REPORT

Managing Cost Variability in Emission Allowance Markets

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B1805
October 2008

This report approved
2009-08-31

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Organization	**Report Summary**
IVL Swedish Environmental Research Institute Ltd.	**Project title**
Address P.O. Box 21060 SE-100 31 Stockholm	**Project sponsor**
Telephone +46 (0)8-598 563 00	The authors gratefully acknowledge financial support from Elforsk and the Mistra foundation (Clipore programme).

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Title and subtitle of the report

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Keyword

Emissions trading, safety valve, cost variability, uncertainty, cliamte change

Bibliographic data

IVL Report 1805

The report can be ordered via

Homepage: www.ivl.se, e-mail: publicationservice@ivl.se, fax+46 (0)8-598 563 90, or via IVL, P.O. Box 21060, SE-100 31 Stockholm Sweden

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1 Introduction

Market based approaches to reducing emissions are becoming increasingly popular with environmental regulators across the globe. The most visible example is emissions cap and trade, which is the centrepiece of the EU climate policy. An emissions cap-and-trade approach combines flexibility in the way that firms must comply with environmental regulation with incentives for achieving an environmental goal. In contrast, under a command-and-control approach, firms are typically required to meet a particular emission rate standard or absolute limit, or to use a particular type of pollution control equipment. With cap and trade, firms have flexibility in how they control emissions and the extent they do so as long as they have sufficient emissions allowances to cover their emissions. The expected market price for emissions allowances will provide incentives to facility owners regarding how to structure operations and investments to limit emissions and how much to use allowances to meet their compliance obligation. The expected effect of emissions trading is that it will identify low-cost ways to reduce emissions and reduce costs overall. If the market price of emissions allowances is reflected in retail prices of energy it also provides an incentive for consumers to adjust their energy consumption and to make investments in end use efficiency.

The electricity industry is a cornerstone of the EU's Emissions Trading System and it would be for any emissions trading system in the US as well. In both the EU and the US, the electricity industry faces concurrent challenges with respect to environmental policy reform including the emergence of climate policy, and market reform and increasing liberalization of electricity markets. Wholesale and retail prices increasingly reflect short-run scarcity of fuel and other inputs to electricity generation. Under newly formed emission-trading programs, emissions allowances are one such input and so the variability in the price of emissions allowances potentially introduces a new source of cost and price variability into electricity markets. Price variability is inherently unpopular among consumers and may impose costs on the general economy. An emerging question in the implementation of emissions trading programs is whether variability in allowance prices may tend to amplify variability in retail prices of electricity and potentially other products, and thereby erode its other cost advantages.

Recent research including work sponsored by Elforsk indicates the introduction of a new market for emissions allowances is likely to amplify the natural variability in electricity prices. Bunn and Fezzi (2007) use time series econometric methods to estimate the relationship among electricity, natural gas and CO_2 allowance prices in the UK, and Fell (2008) conducts a similar analysis for the Nordic electric market. These studies find electricity prices respond positively to a change in the price of emissions allowances. Simulation modelling indicates that higher allowance prices would lead to more gas-fired electricity generation, which has greater price variability than coal (Sijm et al. 2007; Burtraw et al. 2001). Although natural gas has a relatively minor role in the Nordic electricity market, it has a large role in the UK and the US and it is likely to remain the marginal fuel in most electricity markets.

The issue of managing costs in an emissions-trading program has short-run and long-run dimensions. Short-run disruptions in fuel supply due to natural or geo-political events can cause price fluctuations in fuel markets that have negative consequences on the economy, so in the short run policy makers might want to ameliorate these price fluctuations. Another concern has to do with cost management in the long run, where the issue has often played a role as a political proxy for the level of economic commitment to climate policy.

