Allowance Banking in Emissions Trading Schemes: Theory and Practice

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Abstract

Past, current and proposed emissions trading schemes include allowance banking provisions that range from no banking to unlimited banking. Some schemes establish a maximum lifetime, 2 to 10 years, for allowances and so limit the scope for banking. Allowance banking and life provisions affect environmental performance, economic efficiency and emitters' behavior. This paper reviews theoretical predictions relating to the effects of banking and the consequences of the banking provisions adopted by different trading schemes. The environmental consequences depend in part on whether the pollutant is a "stock" or "flow" pollutant. Less restrictive banking provisions enhance economic efficiency by improving price stability, facilitating adjustment to a change in the emissions cap and increasing liquidity in the allowance market. Banking provisions also affect the rate of non-compliance and the resulting excess emissions. Many schemes accumulate a relatively large bank, predictably or unexpectedly, when first implemented. This can have adverse environmental consequences and reduce the economic efficiency of the scheme.

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1. Introduction

Emissions trading schemes are implemented to manage discharges to the environment. A regulatory authority defines a cap (upper limit) on the total quantity of a pollutant that may be released into the environment by a group of sources (affected units) during a given period (compliance period). Allowances equivalent to the cap are distributed and can be traded. Each allowance authorizes the owner to discharge a specific amount (e.g., one tonne) of the pollutant. Every affected unit is required to monitor its releases of the pollutant. At the end of the compliance period, each affected unit must remit to the regulatory authority enough allowances to cover its total pollutant releases.

In some trading schemes an allowance issued for one compliance period may be used by an affected unit for a later compliance period. This is allowance “banking”. Some schemes allow sources without a compliance obligation to earn “credits” for emission reductions. Credits approved by the regulatory authority can be used for compliance by affected units. The term “allowances” will include both allowances and credits, if applicable, unless specifically stated otherwise.

Allowances are often vintaged. The vintage of an allowance is the compliance period for which it can first be used for compliance.[1] In a scheme with annual compliance, a 2007 vintage allowance is an allowance that can be used to cover emissions that occur during 2007. If allowance banking is permitted, a surplus 2007 allowance could be used to cover emissions during a later compliance period.

Every emissions trading scheme must address allowance banking; to state that banking is not permitted (allowances are valid only for the specified compliance period), is restricted in specified ways, or is not restricted (allowances can be used any time during or after the designated compliance period). One way to restrict allowance banking is to limit the life of allowances. For example, if allowances have a five year life, 2007 allowances could be used for compliance in any period from 2007 through 2011. To make a limited life a more effective restriction, it can be combined with a requirement to use allowances issued for the current compliance period first.

Allowance banking, including allowance life, provisions affect environmental performance, economic efficiency and emitters’ behavior. If banking is not permitted, affected units have an incentive to manage their compliance precisely because surplus allowances have no value. This is likely to increase the rate of non-compliance – the fraction of affected sources with excess emissions. If allowance banking is permitted, affected sources have an incentive to implement early emission reductions because the surplus allowances have a market value. Allowance banking also helps affected sources accommodate production and demand changes, facility maintenance, and market (e.g., fuel prices) changes.

Allowance banking defers emissions. If a 2007 allowance is used for compliance in 2009, it means that total emissions were below the permitted level -- the cap -- during 2007. Use of banked 2007 allowances in 2009 could cause total emissions during 2009 to exceed the 2009 cap. However, the aggregate emissions permitted over the entire period do not change. The environmental consequences of such a temporal shift of emissions depend, in part, on whether the pollutant is a "flow" pollutant – whose impacts depend on current emissions – or a "stock" pollutant – whose impacts are a function of cumulative emissions over a relatively long time.

The main benefit of an emissions trading scheme is to reduce the cost of achieving a set of emissions caps over time. Allowance banking should increase the economic efficiency of the trading scheme by improving price stability, facilitating adjustment to changes in the emissions cap, and enhancing liquidity in the allowance market.

This paper reviews theoretical predictions relating to the effects of allowance banking and the consequences of the banking provisions adopted by different trading schemes. The next section summarizes the allowance banking provisions of past, current, and proposed emissions trading schemes. Section 3 summarizes information on the impacts of banking provisions on environmental performance, economic efficiency and emitters' behavior. Conclusions are presented in section 4.

2. Banking and Related Provisions of Emissions Trading Schemes

The banking, allowance life and related provisions of past, current and proposed emissions trading schemes are summarized in Table 1.[2] Although the rules for four schemes indicate that allowance banking is not allowed, limited banking is sometimes possible in practice. In the case of ozone-depleting substances the products could be stored for use during a later period. The scope for such "product banking" is constrained by production capacity, storage capacity, the cost of carrying inventory and other factors. In the RECLAIM program a minor amount of allowance banking is possible due to the overlapping compliance periods; a participant can sell surplus allowances to a buyer with a later compliance deadline and purchase allowances with a later vintage.

Table 1
Summary of Banking and Related Provisions

Scheme		**Banking and Related Provisions**	**Bank**
Lead in leaded gasoline	lead	Nov. 1982 through Dec. 1984 no banking; From Jan. 1985 bank 1985 allowances for use from Jul. 1985 through Dec. 1987; leaded gasoline could be stored	Max. 10 billion grams
Ozone-depleting substances (U.S.)	Ozone-depleting substances	No allowance banking Substances could be produced and stored for later consumption	
Ozone-depleting substances (Canada)	Ozone-depleting substances	No allowance banking Substances could be produced and stored for later consumption	
Non-attainment area emission reduction credits	Mainly NOx	Banking rules vary by jurisdiction Some have limited life, often 10 years	

