility that emissions market models generally tend to overestimate prices. In addition, emissions targets during the years prior to the Kyoto compliance period are likely to be less restrictive than during 2005-7. Consequently, permit supply will be greater and price lower than the prices cited above. Finally, Europe is likely to take advantage of international trading mechanisms that will reduce compliance costs. Already the Netherlands has participated in international trading. Denmark and the European Commission have both issued tenders to develop international project-based crediting procedures and programmes.

If the Commission does, in fact, make the scheme voluntary rather than mandatory, prices would be even lower. The EU trading programme during 2005-7 would operate in much the same as we predict the UK system will first operate, with participation mainly by sources that anticipate their compliance costs will be low. This will lead to abundant permit supply and low prices. Since this scenario now appears most likely, we predict that prices during 2005-7 will be below EUR 10 per ton CO2e. Similarly, the proposal that governments be allowed to grant extra permits to sources under some circumstances suggests that prices will remain low, or that if they rise excessively, governments will act to reduce them.

If national emissions markets remain fragmented either because the proposed EU trading system fails to materialize or because international negotiators are unable to agree details of the Kyoto Protocol, prices will remain different in each national market according to their individual circumstances. In general, we would expect prices to rise in the UK and Denmark relative to the present since emission targets in those years would likely be more stringent than those now in effect. However, to counterbalance this effect, transaction costs will probably decline as participants gain experience, and finalized rules for international projects might allow for creation of additional cheap permit supply. Thus, under continuing fragmentation we would not expect prices to rise markedly above the levels projected for 2000-4.

6.3 2008 to 2012

Model projections again provide a starting point for our predictions of GHG prices during the Kyoto compliance period. Of the three broadly defined scenarios described in Section 2, the most probable outcome appears to be somewhere between full international trading and Annex I only trading. At the recent Bonn negotiations, Parties implicitly rejected quantitative limits on use of the international flexibility mechanisms, which means that Parties are free to engage in full international trading, assuming necessary trading rules can be agreed. Nevertheless, some countries may voluntary decide to limit their use of the mechanisms. To the extent that this occurs, demand and prices will rise in those countries' domestic market and fall in the international market. We expect that few countries will pursue this approach to any great extent, since it would amount to a unilateral inflation of their sources' compliance costs. Thus, model projections of the mostly likely current scenario probably lie somewhere between the approximate consensus prices for Annex I trading (~EUR 20) and for international trading (~EUR 10).

In light of the analyses presented in Sections 3, 4, and 5, we predict that actual prices will probably be lower. Of the points raised in those sections, the US' absence from the international market appears to be one of the most significant reasons for this expectation. As was mentioned previously, some model projections indicate that the US' absence would reduce prices by as much as two thirds. Even under the optimistic scenarios for the US' re-engagement in the Kyoto process, demand would be less than that assumed in most model projections. On the other hand, other variables such as limited sectoral coverage or inefficient market design would result in higher than projected prices. Without knowing the relative impact of the variables discussed in Section 3, it is impossible to know whether upward and downward price pressures will predominate. In the case of the most mature emissions market to-date, various modelling shortcomings led overall to an overestimation of prices. Some similarities between SO2 and GHG market models lead us to believe that the latter too may well overestimate prices. Expectation errors, irreversibility, and political pressure to abate rather than trade may all result in lower than projected GHG prices. Finally, Section 5's consideration of the pre-compliance GHG market shows that current prices are at the low end of projections. Although probable differences between the pre-compliance market and that which will exist during 2008-12 give reason to believe that current prices are discounted, other market dynamics may well offset downward pressures to maintain future prices at roughly their current level. Considering all these factors, we conclude that prices during 2008-12 will remain below EUR 10.

Prices could rise above this level if the United States either decides to rejoin the Kyoto Protocol process or if it develops a domestic emissions trading system that creates additional demand for permits. If emissions permits markets turn out to be highly inefficient or are heavily regulated, prices may also turn out higher.

6.4 Conclusions

For the reasons outlined above, we predict that prices will remain on the low end of most projections throughout 2000-2012. In the early years transactions costs and inefficiencies will be greatest. But the voluntary nature of early trading programmes and the relative permissiveness of emissions targets in programmes' early years will keep prices low. As emissions targets grow tighter, potentially pushing prices higher, markets should begin to operate more efficiently across jurisdictions, thus preventing any major price rise.

7. Conclusions

More than just a topic of academic interest, GHG emissions permit price expectations already play an important role in influencing current decisions taken by policymakers and potential emissions market participants. To date, GHG price expectations have been based to a considerable extent on a cursory understanding of model-generated price projections. Though such projections are undoubtedly useful as a starting point for formulating expectations about absolute price levels and about the relative price impacts of different policy choices, this paper has demonstrated that those projections should be regarded with some scepticism. Rather than relying on model projections alone, decision-makers would be wise to consider additional sources of information that may shed light on how GHG markets will behave in coming years.

This paper examines several of these other information sources in an attempt to refine expectations of future GHG prices. First, the paper draws on several GHG market model surveys to summarize what emissions market models have predicted to date about GHG prices and to clarify the way in which these predictions were formulated. This summary reveals that under the most likely of the broad policy scenarios modelled, consensus price predictions are in the range of EUR 5 to 20 per ton of CO2e, a level lower than some of the more alarmist price projections that have contributed in some places to a vague sense that taking meaningful action against climate change will be exceedingly costly.