Several proposals have been circulated to address both the short-run and long-run aspects of price variability in emissions markets. Some of the approaches suggested to promote price stability include creating a role for offsets. Others have proposed that strategic investments can help manage allowance costs. Such investments might include subsidies for new non-emitting energy technologies and subsidies for improved efficiency in the end-use of electricity. Others have proposed that strategic investments can help manage allowance costs. Such investments might include subsidies for new non-emitting energy technologies and subsidies for improved efficiency in the end-use of electricity. It is generally recognized that a good feature in designing an allowance trading program is the use of banking (and borrowing) and long budget periods. Another suggestion is to rely solely on the private sector to provide financial services that stabilize the price – at a cost to those who require such service. In the US the idea of a cost management board that would have authority to respond to price fluctuations by managing the supply of allowances has been proposed. Each of these proposals may have the effect of lowering allowance prices and reducing the change or variability in electricity prices, although they also may impose additional costs to the public associated with funding for subsidies. Of course, the ultimate cost management tool is an emissions tax because the cost of the tax is predetermined and not subject to vacillations of an allowance market. We develop another idea, which is symmetric cost management within an emissions-trading program, in some detail. This approach would place a "collar" on prices by combining a high-side price safety valve with a price floor.

The next section of this paper provides a brief overview of the different potential approaches for managing costs, and the following section develops the idea of symmetric cost management at length. It is important to recognize in evaluating the proposals for cost management that some are aimed primarily at reducing cost volatility, while others are aimed primarily at reducing cost. The conclusion that we reach is that cost management can contribute to good design in environmental markets, at least, from a conceptual perspective. However, the tools of cost management are also available to be captured by parties who want to use cost management as a Trojan Horse, that is, as a way to strictly constrain costs and emissions reductions below what they otherwise would be expected to be given the identification of emissions reduction targets. To some degree, this gamesmanship may be an inherent part of the political process. However, it also can undermine the integrity of the market and can erode public confidence in the creation of environmental markets. That would be unfortunate, because environmental markets are emerging to play an important role in reducing the cost of environmental protection and thereby enabling even greater levels of environmental improvement in the future. We conclude that the only safeguard against such capture is a simple mechanism that is predictable and transparent. The idea of symmetric cost management is one such proposal.

2 Alternatives for Managing Costs in Emissions Trading Markets

Several alternative approaches have been put forth for managing costs in emission trading markets and we summarize the varied approaches below. The first two policy proposals we mention are often suggested as elements in an emissions-trading program because they serve to directly constrain costs. They do not directly mitigate price volatility, but they may do so indirectly. We then discuss four others that are aimed more directly at reducing price variability. In each case, to some degree, a given tool can accomplish both objectives.[1]

[1] Tatsutani and Pizer (2008) provide a workshop summary that discusses some of the proposals listed here.

Offsets: Offset credits typically are awarded for verifiable reductions in greenhouse gases achieved in sectors or from sources not otherwise covered by the cap-and-trade program. These may include soil and forest carbon sequestration or capturing fugitive methane emissions from sources within the regulated geographic region as well as for qualified projects in other countries. If these types of emission reductions can be achieved as genuine emission reductions and if regulated entities are willing to invest in such options in lieu of making their own reductions, then offsets must necessarily reduce the expected cost of the program. Offsets also can help address short-term cost variability because if prices rise suddenly then it may be possible to expand the role of the offset market as an alternative means of compliance. For instance, the Regional Greenhouse Gas Initiative that introduces a mandatory cap for the power sector in ten Northeastern states in the US has a provision that automatically expands the limits on the use of offsets in response to the market price of emissions allowances.

Offsets have been controversial but in general they have support from environmental groups, at least up to some upper limit, as a way to develop markets and constituencies in developing countries as well as a way to reduce compliance costs. However, there is a concern that excessive reliance on offsets undermines the integrity of the program by eroding the incentive for investments in new infrastructure and new technology by domestic firms with a compliance responsibility. In addition, there is a persistent concern that offsets may not be *bona fide* emission reductions, and that a plethora of low-cost and low-quality emissions offsets could become available.