(ERCs)for large new and expanding sources	and SO_2	Some have annual discounting, e.g., 20% Some have unlimited banking	
Discrete Emission Reductions (DERs)			
Michigan	NOx VOCs	Allowances have a 5 year life	95.7%[A] 96.3%[A]
New Jersey	NOx VOCs	No limit on allowance banking	95.6%[A] 87.1%[A]
Connecticut	NOx	No limit on allowance banking	34.3%[A]
Massachusetts	NOx	No limit on allowance banking	58.8%[A]
New Hampshire	NOx	No limit on allowance banking	96.3%[A]
Texas	NOx	No limit on allowance banking	98.2%[A]
Averaging, banking, trading (ABT) for motor emission standards	Mainly NOx and PM	For heavy-duty truck and bus engines: 1991-1997 annual 20% discounted and 3 year life; since 1998 differential discount based on emission rate of engine family that generates them but no maximum life	
Acid Rain program for electric utilities	SO_2	No limit on allowance banking	11.62 million[B]
Ozone Transport Commission and SIP Call NOx Budget programs	NOx	Progressive flow control. Current vintage allowances must be used before banked allowances. For each source the first X% of banked allowances used, where X depends upon the size of the bank, cover emissions at face value and thereafter they are discounted 50%.[C]	94.2 million 48.7% 207.6 million 44.3%[D]
RECLAIM – Greater Los Angeles area	NOx and SOx	No allowance banking. Can sell surplus allowances to a buyer with a later compliance deadline and buy allowances with a later vintage.	
Houston-Galveston	NOx	Current vintage allowances must be used before banked allowances. Banked allowances expire at the end of the period after the one for which they were issued; in effect allowances have a two year life.	162,000 215.7%[E]
Ontario SOx and NOx	NOx and SO_2	No limit on allowance banking	99.6% 84.2%[F]
Northeastern Illinois	VOCs	2 year allowance life. Current vintage allowances do not need to be used first.	218.1%[G]
Netherlands	NOx	No allowance banking	
Seoul Metropolitan Area, Korea (beginning July 2007)	NOx, SOx, and TSP	Banking for each pollutant limited to 10% of the allowances for the following year. Surplus allowance holdings are cancelled in proportion to limit the bank to 10%. When used banked allowances are discounted by 50%, so the maximum bank is effectively 5%.	

Danish CO_2	CO_2	Annual "saving limits" were set for each participant.[H] If actual emissions were less than the saving limit, the difference could be banked.	
UK emissions trading scheme	GHGs	No limit on allowance banking through 2007. Banking of pre-2008 allowances for use during 2008-2012 is limited to sources with absolute caps to the extent that they have over-complied with their targets.	430.5%[I]
NSW GHG abatement scheme	GHGs	No limit on allowance banking	126.1%[J]
EU emissions trading scheme	CO_2	No restrictions on allowance banking during 2005-2007 and from 2008 onward. Member States may allow banking of surplus 2005-2007 allowances into the 2008-2012 period. Only a few Member States allow such banking and then only under very restrictive terms.	Up to 104.1% Overall 2.5%[K]
Kyoto mechanisms[L]	GHGs	Banking (carry over) of different units from 2008-2012 period to the subsequent commitment period is restricted as follows: • RMUs may not be carried over • ERUs, which have not been converted from RMUs, may be carried over up to a maximum of 2.5% of the party's assigned amount • CERs may be carried over up to a maximum of 2.5% of the party's assigned amount • tCERs and lCERs may not be carried over • AAUs may be carried over without restriction. The quantities of RMUs, ERUs, CERs, tCERs and lCERs are likely to be small relative to the quantity of AAUs, so the banking restrictions can effectively be avoided by using units other than AAUs first for compliance and then banking surplus AAUs.	
Regional Greenhouse Gas Initiative (RGGI)	CO_2	No limit on allowance banking	

Notes:

A Credits banked as a percentage of the credits created through the end of 2000.

B The bank reached a maximum at the end of Phase I (1999). The bank compares to actual emissions of 4.95 million tons during 1999 and 11.20 million tons by a much larger number of participants during 2000.

C X is calculated as 10% of the emissions cap for the next year divided by the allowances banked at the end of the current year. If X is greater than 0.1 (10%) flow control is triggered.

D The bank increased steadily over the 4 years of the OTC program to 94.2 million at the end of 2002 representing 48.7% of the emissions during that ozone season. These banked allowances were not carried over to the SIP Call program. Over the first two years of the SIP

Call program the bank grew to 207.6 million representing 44.3% of the emissions during the 2004 ozone season. Flow control was triggered in every year except 2003, the first year of the SIP Call program.

E Actual emissions during the 2004 ozone season were 75,432 tons. In addition about 28,000 allowances expired.

F The NOx bank at the end of 2005 was 99.6% of the emissions during the year and the SOx bank was 84.2% of the emissions during the year.

G At the end of 2005 the bank was equivalent to 218.1% of the emissions during the 2005 ozone season. In addition allowances equivalent to 125.6% of the 2005 emissions expired.

H In 2001, 2002, 2003 and 2004 the saving limits were 10%, 5%, 0% and 0% respectively below the allowance allocation to each participant.

I Over the first two years of the scheme Direct Entry sources accumulated a bank of 6.5 million, 430.5% of their emission reduction target for 2003 of 1.51 mtCO_2e. Climate Change Levy Agreement sources had banked 0.8 million allowances after buying 1 million allowances from Direct Entry sources. In 2004 six participants agreed to revised targets that increased the cumulative reductions by Direct Entry sources from 11.88 mtCO_2e to 20.78 mtCO_2e. During 2004 actual emissions of Direct Entry sources were 0.20 mtCO_2e lower than their revised targets increasing the bank by this amount.

J Through 2005, 24.394 million certificates were generated and 14.251 million were surrendered, leaving a bank at the end of 2005 of about 10.143 million certificates, 126% of the 8.047 million surrendered during 2005.

K The 2005 compliance summaries for 21 of the 25 Member States indicate that 6 Member States were net purchasers and that 15 had a net surplus. The allowances banked as a percentage of actual emissions in those 15 Member States ranged up to 104.1% (Lithuania). Summing the deficits and banked allowances across the 21 Member States yields a net surplus of 2.5% of actual emissions.

L The Kyoto Protocol establishes three mechanisms to help countries with emissions limitation commitments for 2008-2012 (Annex B parties) meet their targets:

- Joint implementation (JI), Article 6, governs the issuance of emission reduction units (ERUs) for emission reduction and sink enhancement projects in Annex B parties.
- The Clean Development Mechanism (CDM), Article 12, governs the issuance of certified emission reductions (CERs) for emissions reduction projects in non-Annex B parties. Afforestation and reforestation projects under the CDM are subject to special provisions to deal with the non-permanence of the sink enhancements. The units issued for such projects are temporary CERs (tCERs) or long-term CERs (lCERs).
- International emissions trading (IET), Article 17, governs the transfer of assigned amount units (AAUs) and removal units (RMUs) issued to Annex B parties as well as transfers of acquired ERUs, CERs, tCERs, and lCERs to other Annex B parties.

