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# Estimating the price of tradable permits for greenhouse gas emissions in 2008–12

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**Abstract**

Many attempts have been made recently to predict the prices of tradable permits for greenhouse gas (GHG) emissions in the first commitment period of the Kyoto Protocol (2008–12). In this paper, we attempt to refine these price estimates based on (i) the results of economic models and identification of factors which influence prices but are not fully reflected in the models, (ii) lessons from price forecasting experience in the US sulfur dioxide market, and (iii) current price data from the nascent international market for GHG permits. We expect GHG permit prices to be at the lower end of the broad spectrum of existing predictions. This implies, among other things, that resource transfers to developing countries associated with emissions trading will be relatively low. Nevertheless, even a modest price will have a significant influence on the decisions of consumers and investors in energy markets around the world.


*Keywords:* Kyoto Protocol; Tradable permits; Permit price

## 1. Introduction

As domestic greenhouse gas (GHG) emissions trading systems are planned and implemented across Europe (Ellerman, 2000; Missfeldt and Requate, 2001) in preparation for possible entry into force of the Kyoto Protocol, interest in the *emerging international market* for GHG emission permits is rising. Expectations about future GHG permit[1] prices already influence current decision making. For example, sources likely to be affected by GHG regulations compare possible future GHG permit prices to their internal cost of abatement in order to determine whether they will be buyers or sellers in the market and to plan their operations accordingly. Entrepreneurs determine whether anticipated revenue from sales of GHG reductions would justify investment in new emissions-reducing projects.

Yet despite an already large and growing demand for information upon which to formulate reasonable price expectations, little reliable information is available. Numerous models simulate a global market for carbon dioxide ($CO_2$) or GHG emission permits. However, these models offer only limited insight, since their price estimates *differ considerably*, ranging from 3 to 74 USD per ton $CO_2$ under one common policy scenario (Springer, 2002). Moreover, emissions market models' failure to accurately predict sulfur dioxide ($SO_2$) allowance prices in the relatively simple case of the United States Acid Rain Program justifies some skepticism about such models' chances of accurately predicting prices in the more complicated case of the international GHG market. In the absence of more reliable information on which to formulate GHG permit price expectations, many market watchers are forced to rely on mere intuition.

Our paper aims to fill this information gap through a refinement of GHG price expectations, drawing insights from several sources of information. We begin by summarizing results from a number of economic *models* that simulate international emissions trading (Section 2). We show which economic and political parameters are likely to impact demand and supply of permits and discuss the extent to which they are incorporated into existing models. Section 3 compares pre-implementation

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[1] For the sake of simplicity, we refer to all emission rights as "emission permits", whether they represent emission *credits* generated under the rules of Joint Implementation (JI) or the Clean Development Mechanism (CDM), *assigned amounts* held by countries, or *allowances* allocated to private entities under a national trading scheme.

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permit price predictions in the case of the US *sulfur dioxide allowance market* to actual prices over the past several years and discusses what insights this holds for GHG price predictions. We then review *actual price data* and other information from the emerging international GHG market (Section 4). Based on these analyses, we offer a 'best-guess' estimate of GHG permit prices in the first commitment period of the Kyoto Protocol (2008–12) (Section 5). In our judgment, most evidence suggests that prices will be *at the lower end* of the range found in the literature, probably below USD 10 per ton of carbon dioxide equivalent ($CO_2$e). Among other things, this implies that achieving the Kyoto Protocol's objectives will impose a fairly modest net cost relative to some early alarmist predictions, which indicated that the Protocol would cause enormous economic dislocation. In addition, low permit prices suggest that resource transfers to developing countries through investment in emissions-reducing projects may also be fairly small. Nevertheless, even a modest price will have a significant influence on the decisions of investors and consumers in energy markets around the world.