Investments: Technological change and improvements in end-use energy efficiency are expected to contribute importantly to efforts to reduce emissions. Dramatic technical change is expected in the long run, but allowance price variability and associated effects on energy prices pose a near term challenge, especially if consumers have limited options for responding to these price increases in the short run. Some technological measures—potentially funded by allowance or permit sales under a cap-and-trade regime—could play a role in reducing the cost impact of emissions reductions by effectively lowering the marginal cost of emissions reductions. Modelling of the opportunity for end-use efficiency in the electricity sector indicates that the reduction in demand can have an effect on equilibrium prices in electricity markets that largely offsets the increase in price associated with the introduction of emissions allowances (Ruth et al. 2008). This effect addresses the level of costs, but is less likely to address the variability of costs.

Banking and Borrowing: Climate change is a long-term problem, and the short-term variability in emissions that might result from the ability of regulated entities to bank emissions allowances for use in the future has little environmental relevance. However, banking has two profound benefits from an economic standpoint. One is that banking allows the regulated industry to rationalize investments over time, providing the incentive to harvest low-hanging fruit in one case and postpone emissions reductions in another case so as to minimize the net present cost of investments. Second, the existence of an allowance bank provides a built-in reservoir of allowances that can be used to overcome short-run disruptions in the allowance market.

With banking, the allowance price is expected to represent long-term expectations of abatement costs. In effect, this magnifies the allowance pool several fold because allowances are fungible over time; and consequently short-run variability is dampened. The opportunity to bank provides a means to lower overall cost but it is especially relevant because it can play a significant role in reducing short-run price variability.

Banking also has a political dimension. Firms that hold a bank have a vested interest in the security and continuation of the allowance market. However, the opportunity to borrow allowances from the future to cover emissions today has a converse influence. If firms acquire a running debt, then it becomes their political interest to see the emissions cap relaxed or the program suspended altogether to extend or wipe out that debt. Consequently, to achieve the virtues of inter-temporal flexibility in managing allowances our reasoning leads us to recommend in favour of banking and to oppose borrowing provisions.

Private Sector Instruments: Various types of financial instruments provide a means for individual entities to insure themselves against price volatility. Forward contracts, futures and options are routinely used in commodity markets to manage risks that appear similar to the type of risks that plague allowance markets. Making use of these instruments is costly to regulated firms because they require payment of an insurance premium, but in most commodity markets these instruments work effectively. Futures trading is currently available in EUAs and in CO_2 allowances created by the Regional Greenhouse Gas Initiative.

Carbon Market Efficiency Board: This concept was introduced in the US in the Lieberman-Warner legislative proposal (S. 2191) in 2008. The board is described as an entity analogous to Federal Reserve Board with the aim of overseeing emissions allowance markets. The board would be given discretionary authority to intervene, with the ability to alter the supply of allowances within some constraints, in order to maintain price stability. However, the specifics of the board have not been worked out and as many problems as solutions have surfaced since the idea was first suggested.

Quantity-Limited Allowance Reserve: The idea of an allowance reserve is somewhat similar to the description of RGGI's offset market described above. This plan would have a strategic reserve of allowances that would be released into the market if allowance price exceeds some ceiling. The quantity of additional allowances would be limited, so it may fix a short-run problem of price variability but it would not overcome a long-run problem of prices escalating in order to achieve overall program goals. The allowances in the reserve could be set aside at the outset of the program, or they could be "borrowed" from future compliance period budgets.[2]

Safety Valve: The safety valve idea has been suggested as a way to introduce additional emissions allowances into the allowance market if the allowance price reaches a pre-specified ceiling; however, unlike the quantity-limited approach described above, the proposals typically did not constrain the quantity of allowances that could be introduced.

A number of criticisms about the safety valve idea have surfaced. In the next section we address these criticisms and propose a substantial refinement of the safety valve by introducing a symmetric instrument that would respond to significant variations in price in either direction.