Six of the schemes reviewed limit the life of the allowances; the lifetimes range from two to ten years. Five emissions trading schemes restrict banking by other means -- a discount on banked allowances (ABT, some non-attainment districts, and the Seoul program), flow control on the use of banked allowances (NOx Budget program), a savings limit below the emissions cap for banking (Danish CO_2 program) and a 10% cap on the quantity of allowances that can be banked (the Seoul program). Twelve schemes have no restrictions on banking, except to avoid complicating compliance with national emissions limitation commitments under the Kyoto Protocol.

Where an emissions trading scheme allows both allowances and credits for compliance purposes, the banking provisions are identical for both, except in the case of the Kyoto mechanisms. In such systems, the volume of credits is small relative to the quantity of allowances. Thus, differences in banking provisions would simply lead to using the units with the most restrictive banking provisions first for compliance purposes. This is expected to happen in the case of the Kyoto mechanisms.

There are no clear patterns in the allowance banking and related provisions by pollutant. Trading schemes for substances tend not to have allowance banking, but product banking is possible. Greenhouse gas trading schemes tend to have relatively generous banking provisions because the climate change impacts depend on cumulative emissions over a century or more. The emissions trading schemes for common air pollutants -- VOCs, NOx, SOx and TSP -- have a range of banking provisions.[3]

Many schemes have accumulated a relatively large allowance bank quickly. The UK greenhouse gas emissions trading scheme accumulated a large bank quickly and then negotiated larger emission reduction targets with some participants to reduce the bank. The Northeastern Illinois VOM program has accumulated a bank equivalent to two years' emissions with an allowance life of two years. The Houston-Galveston NOx program has a bank of over 2 years' emissions with an allowance life of two years. The Ontario NOx and SOx program, which has no restrictions on banking, has accumulated a bank of 1 year's emissions for NOx and 10 months' emissions for SOx over its first four years.

The appropriate size of the allowance bank depends on the variability of emissions from period to period, future changes to the emissions cap, the growth of emissions in the absence of the trading scheme, the shape of the emission reduction cost function over time, and the discount rate. The size of the allowance bank relative to future changes to the emissions cap is discussed below for the lead in leaded gasoline and SO_2 acid rain schemes.

The environmental impact of using banked allowances depends on whether they cover emissions of a "stock" or "flow" pollutant. The OTC and SIP Call NOx programs are intended to help reduce ground-level ozone, so the emissions during a given ozone season are important. The "flow control" provision discounts the use of banked allowances when the bank exceeds 10% of the emissions cap. The bank has exceeded this threshold every year except the first year of the SIP Call program.

3. Impacts of Allowance Banking Provisions

This section reviews the theoretical literature, experimental literature and empirical data relating to the effects of different banking provisions on the environmental performance, economic efficiency and behavior of participants.

3.1 Environmental Effects of Allowance Banking

Allowance banking changes the temporal pattern of emissions and may change aggregate emissions and so can have environmental, including public health, effects.

Changing the Temporal Pattern of Emissions

A banked allowance represents permitted emissions that did not occur. Use of a banked allowance means the corresponding emissions occur. Thus allowance banking defers the emissions, but does not change the aggregate emissions allowed over the period. If the emissions cap exceeds the "business as usual" emissions, as has been the case during the early years of several schemes, unrestricted allowance banking defers implementation of actual emission reductions. The emissions cap would need to fall below the "business as usual" emissions and the accumulated allowance bank would need to be depleted before actual emissions are reduced. With no allowance banking, emission reductions would occur when the emissions cap falls below the "business as usual" emissions.

If the emissions cap is lower than the "business as usual" emissions, allowance banking may lead to earlier emission reductions. Then allowance banking generates environmental benefits during periods when allowances are banked and increases environmental damages during periods when the banked allowances are used. There may be a net environmental benefit if the emissions cap declines over time so that the emissions are shifted from a period with higher total emissions to a period with lower total emissions.[4]

A temporal shift of emissions is unlikely to provide an environmental benefit or detriment in the case of pollutants whose impacts are a function of cumulative emissions over a relatively long time (decades to centuries) -- "stock" pollutants -- such as ozone depleting substances, greenhouse gases, and acid rain precursors. Deferring some emissions of such a pollutant by a few years does not reduce (or increase) the damages.

For pollutants whose impacts are a function of current emissions -- "flow" pollutants -- such as smog precursors, the environmental impacts of a temporal shift in emissions requires situation-specific analysis. The impacts depend on many factors in addition to the level of emissions. Shifting emissions from a period with higher total emissions to one with lower total emissions will not necessarily reduce the aggregate environmental damage over the period.

The environmental impacts of some "flow" pollutants, such as smog, depend on local weather conditions, which typically have a duration of a few days. The duration of such episodes is very short relative to the compliance periods of the emissions trading schemes for NOx and VOCs, the smog precursors. Reducing total precursor emissions can reduce the number of episodes, but additional measures, such as reduced industrial activity or automobile use, are needed to reduce the severity of an episode when it occurs.[5]

Enforcement, Compliance and Aggregate Emissions

Compliance enforcement is critical to achievement of the environmental goal (emissions cap) of an emissions trading scheme.[6] Non-compliance is a risk for all environmental policies, but the incentive may be stronger for emissions trading schemes.[7] Under other environmental regulations, a source that does not comply saves the cost of implementing the necessary emission reductions. In an emissions trading scheme an affected source that under reports its emissions saves the cost of implementing emission reduction measures and can sell allowances it is allocated.[8]

The compliance impact of increased enforcement activity and/or a higher penalty is partially offset by the indirect effect on allowance prices. A higher level of compliance should lower the quantity of allowances sold by non-compliant sources. A reduced supply would raise the market price of allowances. But a higher market price for allowances would increase the payoff for non-compliance, which partially offsets the impact of the increased enforcement activity and/or penalty. This indirect effect is confirmed in experiments reported by Murphy and Stranlund (2004). The non-compliance penalty and level of enforcement activity should be set to achieve complete compliance taking this indirect effect into account.

Allowance banking has two potential impacts on the rate of non-compliance – the percentage of affected sources that do not comply:

- With unrestricted allowance banking, the extra allowances a non-compliant source might be able to sell have a market value beyond the current compliance period. This payoff for non-compliance made possible by allowance banking could *increase* the rate of non-compliance.

- If allowance banking is prohibited, affected sources try to manage their compliance for each period more precisely because surplus allowances have no value, so unanticipated developments are more likely to lead to them missing their targets. If allowance banking is permitted, even if it is restricted, affected sources can buy enough allowances to provide a comfortable compliance margin and bank the surplus allowances. Thus, allowance banking also could *reduce* the rate of non-compliance.