Table 1
Annex B trading under the 'original' Kyoto Protocol ($CO_2$ only)

| Model | Permit price (2000 USD/ t $CO_2$) | Quantity (million tons $CO_2$) | Trade volume (million 2000 USD) |
|---|---|---|---|
| AIM | 21 | 1467 | 30807 |
| ECN | 19 | — | — |
| ENEA | 18 | 660 | 11880 |
| EPPA | 44 | 1265 | 55660 |
| G-CUBED | 18 | 2017 | 36306 |
| GEM-E3 | 17 | — | — |
| GRAPE | 22 | 1283 | 28226 |
| GREEN | 18 | 1503 | 27054 |
| GTEM | 36 | — | — |
| MERGE | 74 | — | — |
| MS-MRT | 29 | 1852 | 53708 |
| OXFORD | 71 | 1074 | 76254 |
| POLES | 17 | 1467 | 24939 |
| RICE-98 | 18 | — | — |
| R&S | 3 | 950 | 2850 |
| WORLDSCAN | 6 | 2592 | 15552 |
| *Average* | 27 | 1466 | 33021 |

*Source:* Springer (2002).

## 2. Prices from emissions trading models

In the last three years, a number of modeling teams have addressed the issue of GHG emissions trading.[2] Without exception, they find that emissions trading significantly lowers the cost of reaching a Kyoto-like GHG emissions-reduction target. Yet, when it comes to predicting the absolute level of future GHG permit prices, the similarity ends. Table 1 shows prices of GHG emission permits found in different models that simulate an Annex B trading scenario.[3] Estimates of permit prices in 2010[4] range from USD 3 to 74 per ton of $CO_2$.

Two main factors explain the large differences between model results (Springer, 2002):

1. Business-as-usual emissions projections.
2. Model design features.

### 2.1. Business-as-usual emissions projections

Emission reduction commitments in the Kyoto Protocol are specified in absolute terms.[5] This implies that the level of emission abatement necessary to achieve compliance with the Protocol grows along with emissions growth. Hence, one of the main determinants of the model results is *projected emissions growth*, specified as the business-as-usual (BAU) scenario. These scenarios vary strongly across models. The EPPA model, for example, assumes a 19% increase in Annex B emissions from 1990 to 2010, which implies a 24% cut to achieve the Kyoto targets (Ellerman et al., 1998). Consequently, the resulting price for an Annex B trading scenario, USD 44, is at the high end of the spectrum. Capros (1999), on the other hand, only assumes a 5% increase of emissions in his BAU scenario. The resulting price prediction, USD 17, reflects the assumption that achieving compliance will require a smaller quantity of abatement than under the EPPA BAU scenario.

### 2.2. Model design

Naturally, a large number of technical questions have to be solved when modeling a system as complex as the international GHG market. We do not discuss modeling issues in detail here.[6] However, two issues, no-regret measures and multiple GHG, deserve mention.

*No-regret measures* (or negative-cost options) are measures for which benefits (i.e. energy cost savings) exceed costs. Common examples include the introduction of high-efficiency light bulbs, improved cooking

[2] See IPCC (2001), Morozova and Stuart (2001), Springer (2002), or Weyant and Hill (1999) for an overview and discussion of these models.

[3] Annex B of the Kyoto Protocol contains 38 industrial countries and countries with economies in transition.

[4] The year 2010 is taken to be representative of the Kyoto Protocol's first commitment period, which runs from 2008 to 12.

[5] Annex B of the Kyoto Protocol also contains the reduction commitments of each Party, expressed as a fraction of its carbon dioxide emissions in 1990. The European Union, for example, has an overall reduction commitment of 8% (92% of 1990 emissions).

[6] See Grubb et al. (1993) or Hourcade et al. (1996) for a description of different model types and a discussion of the main controversies in energy system modeling.

stoves, or building renovations. The assumed existence of no-regret measures has large implications for the supply side of an emissions trading market. If a large quantity of such measures exist,[7] emission reduction targets obviously become easier to achieve because some quantity of reductions can be achieved at no cost in every participating country.