3 Symmetric Cost Management

Economists have shown that when there is uncertainty about benefits and costs of regulation the nature of that uncertainty affects the type of policy that would be most efficient (Weitzman 1974, Roberts and Spence 1978, and Pizer 2002). Uncertainty about control costs has been particularly salient in debates over climate policy, which could prove much more costly than prior regulatory efforts to limit emissions of air pollution. The idea of a safety valve mentioned previously suggests a ceiling on the price of carbon emission allowances that would be maintained by increasing the provision of allowances in the market (Pizer 2002; Kopp et al. 2002). This proposal has found

[2] Murray, Newell and Pizer, 2008.

favour with some federal policy makers in the US and has been a part of several legislative proposals.

Burtraw and Palmer (2008) have analyzed the safety valve proposal using a detailed simulation model of the electricity sector, and identify two pervasive concerns with a safety valve if it is implemented as a single-sided instrument designed only to guard against unexpected increases in price. One is the safety valve affects expectations of allowance price levels, and thereby affects the expectations about the payoff from various investment strategies. The second is that the safety valve affects the ability to achieve the environmental target. Using a detailed simulation model and accounting for uncertainty in the future price of natural gas, we find that the single-sided safety valve is likely to reduce the investment in nonemitting technology and increase the expected emissions that obtain under the policy. In this discussion we explain these ideas more fully and propose a remedy that would involve a symmetric safety valve that provides both a price ceiling and price floor in the allowance market.

a) Investor Expectations

Potential future profits for investors in clean technologies such as renewable generation are positively related to the expected value of the future electricity price, which, in turn, depends on the level of the allowance price. If the allowance price is capped then the upside profit potential for investors in clean technology is lower than in the uncapped case. Thus, the one-sided safety valve lowers the investor's expected future profits and thereby limits incentives to invest in clean technology.

Considering the profit function for a single firm that offers nonemitting electricity generation:

$$\pi = q\,P\left(Q, P_A\right) - C\left(q\right) \qquad (1)$$

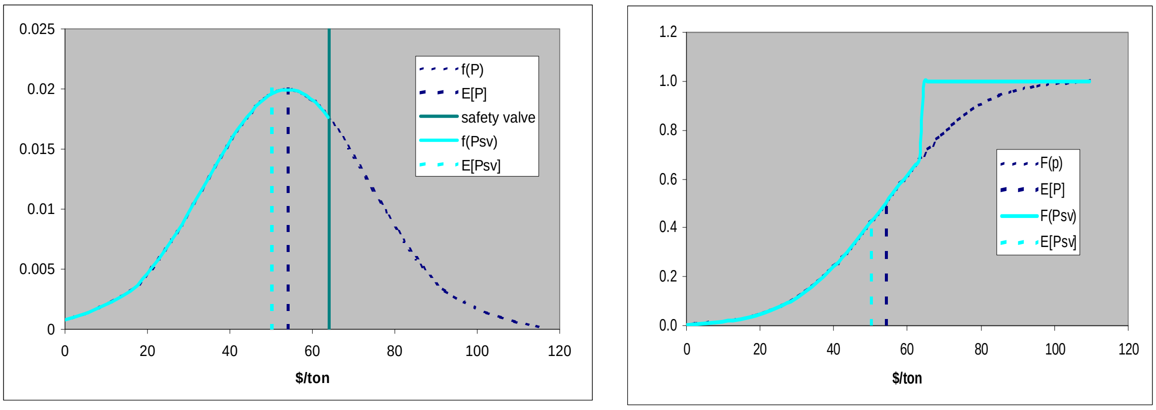
where q is the quantity produced by the potential investment, Q is the aggregate quantity in the market and P_A is price of allowances. Cost is a function of the quantity of production. The price of emission allowances is not included because the facility is nonemitting. We assume that the electricity price function and the cost function are increasing in their arguments.

The firm maximizes profits by choosing quantity (q). Under the assumption that the facility's output is too small to make an impact on the aggregate production and price, then $\delta P / \delta q = 0$ and the firm maximizes profits by choosing q such that marginal revenues equal marginal costs:

$$P\left(Q, P_A\right) = \frac{\delta C}{\delta q} \qquad (2)$$

In general we expect the aggregate quantity and price of allowances to be uncertain, so that $Q = \tilde{Q}$ and $P_A = \tilde{P}_A$ (where $\tilde{Q}$ and $\tilde{P}$ represent uncertain variables), which cause the product price to be uncertain ($P = \tilde{P}$). Assuming the firm is risk neutral, the profit maximization condition would require the firm to equate expected marginal revenue with marginal cost: $\mathrm{E}\left(P\right) = \delta C / \delta q$.