Since the two potential impacts have opposite effects on the rate of non-compliance, the net impact is an empirical question.

Evidence suggesting that allowance banking *increases* the rate of non-compliance is limited. Loeb (1990) asserts that the introduction of banking in 1985 led to an increase in the number of violations in the lead in leaded gasoline program.[9] He provides no evidence that the increase in the number of violations was due to the introduction of banking rather than the higher compliance costs due to the 90% reduction in the allowable lead content of leaded gasoline. In their experiments Cason and Gangadharan (2004) find that allowance banking increases non-compliance and total emissions in a hypothetical scheme with weak enforcement.[10]

Evidence suggesting that allowance banking *reduces* the rate of non-compliance comes from the experience of several emissions trading schemes. Table 2 summarizes the non-compliance experience of schemes for which data are available. When there is non-compliance, the rates for the RECLAIM SOx and New South Wales GHG schemes are relatively high due to the small number of participants (30 to 40 in both cases). For the remaining schemes the non-compliance rate drops as the banking provision becomes less restrictive, being highest for the RECLAIM NOx program, lower for the Illinois VOM program, lower still for the NOx Budget program, and lowest for the Acid Rain SO_2 program. The percentage of excess emissions is lower than the percentage of non-compliant sources in every case.

Non-compliance occurs even in periods for which allowances representing thousands of tons of emissions expire or are banked, since the total excess emissions are almost always less than 100 tons, an insufficient supply of allowances is almost never the reason for the non-compliance. Rather, the small size of the average excess emissions (less than 10 tons) indicates that non-compliance is caused by attempts to manage compliance precisely. The non-compliance is often due to clerical errors or failure to transfer the correct number of allowances rather than excess emissions.

The highest rate of non-compliance occurred in the RECLAIM NOx program in 2000 due to California's electricity crisis. Electricity generators in the scheme were required to produce much more than their historical output. Although they purchased all available allowances, driving up prices significantly, their emissions exceeded their allowance holdings. NOx allowance prices increased from $2,557/ton in 1999 to $21,255 in 2000 and $34,163 in 2001 before dropping back down to $5,555/ton in 2002.

The existence of a bank of allowances could have mitigated the price increase and non-compliance by the electricity generators, but the emissions might have been higher. As shown in Figure 1, actual emissions were substantially below the NOx emissions cap during the early years of the scheme. With unlimited banking, 42,368 allowances would have been available to cover the excess emissions during 2000 and 2001.[11] It is likely that such a large bank, 2.5 years' emissions, would have reduced the extent of the non-compliance and moderated the price increase.

A higher rate of non-compliance does not necessarily imply higher aggregate emissions. If banking is prohibited, the actual emissions of most sources are lower than their allowance holdings and the surplus allowances expire unused. The excess emissions of non-compliant sources are usually small due to the penalties. As a result, actual emissions for each period are usually lower than the overall emissions cap, as can be seen in Figure 1, despite non-compliance by some sources.

Table 2

Number of Non-compliant Sources and Excess Emissions of Non-compliant Sources in the RECLAIM, Acid Rain SO_2, NOx Budget, Illinois VOM and New South Wales Greenhouse Gas Emissions Trading Schemes

	RECLAIM NOx		**RECLAIM SOx**		**Acid Rain SO_2**	
	Sources	**Amount (tons)**	**Sources**	**Amount (tons)**	**Sources**	**Amount (tons)**
1994	44 (12.8%)	511 (1.27%)	6 (15.8%)	37 (.36%)		
1995	28 (8.4%)	372 (1.03%)	1 (2.7%)	7 (.07%)	0	0
1996	49 (14.9%)	na	0	0	0	0
1997	19 (5.8%)	na	0	0	0	0
1998	27 (8.2%)	na	0	0	0	0
1999	31 (8.8%)	na	0	0	0	0
2000	41 (12.2%)	1,089 (6.33%)	0	0	6 (.27%)	54 (.001%)
2001	15 (4.5%)	16 (0.10%)	0	0	2 (.07%)	11 (.001%)
2002	9 (2.7%)	55 (0.39%)	2 (5.6%)	4 (.08%)	1 (.03%)	33 (.003%)
2003	10 (3.1%)	8 (0.06%)	0	0	1 (.03%)	14 (.001%)
2004	13 (4.0%)	58 (0.46%)	0	0	4 (.12%)	465 (.005%)
	NOx Budget		**Illinois VOM**		**NSW GHG Scheme**	
	Sources	**Amount (tons)**	**Sources**	**Amount (tons)[a]**	**Sources**	**Amount (tons)**
1999	1 (.1%)	1 (.000%)				
2000	2 (.2%)	9 (.003%)	8 (4.5%)	26.4 (.28%)[a]		
2001	5 (.5%)	19 (.009%)	3 (1.7%)	5.3 (.05%)[a]		
2002	4 (.3%)	26 (.012%)	4 (2.3%)	8.9 (.09%)[a]		
2003	7 (.7%)	25 (.015%)	3 (1.7%)	2.6 (.03%)[a]	0	0
2004	2 (.08%)	9 (.001%)	2 (1.1%)	0.2 (.002%)	1 (3.2%)	2 (.000%)
2005			2 (1.2%)	7.9 (.19%)	0	0

Other Schemes

Houston-Galveston NOx, 2004: 17 accounts (about 4.8%) with total excess emissions of 109.6 tons (0.08%)

Ontario SOx and NOx: No participants out of compliance for either SOx or NOx during 2002, 2003, 2004 and 2005

EU ETS, 2005: Data for 16 Member States indicate non-compliance of 0% to 20.6% (Greece) of the installations with excess emissions ranging up to 1.5% of the allowances allocated (Greece).

Notes: Non-compliant sources are expressed as a percentage of the number of participants and excess emissions are expressed as a percentage of the emissions cap for the year.