Typically, energy system models, which follow a technology-based 'bottom-up' modeling approach, include no-regret measures and yield much lower cost and permit price estimates than other model types. For example, the Netherlands Energy Research Foundation (ECN) applied a version of the widely used MARKAL model to estimate permit prices, distinguishing cases with and without no-regret measures. For a global trading scenario, permit prices decrease from USD 8 to 3 if no-regret measures are included (Sijm et al., 2000). Computable general equilibrium (CGE) models like EPPA, on the other hand, do not include any measures at negative cost[8] and usually yield significantly higher prices than energy system models.

Another reason for the large differences between model results are divergent system boundaries. Most emissions trading models only consider emissions of $CO_2$, largely because the quality of data for emissions of *non-*$CO_2$ *GHG* (methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride) is poor. While this is an understandable practice in light of available information, these models systematically *overstate* costs and permit prices because the inclusion of non-$CO_2$ GHGs is thought to decrease overall compliance costs by making available significant additional low-cost abatement options.

### 2.3. The Kyoto Protocol without the United States

The models listed in Table 1 assume that all Annex B countries participate in emissions trading. However, President Bush announced in March 2001 that the United States would not ratify the Kyoto Protocol. As a result, Canada, Japan, and Russia became pivotal players in the negotiations because their refusal to ratify the agreement could make the Protocol's entry into force impossible.[9] The higher bargaining power of these countries vis-à-vis the European Union is reflected in the additional sink credits they were granted during the negotiations in Bonn and Marrakech to preserve their support for the Protocol. Canada, for example, is allowed to account for 12 megatons (Mt) of carbon per year from forest management activities, Japan may account for 13 Mt, and the Russian Federation for 33 Mt.[10] By contrast, the additional sink credits of all other Annex B countries amount to less than 2 Mt C annually (UNFCCC, 2001). These additional sink credits reduce the burden of achieving the Kyoto obligations significantly for Canada and Japan, and further increase the amount of 'hot air' for Russia.[11]

Several modeling teams have analyzed the effect of the US' withdrawal on global emissions and permit prices under the terms of the Bonn agreement (Böhringer, 2002a; Hagem and Holtsmark, 2001; Jakeman et al., 2001; Löschel and Zhang, 2002; Kemfert, 2001; Manne and Richels, 2001; Nordhaus, 2001). They find that the absence of the potentially largest buyer of permits reduces the permit price in 2010 to a value *close to zero*. However, this price results only under the assumptions that:

- the major sellers of permits, Russia and Ukraine, do not exert market power; and
- the 'game is over' after the first commitment period, i.e. surplus permits (including 'hot air') may not be banked to subsequent periods.

Table 2 shows permit prices for a scenario in which the remaining Annex B countries face monopolistic supply of permits from Russia and Eastern Europe. In that case, permit prices are higher than under competitive supply, ranging from 5 to 22 USD per ton $CO_2$e. Given the fact that accession to the EU is the main foreign policy goal of Eastern European countries, a very restrictive permit supply from those countries is rather unlikely, so that a cartel including only Russia and Ukraine is the most plausible scenario. Moreover, selling even fewer permits (than the revenue-maximizing amount for the first commitment period) and saving them for the second commitment period could be profitable for the cartel if targets are more restrictive and prices significantly higher in the second period.[12] Thus, under realistic assumptions, permit prices in the first commitment period are likely to be positive.

[7] For a comprehensive discussion of the existence and role of no-regret measures in climate policy, see Hourcade et al. (1996) and Sutherland (2000).

[8] CGE models usually assume that profitable measures are carried out anyway and hence include them in the BAU scenario.

[9] Entry into force of the Kyoto Protocol requires ratification of not less than 55 countries representing at least 55% of the total carbon dioxide emission of parties with emission targets in 1990 (Article 25). The US has the largest share of total carbon dioxide emissions in 1990 (36.1%), followed by the EU (26.9%), the Russian Federation (17.4%), and Japan (8.5%).

[10] 33 megatons carbon correspond to 121 megatons carbon dioxide. This is more than the total annual $CO_2$ emissions of Belgium (in 1990).

[11] Along with the decline of industrial production, GHG emissions in Russia and other Eastern European states have decreased sharply since 1990. Most forecasts predict emissions in those states to remain below their assigned amounts during the first commitment period. The gap between assigned amounts and emissions is called 'hot air', since it is not the result of any purposeful policy measures to reduce GHG emissions.