The effect of the safety valve on expectations of allowance prices is illustrated in Figure 3.1. In panel (a) of the graph, f(P_A) represents the distribution of allowance prices in the absence of a safety valve with the expected value shown as E(P_A). The safety valve is indicated by the solid green line at just above $60 per ton. With this cap, the distribution of possible allowance prices is capped (as illustrated by f(Psv)) and the expected allowance price falls as shown by the vertical dashed line at E(Psv). The cumulative distribution is illustrated in panel (b).



Panel (a): Probability Distribution Panel (b): Cumulative Density Function

Figure 3.1. Distribution of Allowance Prices with Uncertain Gas Price Outcomes.

A consequence of the change in the allowance price would be a change in the equilibrium in the electricity market, leading to a lower price under the safety valve, $E\left(P^{sv}\right) < E\left(P\right)$. The individual profit maximizing investor described in equation (1) would choose a level of production under the safety valve where:

$$E\left(P^{sv}\right) = \frac{\delta C}{\delta q^{sv}} < \frac{\delta C}{\delta q} = E\left(P\right) \qquad (3)$$

leading to a reduction in its investment and output, $q^{SV} < q$. The consequence of the high-side safety valve in this example is to reduce investment in the nonemitting facility.

One can conjecture that in the aggregate the policy leads to less investment in renewable technology or low-emitting technology. The cap-and-trade program serves as a mechanism to internalize into investment decisions the social cost of technology choices and to "level the playing field," as many observers have suggested. However, the single-sided safety valve would appear to provide an asymmetric influence that would tilt the playing field away from investments in nonemitting sources.

Note that the set of distributions illustrated in figure 3.1 is naïve in the sense that the effects of the safety valve on investment decisions by other firms and on the allowance market. For instance, one could imagine that a lower allowance price would lead to more fossil generation, which would seem to lower electricity price and reinforce the effect described above. However, the lower allowance price also might increase the emission intensity of generation for any given level of production and would cause a bounce back in the price of allowances. In addition, whatever is the underlying source of uncertainty for allowance price, it is also likely to affect directly the cost and aggregate quantity of production.

This panoply of reactions causes us to conjecture that the new equilibrium yields an expected price under this safety valve between the two expected prices illustrated in figure 3.1. Identifying the equilibrium outcome in a general model with such feed backs incorporated is difficult without simulation modeling. Therefore we turn to that platform. In doing so, we conjecture *a priori* that the high-side safety valve should lead to less investment in non-emitting and low-emitting sources of generation than in the absence of the safety valve, as well as a lower expected allowance price, a lower electricity price and greater expected emissions.

b) Symmetric Cost Management

To date most advocates of the safety valve approach focus exclusively on the situation where the realized costs of reducing pollution turn out to be higher than expected. The previous section reinforces the criticisms of many observers that such a policy would lead to an increase in emissions and a decrease in investment in low emitting technology.

Furthermore, the focus on a one-sided safety valve is often motivated by a one-sided concern about potential price spikes. However, evidence is that *ex post* actual costs of government regulation are more often lower than *ex ante* expected costs (Harrington et al. 2000).

The possibility that costs may turn out to be lower than expected or benefits higher than expected suggests that the single-sided safety valve in the form of a cap does not provide sufficient insurance against uncertainty. With lower than expected costs or higher than expected benefits, the established emission cap could prove dramatically insufficient. A regulatory design that could help improve the efficiency of policies in this situation would be a double-sided, or *symmetric* cost management that sets both a floor and a ceiling on the price of emission allowances.