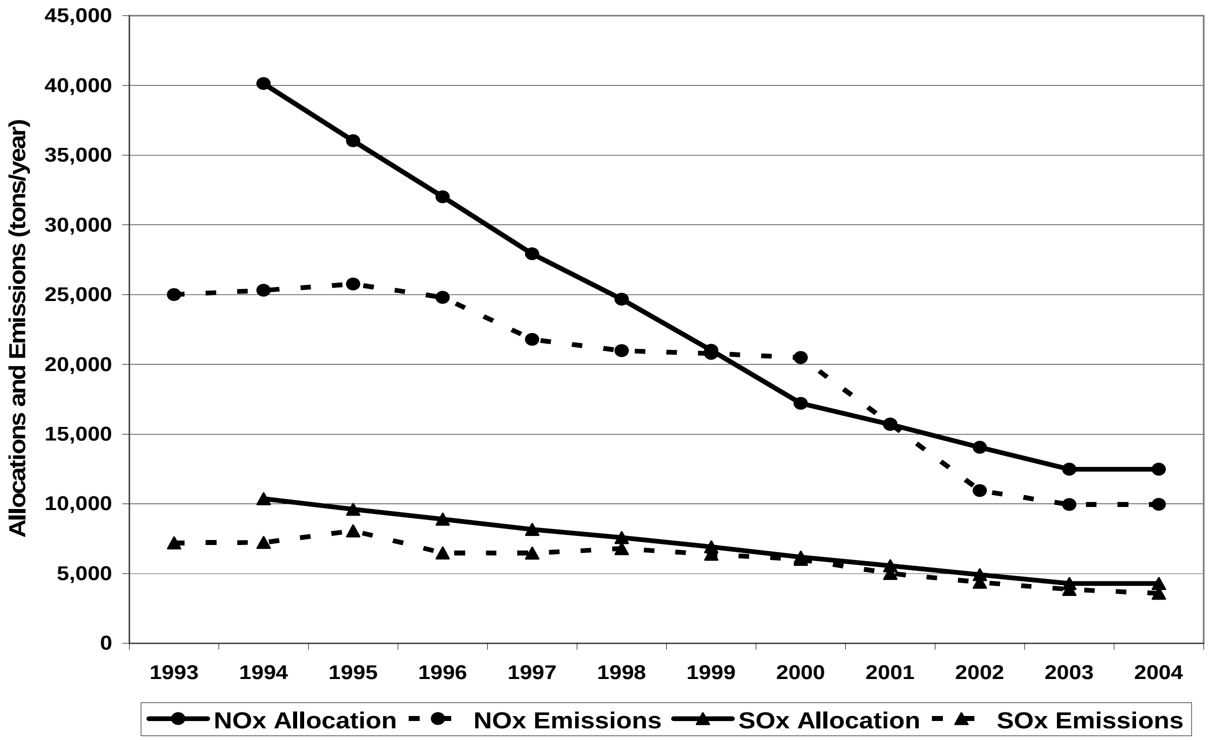
na = data not available.

a: The actual excess emissions are a little lower than these figures. The compliance reports provide the number of allowances deducted for excess emissions, but the allowances deducted are a multiple of the excess emissions where the multiple varies with the frequency of non-compliance. These figures are estimated using the highest multiple.

Sources: Compiled from annual compliance reports for the respective schemes.

Figure 1

Emissions Caps and Actual Emissions for RECLAIM, 1993-2004



Source: Annual RECLAIM Audit Report for the 2004 Compliance Year, Tables 3.1 and 3.4.

3.1 Economic Effects of Allowance Banking

Economic Efficiency of Allowance Banking

There is a relatively large theoretical literature on the economic efficiency of allowance banking. Most of these analyses assume that the abatement cost function does not change over time, the environmental damage function is known and does not change over time, the emissions of each affected source are known with certainty for all future periods, and the emissions trading scheme covers a "flow" pollutant with the emissions cap set at the socially optimal level for each compliance period.

With those assumptions Kling and Rubin (1997) show that unrestricted allowance banking (or borrowing) reduces economic efficiency because actual emissions differ from the emissions caps, which are socially optimal, during the periods when the allowances are banked and used. If allowance banking is permitted, affected sources bank allowances when the private discount rate differs from the social discount rate. Then banking leads to a temporal emissions profile that is not socially optimal. Salmons (1998) confirms this result in a general equilibrium context. Both Kling and Rubin and Salmons propose mechanisms to induce the socially optimal level of emissions during each period.

Leiby and Rubin (2001) modify the analysis to cover a "stock" pollutant and a non-optimal emissions cap. They still assume the abatement cost function does not change over time, the environmental damage function is known and does not change over time, and the emissions of each affected source are known with certainty for all future periods. Unrestricted allowance banking still is not necessarily socially optimal. They propose that the regulator use the (assumed to be known) information on marginal damages, marginal abatement costs and emissions for future periods to set an inter-temporal trading rate to induce the socially optimal level of emissions during each period.

Williams (2002) shows that the efficiency of banking depends on the relative slopes of the marginal cost and marginal damage functions and the degree of substitutability among the goods produced by affected sources. When the slope of the marginal cost function exceeds the slope of the marginal damage function an emissions tax is a more efficient regulatory policy than an emissions cap. Newell, Pizer and Zhang (2003) demonstrate that an emissions trading scheme with banking can be used to create the same outcomes as an emissions tax through rules that adjust the effective allowance cap for unexpectedly low or high costs.

Assuming a "flow" pollutant with the emissions cap set at the socially optimal level for each compliance period Yates and Cronshaw (2001) show that allowance banking can improve economic efficiency in some situations if future emissions are uncertain. Innes (2003) also shows that allowance banking can increase economic efficiency when the emissions of affected sources are uncertain and compliance enforcement is costly.

Three empirical estimates of the economic efficiency of allowance banking are available. When the banking provision for the lead in leaded gasoline program was introduced, the EPA estimated that it would lead to banking of 9.1 billion grams and reduce compliance costs for refiners by $226 million.[12] A bank of just over 10 billion grams of lead was accumulated, so the actual savings might have been a little higher than the projection.

Rubin and Kling (1993) estimate the savings due to banking, prior to the start of the scheme, in a California averaging, banking and trading (ABT) scheme for hydrocarbon emissions covering light-duty vehicle manufacturers. The projected savings due to banking are roughly the same regardless of whether averaging and trading are also allowed. But the savings due to banking are highly dependent on the discount rate; ranging from 3% of the total potential saving with a 15% discount rate to about 33% of the total saving with a 0% discount rate. With a high discount rate affected sources are less concerned about future abatement costs and so do not take advantage of the opportunity to bank allowances.

Burtraw and Mansur (1999) model the effects of allowance banking in the Acid Rain SO_2 program. They find that allowance banking leads to early emission reductions and later emission increases.[13] This shift yields a net public health benefit. They find that banking increases compliance costs. This is because the banking scenario includes installation of several scrubbers, some mandated by state legislatures or regulators, that appear, ex post, to be inefficient investments. The cost of this inefficient banking scenario is compared with the cost of efficient compliance with no banking. They did not compare the cost of efficient compliance with and without allowance banking.