[12] See Manne and Richels (2001) and Bernard et al. (2002) for a—necessarily speculative—exploration of intertemporal permit banking.

Table 2
Annex B trading (without the US) with monopolistic supply

| Model | Permit price (2000 USD/ t $CO_2$e) | Share of 'hot air' sold (%) | Trading | Sinks |
|---|---|---|---|---|
| *Cartel: Russia, Ukraine, and Eastern Europe* | | | | |
| MACGEM | 22 | 17 | World wide | None |
| PACE | 17 | 40 | Annex B | B |
| POLES | 19 | 36 | Annex B | B, M |
| POLES&ASPEN | 5 | 10 | World wide | B, M |
| WORLDSCAN[a] | 5 | 60 | World wide | B, M |
| *Cartel: Russia and Ukraine* | | | | |
| EPPA[b] | 7 | 50 | Annex B | B, M |
| GTEM[b] | 12 | 55 | World wide | B |
| POLES | 11 | 34 | Annex B | B, M |

*Source:* Springer (2002)
Sinks: Bonn (B), Marrakesh (M)
[a] Includes hot air from Kazakhstan (Scenario A1B).
[b] Include non-carbon GHG.

### 2.4. Additional factors

Several factors that may influence GHG permit prices are not reflected in market models. Below we identify some of the most important additional factors and discuss the nature of their possible influence on prices.

*Additional factors that could raise prices*

- In practice, emissions market participants will face *transaction costs* such as emissions monitoring and verification expenditures and fees for lawyers and brokers to assist with transactions. Onerous or complicated trading rules and failure to harmonize national trading systems will increase such costs.
- Because emissions trading is not well suited to some sectors of the economy with numerous small sources, such as housing and transport, emissions reduction opportunities will have to be captured by other, potentially less-efficient policies. To the extent that some of these opportunities are *not covered* by an emissions trading regime or not captured by non-trading policy measures, those sectors that *are* covered by emissions trading will have to shoulder a greater share of countries' national emissions reduction targets, which will raise abatement costs and permit prices.
- The *compliance reserve* that aims to prevent countries from overselling may *temporarily* restrict transactions and is expected to reduce market liquidity. However, the magnitude of the efficiency loss due to the reserve is likely to be rather small (Baron, 2001).

*Additional factors that may decrease prices*

- Calculations of likely permit prices in any one time period overlook the possibility of capturing cost savings by *banking* unused permits from one time period to another. Most proposed emissions trading programs would allow for some form of banking. In this sense, *intra-period* banking could exert downward price pressure. (As noted above, *inter-period* banking is likely to raise permit prices.)
- Penalty charges act as a ceiling on permit prices. If the market permit price were to rise above the level of the per-unit penalty, sources would choose to pay the penalty rather than acquire permits. Generally, less stringent *sanctions* for non-compliance imply lower permit prices.
- In the presence of transaction costs, the *allocation* of permits to industrial sectors is not only a matter of equity, but also of efficiency (Stavins 1995). In other words, permit prices are not independent of the allocation method. In a simulation of an emissions trading scheme for the European power sector, Böhringer (2002b) finds that prices and total compliance costs are *lower* if permits are *auctioned* rather than given away for free (grandfathering).[13]
- Although a *quantified* "supplementarity" rule was rejected by negotiators in Bonn, Parties agreed that "the use of the mechanisms shall be supplemental to domestic action and that domestic action shall thus constitute a significant element of the effort made by each Party" (UNFCCC, 2001). How individual countries will interpret this clause remains to be seen. If the EU, for example, should pursue a strict interpretation and buy only small amounts of permits from other countries, EU-internal prices would rise and *international* prices fall.

Naturally, the net effect of the factors described above depends on the relative individual impact of each. Though these are not known, we are inclined to believe that the significance of the US' absence from the market and the inclusion of a large supply of low-cost credits for sinks justify the expectation that actual prices will be on the low end of those found in emissions trading models. Past experience with modeling emissions permit markets gives further support for this expectation.