To explore the role of uncertainty and the determination of prices, emissions and investment we employ simulation methods to model underlying uncertainty about natural gas prices in the future. As the central case we adopt EIA (2006) forecasts reported in the *Annual Energy Outlook*. We consider two alternatives, which are labeled high and low gas price cases and incorporate a 30% increase and decrease in gas prices. We assume gas price is normally distributed. High and low prices are picked to represent prices that are one standard deviation away from the mean. We essentially model each case with and without the relevant side of the symmetric safety valve: a floor for low gas prices and a ceiling for high gas prices.

In this modeling exercise we freeze natural gas and coal prices at the assumed forecast values in each year and thus these fuel prices are not allowed to vary with the level of fuel used. We also freeze the level of electricity consumption in order to avoid second best issues in the welfare calculation that are associated with differences between price and marginal cost. For all of the pollution policies emission allowances are allocated to emitters on the basis of historic generation and additional permits are purchased at the safety valve price.

We find that emissions are higher with the high gas price and a safety valve and that social welfare is higher with the safety valves than without. We find the expected result that the effects of the gas price swings on electricity price are limited by the presence of the relevant safety valve.

The simulation model is deterministic, meaning that it incorporates certain foresight about potentially uncertain variables. Investment decisions are made as though each actor knows for certain the future values of every variable, as well as the decisions of every other actor, so there is no uncertainty taken into account in the model solution. However, although the model is itself deterministic, we can use a collection of model solutions to make a mathematical inference about the outcome of the market equilibrium when investors make decisions taking uncertainty into account.

Using the results from the deterministic model for various realizations of the underlying uncertain parameter, we construct a linearization using the delta approach, which is a variation of a Taylor series expansion. The expected value of a function ϕ of a random variable $\tilde{g}$ with expected value $\bar{g}$ and variance σ_g^2, can be approximated by:

$$\begin{aligned} \mathrm{E}[\phi(\tilde{g})] &\cong \phi(\bar{g}) + \phi'(\bar{g})\mathrm{E}[(\tilde{g}-\bar{g})] + \frac{1}{2}\phi''(\bar{g})\mathrm{E}\left[(\tilde{g}-\bar{g})^2\right] \\ &= \phi(\bar{g}) + \frac{1}{2}\phi''(\bar{g})\sigma_g^2 \end{aligned} \quad (4)$$

where ϕ' and ϕ'' ' are first and second derivatives of the function.

The function ϕ can represent a variety of measures that we are interested in including aggregate economic welfare, electricity price, allowance price or the installed nonemitting generation capability. For this experiment, the random variable $\tilde{g}$ is the natural gas price. We consider low, mid and high values of $4.42/mmBtu, $6.31/mmBtu, and $8.21/mmBtu in 2020 (2004$). We assume it is common knowledge that these prices are distributed normally with an expected value of $6.31/MMBtu and a standard deviation of $1.90/MMBtu, so the mid value in this experiment is the mean value of the natural gas price and the low and high values are both one standard deviation from the mean.

The results from this experiment displayed in Figure 3.2 match our expectations. The high-side safety valve leads to the expectation of greater emissions than in the no safety valve case because with some probability the safety valve will be triggered, thereby placing extra allowances on the market. As a consequence the allowance price and electricity price are lower. The results show that welfare is higher with the high-side safety valve and even higher with the symmetric safety valve. A potentially important unintentional result is that the lower expected allowance price with a high side safety valve leads to lower expected payoffs to investment in renewable technologies. Consequently we see a decline in renewable generation.