In summary, the theoretical literature suggests that allowance banking improves economic efficiency under some circumstances. The relevant question is whether allowance banking improves economic efficiency in practice. Very little empirical evidence is available to answer this question. Ex ante studies find that banking reduces compliance costs and so improves economic efficiency. The only ex post study finds that banking increases costs, but that result was derived by comparing an inefficient banking scenario with efficient compliance and no banking.

Transaction Costs

Transaction costs are the costs involved in buying or selling allowances, such as the fees paid to brokers and the legal costs of preparing the sales contract. If the initial distribution of allowances corresponds to the holdings required for least-cost compliance, no allowance trades are needed and the transaction costs are irrelevant. In practice, the initial distribution of allowances differs from the holdings required for least cost compliance, so allowance trades are needed to minimize the total compliance cost. Transaction costs inhibit trading, which reduces the likelihood of minimizing the total compliance cost, so they reduce economic efficiency.

Stavins (1995) demonstrated that if marginal transaction costs are constant, they do not change the market price or the volume of allowances traded regardless of the initial distribution of allowances. If marginal transaction costs decline, the market price and volume of allowances traded will deviate from those needed to minimize the total compliance cost. The price and volume deviations will be smaller, the greater the difference between the initial allowance distribution and the holdings required for least cost compliance. The more trades needed, the lower the marginal transaction cost and the smaller the impact of transaction costs.

Cason and Gangadharan (2001) confirm Stavins' theoretical predictions experimentally. They find that when marginal transaction costs decline, prices deviate less from the competitive equilibrium the greater the difference between the initial allowance distribution and the holdings required for least cost compliance. The deviation from the cost competitive equilibrium does not vary with the initial allowance distribution when marginal transaction costs are constant.

With allowance banking the effect of transaction costs also depends on whether the marginal transaction cost changes over time and the difference between the initial allowance distribution and the holdings required for least cost compliance over time.

Studies of the impacts of transaction costs are available for the lead in leaded gasoline and RECLAIM programs. Kerr and Mare (1995) estimate the efficiency losses from transaction costs for the lead in gasoline program during 1983 and 1984 (before banking was introduced) were about 10% and that the probability of trading would increase by 12% without transaction costs. Gangadharan (2000) estimates that transaction costs for RECLAIM reduced the probability of trading by 32% in 1995 and by 12% in 1996, the second and third years of the scheme. Anecdotal evidence indicates a significant decline over time in broker's fees for the Acid Rain SO_2 program.[14]

In summary, with banking the impact of transaction costs on economic efficiency depends how the nature and magnitude of the marginal transaction costs change over time as well as the difference between the initial allowance distribution and the holdings required for least cost compliance over time. The limited empirical evidence suggests that marginal transaction costs decline over time so the allowance holdings for least cost compliance are unlikely to be achieved. However, the banking provision is only one of the factors contributing to this loss of economic efficiency.

Price Stability

Allowance banking links future allowance prices to the current ("spot") market price. Maeda (2001) shows that the relationship between the current and future prices depends upon the proportions of affected sources and non-emitters in the market.[15] Expectations about future developments affect the spot market price and future prices; technological progress should reduce the spot market price while projected increases in emissions and more stringent emissions caps should increase the spot market price. However, the spot market price should not fall below the equilibrium price with no banking.

Allowance banking should improve price stability. If banking is not allowed, allowance prices are likely to be unstable at the end of each compliance period. With no banking, if actual emissions are lower than the cap for the compliance period, the price of allowances should fall to zero at the end of the period since any remaining allowances have no value. With no banking, if actual emissions are higher than the cap for the compliance period, the price of allowances should rise sharply at the end of the period.[16] Allowance banking should dampen such end-of-period price fluctuations and so improve price stability.

Stability of allowance prices is important for a variety of reasons. For affected units purchasing allowances is an alternative to implementing emission reduction measures. They are better able to identify cost-effective emission reduction measures if allowance prices are stable. Allowance prices also provide an indication of the value of emission reductions and so stimulate research and development investment on abatement technology. More stable prices are more likely to lead to the efficient level of research and development investment. Thus, price stability should improve economic efficiency.

No empirical studies of price stability for different emissions trading schemes were found. However, two experimental studies have addressed price stability and banking. Godby, et al. (1997) find that uncertainty in emissions control leads to substantial price instability when allowance banking is not allowed. Allowance banking virtually eliminated the price instability. However, banking reduces economic efficiency in their experiments and they speculate this may be due to the added complexity of optimizing compliance decisions over time given an uncertain future.

Cason and Gangadharan (2004) also find that allowance banking helps smooth out the price variability arising from the imperfect control of emissions. This greater price stability comes at a cost since banking leads to greater non-compliance and higher total emissions in their experiments. In the experiments non-compliance is a function of the penalty and probability of being audited. Banking increases the expected value of surplus allowances and hence leads to more non-compliance.

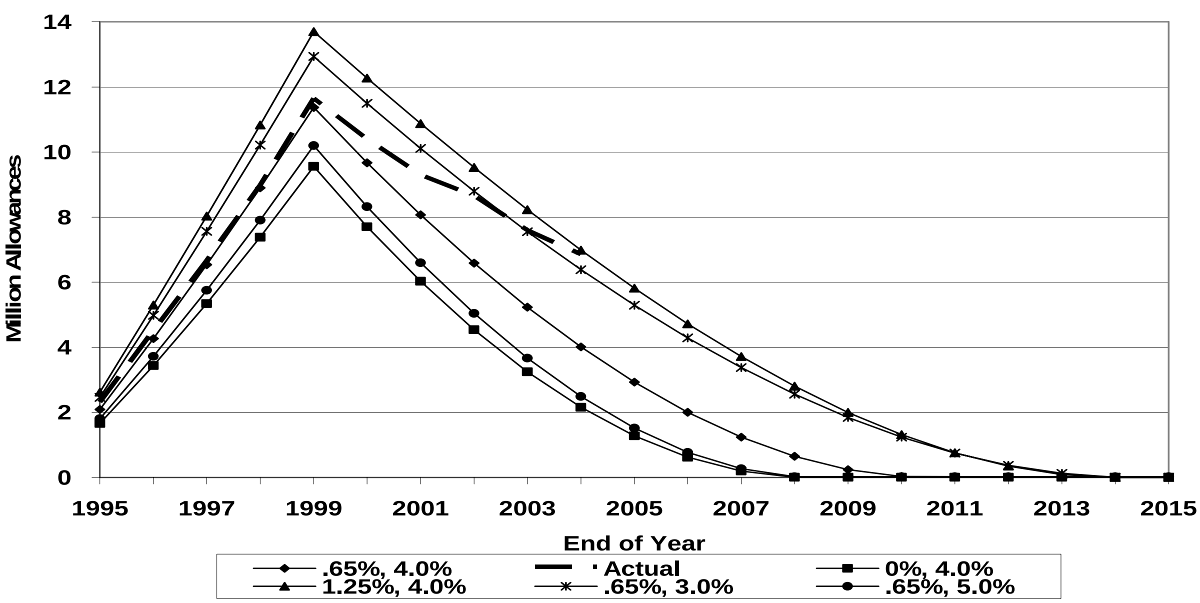
In summary, banking improves price stability and thereby improves economic efficiency, but part of this benefit is offset by other impacts of banking on economic efficiency.