## 3. Lessons from the $SO_2$ allowance market

Modelers of what has become the worlds' most mature and best-known emissions trading program, the US $SO_2$ allowance program, faced a set of uncertainties similar though smaller than that faced by modelers of future GHG markets. Various modeling

[13] This somewhat counter-intuitive result is due to the fact that grandfathering works as an implicit subsidy which lowers the relative prices of emission-intensive power production. This in turn creates higher demand and consequently increased energy generation and higher permit prices.

efforts prior to implementation of the program predicted that prices upon full implementation would be in the range of USD 389 to 1005 per ton $SO_2$ (Smith et al., 1998). Fig. 1 indicates that actual prices since 1994 have not exceeded USD 250 (Natsource, 2001).

### 3.1. Explanations for the overestimation of $SO_2$ allowance prices

Ex-post analyses reveal several factors that led to this overestimation of prices. Railroad deregulation 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 (Ellerman and Montero, 1998). 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 $SO_2$ allowances.

Scrubbers, one of the main technical compliance options available to sources affected by the $SO_2$ program, are both capital-intensive and can take up to 3 years to become operational once the decision to install them has been made. Sources facing a choice of whether to comply by abatement or by allowance purchases focused not so much on present allowance prices, but rather on *expected* allowance prices at the time installed scrubbers would be operational. 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 cost of operating and maintaining the scrubbers is 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 and depressed demand for allowances.

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.

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 plant 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 (Morel et al., 2000). This creates an incentive for early over-compliance, which reduces allowance demand.

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 $SO_2$, scrubbing has turned

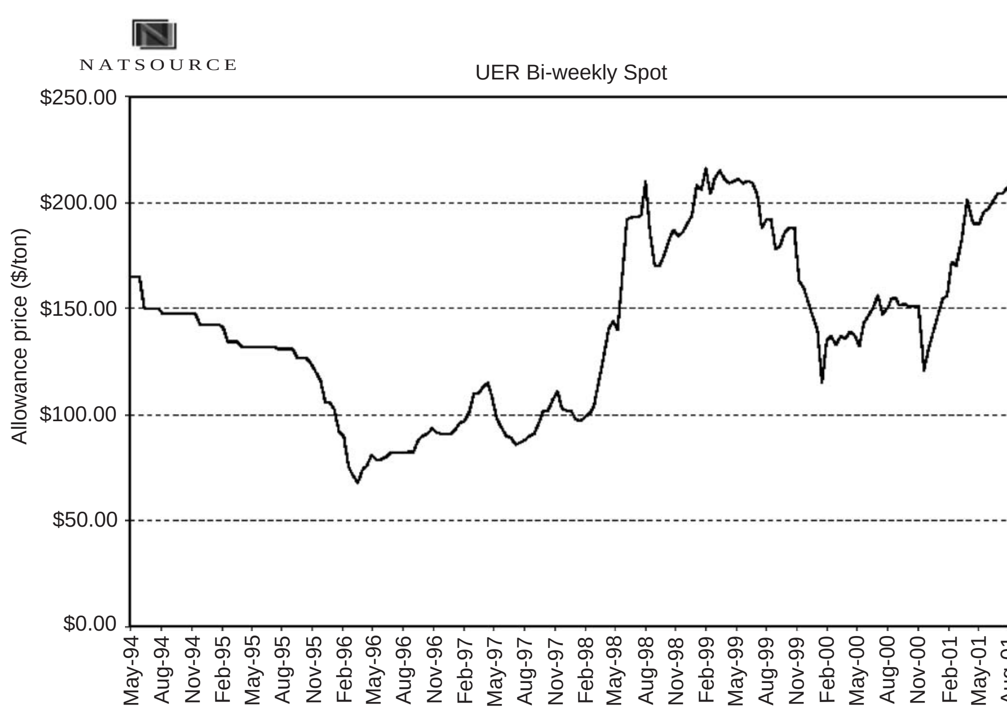


Fig. 1. Historical $SO_2$ allowance prices.