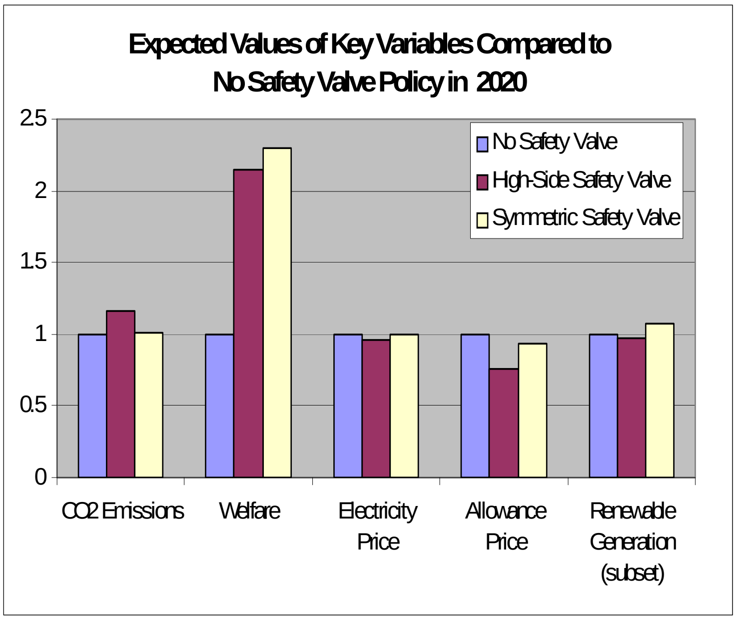


Figure 3.2. Delta Method Approximation of Outcomes Underlying Uncertainty

Many observers have criticized the high-side safety valve because it might undermine the environmental targets of the program, and that is the result we obtain. Expected emissions are higher and investments in new technology are lower as a result of the safety valve. The reduction in investments initiates a cascade of consequences, as there is less technological learning as a result of the decline in investment, so the costs of renewable technologies remain above their levels in the absence of the safety valve.

However, the unintended consequences are remedied when the safety valve is made symmetric. In this case, expected emissions fall back to virtually the same level as in the absence of a safety valve, and renewable investments increase to above their level in the absence of a safety valve. [3] Not only do measures of interest to environmental advocates return to their intended levels with a symmetric safety valve, but welfare improves even further than in the case with only a high-side safety valve. Also, electricity price and allowance price return to nearly the same level as in the absence of the safety valve.

4 Conclusion

Perhaps the biggest hurdle for climate policy is the expected high cost of bringing about important reductions in emissions of greenhouse gases, and the natural price variability that could send prices even higher. Under a cap and trade policy, both trends in costs and cost variability are manifest in the fluctuations in CO_2 allowance prices. Theory and experience suggest that cap and trade is the low cost regulatory approach, but high sustained costs or large fluctuations in costs may threaten

[3] In this analysis, only a subset of renewable technologies is allowed to change because biomass investment is held constant. If biomass were allowed to change one would see even more of an effect on renewable generation under the two policies.

public confidence in this new regulatory institution. Thus finding a way to manage both the overall cost of the policy and short-run price variability will be a key to policy success.

Several approaches have been suggested to manage cost in an emissions allowance market and a combination of approaches is likely to be the best strategy. Cost management mechanisms should be both transparent and designed to function in a predictable way. In general good market design promotes transparency and this is especially important with respect to markets for environmental goods because these markets are new and relatively unfamiliar to, investors. Also, because these markets are created by policy, investors may feel that the markets may be manipulated by policy. Therefore transparency and especially the predictability of changes may help boost investor confidence.

The best way to approach cost management is through a smart market design that includes the opportunity for banking and the judicious use of offsets. Many economists have also advocated for an upper bound on that cost in the form of a cap on the price of emission allowances. However, this one-sided approach to cost control has an important downside of capping the potential returns to investors in clean energy technologies and thus limiting incentives for those investments.

We suggest a formal and predictable mechanism – symmetric cost management or a symmetric safety valve - for adjusting the goals of the program in the face of unexpected price volatility. This can be achieved with a two-sided cost control mechanism that places both a floor and a cap on emission allowance prices. By providing for a ceiling and a floor on allowance prices, the mechanism we propose preserves incentives for investors to invest in clean technologies, which helps address the long-run issue of the cost of emissions reductions, and also guards against short-run variability. Such a mechanism could help the world to achieve the near term incentives to trim emissions that come with putting a price on CO_2 with the longer run gains that come from greater investment in clean technologies such as renewables that might spark cost-reductions and technological breakthroughs that will be necessary to fight global warming effectively.

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