Changes in the Emissions Cap

Allowance banking should facilitate adjustment to changes in the emissions cap. Allowances can be banked in anticipation of the more stringent cap and be used for compliance after the cap has been tightened. Thus banking should reduce the time and/or cost of adjusting to a more stringent emissions cap. Banking facilitated adjustment to a 90% reduction in the lead content of leaded gasoline and is currently being used to adjust to the Phase II cap of the Acid Rain SO_2 program.

Ellerman and Montero (2003) analyze the efficiency of banking behavior in the Acid Rain SO_2 program. The economically optimal level of banking depends on the SO_2 emissions in the absence of the trading scheme, the SO_2 emission reduction cost function, and the discount rate. Using ranges of reasonable values for the discount rate and the rate of growth of SO_2 emissions in the absence of the trading scheme, Ellerman and Montero find that banking behavior has been reasonably efficient during Phase I and the first few years of Phase II as shown in Figure 2.[17]

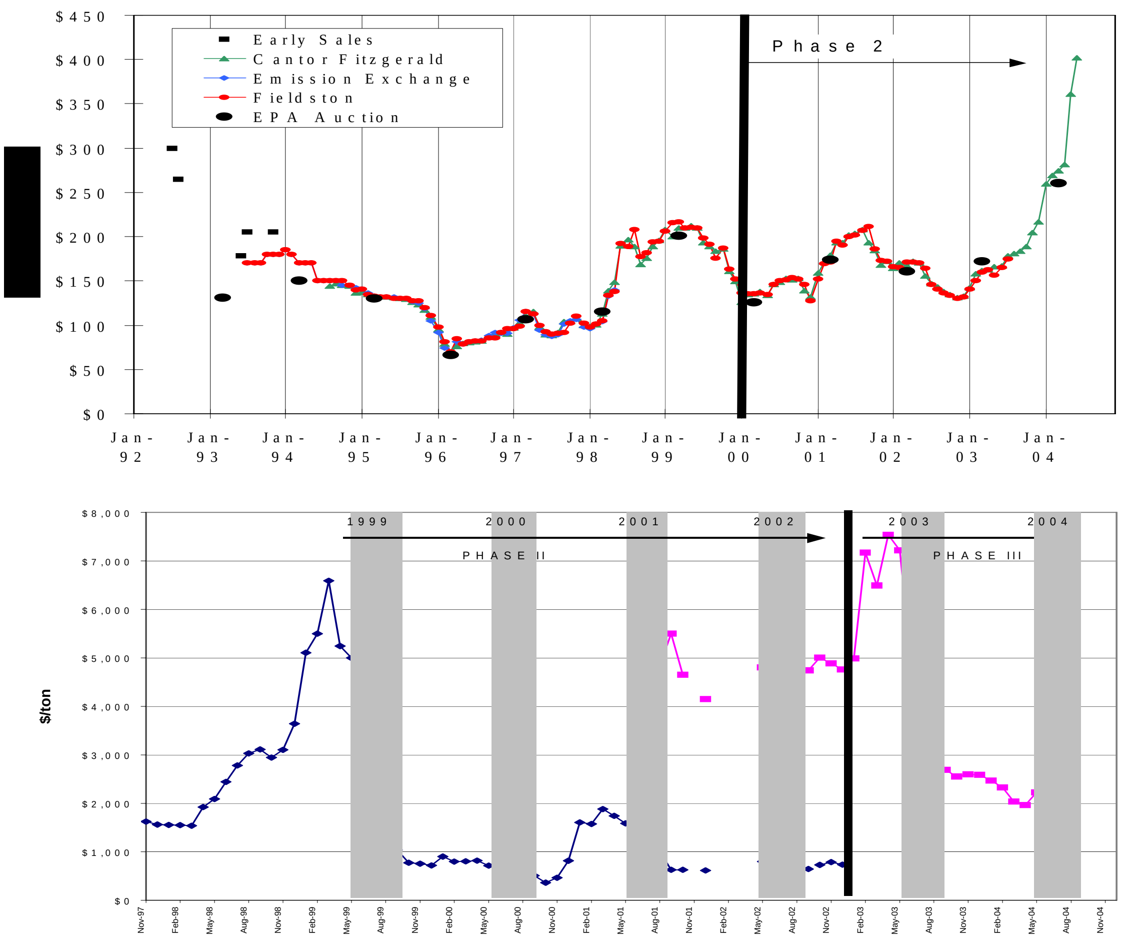
Figure 2
Optimal Allowance Banking in the Acid Rain SO2 Program



Source: Ellerman and Montero (2003), Figure 4 updated to 2004.

Allowance banking also affects the market price during the adjustment to a change in the emissions cap.[18] Allowance prices are higher than they would be without banking as allowances are accumulated. And allowance prices are lower than they would be with no banking as the banked allowances are used to meet the more stringent cap. Ellerman (2004) demonstrates this by showing that there was a significant jump in allowance prices between the OTC (Phase II) and SIP Call (Phase III) NOx Budget programs, where banking was not possible, while there was no discontinuity in allowance prices between Phase I and Phase II of the Acid Rain SO_2 program where banking was possible, as shown in Figure 3.

Figure 3
Allowance Prices for the Acid Rain SO_2 and NOx Budget Programs



Source: Ellerman (2004)

Erhardt, et al. (2005) find that a ban on banking pre-2008 allowances into 2008-2012 leads to an inefficient adjustment to the more stringent cap assumed for the latter period. In their simulation of the EU Emissions Trading Scheme, the ban on banking leads to a low price for allowances during 2005-2007 and under-investment in emission reduction measures. The more stringent cap triggers a price spike during 2008 and 2009. The higher allowance prices induce over investment in emission reduction measures, which causes the price to fall back to the optimal level by 2012. They note that in practice the ability to use credits from the Clean Development Mechanism for compliance during both periods will limit the magnitude of the allowance price spike.