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.

In a sense, some of the factors described above are unique to the case of $SO_2$ allowances. However, we believe that some interesting lessons can be learned from examining the similarities and differences between the $SO_2$ market and the future GHG market.

### 3.2. National vs. international markets

First of all, it is important to note that the Kyoto Protocol establishes the framework for an *international* market for tradable GHG permits. It contains rules regarding the exchange of emission rights between sovereign countries. Whether and to what extent private companies may trade emission permits depends on the national implementation of climate policy. As Hahn and Stavins (1999) note, the Kyoto Protocol leaves the Parties full sovereignty in their choice of policy instruments, and it is unlikely that all governments will choose tradable permits as their sole instrument of national climate policy. The $SO_2$ market, on the other hand, is a *national* market in which large emitters of sulfur dioxide trade allowances. Its rules are clearly defined and enforced by a national authority. In contrast, the participants of the international GHG market can change the rules themselves, and sanctions for non-compliance are weak, both of which imply that prices are unlikely to rise to very high levels.

Generally speaking, participants in the $SO_2$ market trade allowances to minimize compliance costs.[14] In the market for GHG emission permits, on the other hand, economic *and* political motives (such as EU accession) are likely to determine the magnitude and price of transactions.

### 3.3. Fuel switching

One of the most important reasons that $SO_2$ allowance prices were far lower than expected was the substantial amount of *fuel switching* to low-sulfur PRB coals. In the case of GHG, the most likely analogy is fuel switching from coal to natural gas. *Natural gas* is the second-fastest growing fuel worldwide after (non-hydro) renewables and will be the fuel of choice for most new power plants installed in the coming years (IEA, 2002). Natural-gas-fired plants emit less $CO_2$ and local air pollutants than coal and oil-fired units.

In the US, the supply curve for low-sulfur coals has been quite elastic, so that substantial $SO_2$ abatement could be achieved at relatively low additional cost. Can we expect a similar market penetration of natural gas worldwide as a result of climate policy?

The World Energy Outlook 2001 predicts the share of natural gas in world primary energy demand to rise from currently 22% to 26% by 2020 (OECD/IEA, 2001). According to this forecast, increased demand can be met *at stable natural gas prices* until 2010 in most regions except for the United States, where known reserves are very small.[15] Europe imports half of its natural gas consumption from Russia and Algeria. Russian reserves hold more than enough gas to meet the growing demand in Europe, but it is uncertain whether the necessary investments will be made given the uncertainties regarding its economic and political environment. Furthermore, political resistance against a higher dependence on Russia may also limit the growth of gas in Europe.

On the other hand, the liberalization of gas markets is likely to exert downward pressure on gas prices, thereby stimulating demand. Australia and Canada are net-exporters of natural gas. In both countries, a significant shift to gas is therefore possible. Japan, on the other hand, does not possess any indigenous reserves and must cover its consumption by importing liquefied natural gas which limits the scope for expanded use of natural gas.

Hence, large-scale substitution of coal by natural gas could take place in some Annex B countries (Australia and Canada). Such a scenario is more uncertain in Europe and rather unlikely in Japan. Importantly, even if a major shift to gas will take place, its effects on GHG permit prices will not be comparable to the effect fuel switching had on $SO_2$ allowance prices, since the number of sectors and countries affected by climate policy is much larger than for air pollution control. Consequently, a single technological break-through or political event would affect only a fraction of affected sources and can thus be expected to have a smaller effect on permits prices. At a minimum, however, it seems safe to say that at least one type of uncertain yet still probable development, that of cost-saving *technological progress*, will exert downward price pressure over time. Whether countervailing developments offset this influence remains to be seen.

In the case of $SO_2$, overestimation of future prices led to excessive early abatement and low actual prices. Anecdotal evidence from the GHG market's early days suggests that price expectations were similarly inflated. More recent evidence, though, seems to indicate that price expectations are on the lower end of the price range predicted by market models. For example, a

[14] As mentioned above, political pressure *not* to trade seems to have played a role in the $SO_2$ market as well.