After reviewing model projections, the paper considers a number of policy variables that are reflected in few or none of existing model projections, but which nevertheless may have important impacts on GHG prices. Omission of these variables resulted in part from the need to avoid excessive complication of econometric emissions market models. In addition, few analysts have yet had the opportunity to integrate policy decisions taken at recent treaty negotiations into their modelling efforts. Several of the variables discussed in Section 3 give reason to believe that the current price projections under-estimate future prices. For example, if emissions limitations and trading rights apply only to a narrow set of sectors, prices may rise above current projections, which assume broad coverage. Likewise inefficient market structures, a liquidity-reducing compliance reserve, and failure to achieve compatibility across national emissions markets could push prices higher than projections. On the other hand, several other policy outcomes could result in lower than projected prices. For example, the US' absence from the international GHG market, broader coverage of gases, and generous crediting for sinks projects may well produce lower-than-projected prices. The net effect of these variables opposing factors will depend on the unknown relative impact of each variable.

Modellers of what has become the worlds' most mature and best-known emissions permit market, the SO2 allowance programme, faced a set of uncertainties similar though smaller than that faced by modelers of future GHG markets. Section 4 of this paper notes that in the case of SO2, the net effect of the models' assumptions to address these uncertainties was over-estimation of actual prices observed since the mid-1990s. The paper then examines some of the factors that led to this overestimation and reveals that several of these including expectation errors, irreversibility, and political pressure to abate may apply also to the case of GHG projections, giving reason to expect that they too may over-estimate actual prices.

Reduced price expectations are consistent with actual prices currently observed in the pre-compliance market for GHG emissions reductions. Though demand is limited by the lack of binding emissions limitations and by uncertainty about the utility of the VERs most commonly exchanged, supply too may be presently limited by the lack of clear crediting rules and high transaction costs. Once governments have established legislated emissions markets, supply and demand may both increase leading to greater trading volumes at prices near today's levels.

Our consideration of the preceding analyses leads us to project that during 2000 to 2004 markets will remain fragmented with prices generally in the range of EUR 5 per ton, with some premium placed on government-issued permits as compared to privately-defined VERs. Interest in the latter is likely to wane as the creation of more legislated emissions trading programmes offer more opportunities to acquire permits, which are expected to be a superior risk-hedging instrument for sources who anticipate imposition of a binding emissions restriction. 2005-7 may see the introduction of an EU-wide GHG trading system. If, as now seems most likely, this trading programme turns out to be voluntary rather than mandatory, prices will probably be below EUR 10 per ton CO2e. Assuming that implementation of the Kyoto Protocol proceeds according to its current schedule, 2008-12 will be the first period in which industrialized countries are obligated to reduce their national GHG emissions in line with individual national targets. Considering the consensus projections of emissions market models and the predominance of factors suggesting that these projections over-estimate prices, we conclude that for 2008-12 prices will remain below EUR 10.

While these figures constitute our best estimate of absolute GHG price levels during 2000-12, the inherent difficult of forecasting makes our projections as likely to be inaccurate as the projections of any other regulatory analyst -- or weatherman, for that matter. But whether the various uncertainties surrounding the GHG market eventually result in prices that are lower or higher than our predictions, the identification and examination in this paper of a broad set of indicators that shed some light on future GHG prices will contribute at least to a better understanding of the bases on which price expectations ought to be constructed.

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Appendix 1: GHG Models Surveyed

Acronym	Model Name	Reference
AIM	Asian-Pacific Integrated Model	Kainuma et al. (1999)
CERT	Carbon Emission Reduction Trade	Grütter et al. (2000)
ECN		Sijm et al. (2000)
EPPA	Emissions Projections and Policy Analysis Model	Ellerman et al. (1998), Ellerman and Wing (2000)
FUND	Climate Framework for Uncertainty, Negotiation and Distribution	Tol (1999)
G-Cubed	Global General Equilibrium Growth Model	McKibbin et al. (1999a, 1999b)
GEM-E3	General Equilibrium Model for Energy, Economy, and Environment Interactions	Capros et al. (1997), Capros (1999)
GRAPE	Global Relationship Assessment to Protect Environment	Kurosawa et al. (1999)
GREEN	General Equilibrium Environmental Model for Assessing the Economic Impacts of Limiting Carbon Emissions	Burniaux (1998), van der Mensbrugghe (1998)
GTEM	Global Trade and Environment	Tulpule et al. (1999)
IGSM	Integrated Global System Model	Reilly et al. (1999)
MARKAL		Kanudia and Loulou (1998), Gielen and Kram (2000)
MERGE	Model for Evaluating the Regional and Global Effects of Greenhouse Gas Reductions Policies	Manne and Richels (1999, 2000)
MS-MRT	Multi-Sector, Multi-Region General Equilibrium Trade Model	Bernstein et al (1999a, 1999b)
Oxford	Oxford Economic Forecasting Model	Cooper et al. (1999)
POLES		Criqui and Viguier (2000)
RICE	Regional Integrated Climate and Economy Model	Nordhaus and Boyer (1999)
Rose		Rose and Stevens (1993, 2001)
SGM	Second Generation Model	MacCracken et al. (1999)
WAGE	World Applied General Equilibrium Model	Kemfert (2000)
WorldScan		Bollen et al. (1999)
ZEW		Bohringer (2000)
Zhang		Zhang (2000)

Source: Adapted from Springer (2001).