[15] Recent calculations by Siddiqi (2002) show that the ratio of natural gas reserves to total energy consumption is less than 3 years for the United States.

survey of 35 firms likely to participate in the GHG market found that most expect prices around 10 USD per ton $CO_2$e during the first Kyoto compliance period (Natsource, 2002). As expected prices fall, so too does the likelihood of significant over-compliance. However, even these lower price expectations exceed actual prices observed so far in the emerging GHG market, which we discuss in the following section.

## 4. Current prices in the emerging GHG permit market

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 types of GHG related commodities, and the features of these trades provide some insight into the nature of a future compliance-based GHG market.

### 4.1. What is traded?

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, 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 programs. Less commonly, participants trade *Emissions Reductions* (ERs), which have not been verified by 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. However, because trades in these legislated domestic markets involve only pre-2008 vintages, we focus our analysis on VER trades, many of which involve reductions to be carried out during the first Kyoto compliance period, which is the focus of this paper.

### 4.2. Current prices

To some extent, different prices paid in the GHG market to-date can be attributed to different features of the permits 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 permits procured were in many ways similar in character to those exchanged in company-to-company transactions at much lower prices.

Table 3 shows GHG permit price ranges in nominal USD differentiated by permit type and vintage for market activity since 1996–97. VERs as a group have traded between about 0.60 and 5 USD per ton $CO_2$e. Prices are segmented by vintage and location mainly because of expectations about future crediting rules. In particular, reductions in Annex B countries undertaken after the base year for Kyoto commitments (1990) and before the first commitment period (2008–12), 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

Table 3
Prices for currently traded emission permits

| Permit type | Vintage year | Permit price (USD/ t $CO_2$e) |
|---|---|---|
| Verified emission reductions | | |
| Annex B VERs | 1991–2007 | 0.60 – 1.50 |
| Annex B VERs | 2008–2012 | 1.65 – 3.00 |
| CDM VERs | 2000–2001 | 1.15 – 4.83 |
| Emission reductions | | |
| ERs | 1996–2012 | 1.00 – 2.70 |

*Source:* Natsource (prices updated September 25, 2002).

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.

### 4.3. What do current market prices tell us about the future?

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. Nevertheless, these prices represent the first concrete evidence about future GHG reduction valuations.

Analytically, pre-compliance trading can be divided into voluntary and early trading activity. *Voluntary trading* is driven by buyers that engage in the GHG permit market to demonstrate leadership, comply with voluntary commitments, or influence public policy by showing the practicability of emissions trading (Rosenzweig et al., 2002). Prices of such transactions are only weakly related to future prices of GHG permits, since they are not driven by mandatory targets. Most buyers would likely curtail their purchases if the cost of acquiring reductions were considerably higher than it is now, which implies that there exists a de-facto price ceiling for voluntary trades.

A number of market participants acquire permits which they expect to be valid for compliance with future mandatory emission targets. One of the main motives for such *early trades* is to hedge risk. Prices of these trades contain some information about future prices, since the permits traded could potentially be valid in the first Kyoto commitment period. However, 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 have a lower willingness to pay for pre-compliance permits. 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 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*.

Furthermore, the *amount* of trading so far is much smaller than the volume of international trade predicted for 2010. The World Bank estimates that approximately 150 million tons of $CO_2$e have been exchanged since the market's first trades in 1996–97 (PCF, 2002).[16] In contrast, the market volume in the first commitment period is estimated to be approximately 700 million tons $CO_2$e *annually* (Löschel and Zhang, 2002). Hence, to date were emission reductions traded most likely a product of low-cost or no-regret (i.e. negative-cost) measures, i.e. abatement projects realized at low or even negative cost. In fact, the majority of reductions traded since 1996 has been generated by landfill-gas capture, energy efficiency and fuel switching, and carbon sequestration (Rosenzweig et al., 2002; PCF, 2002). Since the potential of such low-cost measures is fairly limited (except for sequestration), the prices of voluntary transactions cannot offer much guidance regarding

[16] This estimate includes extra-regulatory trades and those within the Danish and UK domestic markets. It excludes trades of less than approximately 1000 tons as well as trades within internal corporate trading systems (such as those operated by BP and Shell).

the cost of *large-scale* GHG abatement. However, the Kyoto Protocol after Marrakesh does not require significant cuts of GHG emissions (see Section 2), which implies that current prices may not be very far from the level of future prices.

## 5. Summary and conclusions

The prices found in emissions trading models provide a useful starting point for our analysis of GHG permit prices during the first Kyoto commitment period. A large number of research teams have modeled emissions trading under the 'original Kyoto commitments', using data on $CO_2$ emissions. Prices from those models range from USD 3 to 74 for Annex B trading. Differences among model results are mostly due to divergent emissions growth projections and different modeling approaches. Several factors addressed by a minority of models, such as non-$CO_2$ GHG, US rejection of the Kyoto Protocol, and the potentially monopolistic behavior of large permit sellers, suggest that actual prices will be lower than those found in earlier studies, but well above zero.

*Additional factors* not fully reflected in models provide further insight into possible future prices. Those factors that suggest prices will be higher than predicted by models include transaction costs, limited sectoral coverage of emissions trading systems, and the exercise of market power by large permit sellers. On the other hand, permit banking may prevent excessive price rises and fluctuations. Also, auctioning of permits would lead to lower permit prices than grandfathering. Experience and experiments have shown that agents in emissions trading markets neither posses perfect foresight nor always behave rationally, contrary to the assumptions of most models. Unexpected political and economic developments, irreversibility of investments and political pressure to abate rather than trade caused prices in the US $SO_2$ market to deviate strongly from their predicted levels. Similar forces may operate in the case of GHG, giving further justification for the expectation that actual prices will be on the low end of the range predicted by models. However, fuel switching is unlikely to affect permit prices as strongly as it did in the US market for sulfur dioxide allowances.

*Pre-compliance trading* in the nascent GHG market has occurred at the extreme low range of predicted prices. Although the voluntary nature of a large segment of current trading and uncertainty about whether VERs will be recognized under formal crediting rules give reason to believe that current prices are discounted, the weakened Kyoto targets and market dynamics may prevent prices from rising far above their current level.

In light of the analyses presented in the preceding sections of this paper, we predict that permit prices for tradable GHG emission permits will be *below USD 10* per ton of $CO_2$ in 2010. 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. The *law of one price* will probably not apply to GHG permits. Permit prices are likely to be differentiated according to their origin as a result of concerns about the environmental integrity or social effects of the projects that generated them. Stricter policies in a country or region as well as voluntary restrictions on the use of the Kyoto mechanism could raise permit prices in a country or region above the world market price as well.

Low permit prices imply that the aggregate cost of achieving the Kyoto Protocol's objectives (at least during the first commitment period) will be relatively modest relative to some early alarmist predictions. *Resource transfers* from industrial countries to developing countries associated with international emissions trading have been estimated to be around 10 billion USD annually for the 'original' Kyoto targets (Baron, 1999; Ellerman et al., 1998).[17] Our lower price estimate implies that these transfers are likely to be significantly *smaller*. In general, a lower price need not imply that revenues must shrink, as the price decrease could be compensated by an increase of the quantity traded. However, this is not the case here. Future demand for permits has decreased sharply as a result of the withdrawal of the largest potential buyer, the United States. Remaining demand can be met in large measure by existing supply from low-cost emissions reduction opportunities within Annex B and by permits generated through sink enhancement.

Both project level calculations (PCF, 2001) as well as simulations for entire countries (Mathy et al., 2001) show that even at a modest GHG price, a large number of projects and measures would be raised above the threshold at which benefits exceed risk-adjusted costs, so that private entities find it profitable to save energy, reduce emissions or capture greenhouse gases that would otherwise escape. Relative to today's effective price of almost zero, the existence of even a low GHG price in the future will contribute to a more accurate economic measure of the full environmental impacts of GHG-emitting activities.

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[17] Note that Baron (1999) considers these estimates based on economic models as improbable.

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