Liquidity

Allowance banking should improve liquidity in the allowance market. Liquidity is the ease with which a good can be bought or sold. Liquidity is a matter of degree, so it is not possible to specify what level of liquidity is "necessary" or "satisfactory" for a given market. Greater liquidity should reduce transaction costs and increase the willingness of affected sources to use purchased allowances as part of their compliance strategy. Increased willingness to use allowance trading for compliance should reduce compliance costs and so improve economic efficiency.

Allowance banking tends to increase the quantity of allowances available to the market and so should improve liquidity and increase the volume of allowances traded. In their experiments, Godby, et al. (1997) and Cason and Gangadharan (2004) find that allowance banking increases trading activity.

Table 3 summarizes trading activity for several schemes where data are available. Allowances traded between economically independent entities during a year are related to total emissions during the year so that trading activity can be compared across schemes.[19] The first year of each scheme is excluded because the level of trading activity is much lower than for any subsequent year for all schemes.[20] As can be seen from the ranges, trading activity fluctuates widely from year to year.

The available data on the quantity of allowances traded include all vintages. The quantity of current vintage allowances traded relative to annual emissions would be a more relevant measure of liquidity, but the data for that calculation are not readily available. Thirty years of allowances are issued for the Acid Rain SO_2 program, while at most a few years of allowances are issued for the other schemes. Thus the figures in Table 3 need to be interpreted cautiously.

The volume of trades is highest for the Acid Rain SO_2 program, which has unrestricted allowance banking. The volume of trades in the Acid Rain SO_2 program is always higher than for the schemes with restricted allowance banking, except for one year each for the RECLAIM NOx and SOx programs.[21] In other words, the volume traded is always less than 75% of the actual emissions for the schemes with restricted banking with two exceptions in the RECLAIM program. The emissions cap for the Northeastern Illinois VOM program is roughly double the actual emissions so relatively few sources need to buy allowances to achieve compliance. In the Ontario SOx and NOx program the allocations have been such that there has been only one buyer of NOx allowances.

Table 3
Summary of Liquidity Data for Emissions Trading Schemes

Scheme	**Allowances Traded as % of Annual Emissions**[a]
Production Allowances for Ozone Depleting Substances in the U.S., 1991 through 1995	30% to 110% 45%[b]
Acid Rain SO_2 Program, 1996 through 2004	75% to 180% 115%[b]
RECLAIM NOx Program, 1995 through 2004	20% to 125% 50%[b]
RECLAIM SOx Program, 1995 through 2004	10% to 105% 40%[b]
NOx Budget Program, 1999 through 2002	30% to 60% 45%[b]
Northeastern Illinois VOM Program, 2001 through 2004	5% to 15% 10%[b]
Ontario NOx and SOx Program, 2002 through 2005	No trades for SOx in any year No trades for NOx in 2002-2004 NOx trades < 0.1% in 2005

Notes: a Trades between economically independent entities. All values are rounded to the nearest 5%
b Median. Where there is an even number of observations it is the average of the two central values.

Source: Haites and Missfeldt, 2004, Table 2, p. 859 with updated data.

A higher level of trading activity for the Acid Rain SO_2 program, the scheme with unrestricted banking, relative to the schemes with restricted banking is consistent with the expected effect of banking on liquidity. However, the result may be due, at least in part, to the larger quantity of allowances issued for the Acid Rain SO_2 program.

Innovation and Diffusion of Technology

An emissions trading scheme creates a continuous financial incentive to improve emissions abatement technology and to adopt more efficient fuels, processes, and abatement technologies. Improvement in the abatement technology can lead to lower costs and/or lower emissions, which reduces the cost of operating the technology or the number of allowances needed for compliance. The financial incentive is the money saved or the market value of the allowances saved. Allowance banking should enhance the innovation and diffusion of more efficient abatement technologies by providing greater price stability.

Jaffe, et al. (2002) review the literature on the relationship between environmental policy and technological change. They report that the empirical evidence is generally consistent with theoretical findings that market-based instruments for environmental protection are likely to have significantly greater, positive impacts over time than conventional regulatory approaches on the invention, innovation, and diffusion of desirable, environmentally-friendly technologies.[22] An emissions tax provides a stronger incentive for technology diffusion than an emissions trading scheme, assuming the two are equivalent before diffusion occurs, because diffusion lowers the allowance price and thereby lowers the incentive for affected sources to adopt the technology.

Gagelmann (2003) reviews the literature on the impacts of the early emissions trading schemes -- lead in leaded gasoline, RECLAIM, Acid Rain SO_2 and NOx Budget programs -- on innovation. He concludes that the existing evidence is not sufficient to assess impact of emissions trading schemes on the rate of technology innovation, but the evidence clearly demonstrates that emissions trading schemes lead to very efficient use of technological and organizational progress.

Kerr and Newell (2001) assess the effect of the lead in leaded gasoline program on technology diffusion by comparing adoption data during the program with data for earlier and later periods when each refinery had to comply individually. They found that the emissions trading scheme provided incentives for more efficient technology adoption decisions.

An EPA (2002) evaluation of the RECLAIM program concludes that while many affected sources have relied upon existing “off-the-shelf” technologies, some have been able to employ innovative methods of emission reduction. But the market and structure of RECLAIM have not encouraged innovation to the extent anticipated when the scheme was developed. Given the relatively small number of affected sources participating in RECLAIM and the fact that the emissions cap was not binding until 1998 or 1999, these conclusions are not surprising.[23]

The most comprehensive reviews of the technological developments triggered by the Acid Rain SO_2 program are Burtraw (2000) and Swift (2001). The dominant abatement strategy during Phase I (1995-2000) was the substitution of low-sulphur coal for high-sulphur coal. This strategy was economically attractive due to price and transportation cost reductions for low-sulphur coal, but required generating plants to modify boilers, coal handling equipment and particulate controls to allow the use of blends with of low-sulphur coal. Installation of “scrubbers” that remove SO_2 was the other significant abatement strategy. The scheme led to a significant reduction in the cost of scrubbers, increased removal efficiency and higher scrubber utilization.[24]

Swift (2001) compares compliance by affected sources under the NOx Budget program with compliance by similar sources with various NOx regulations. He finds that NOx Budget program promoted broader technology choice and thereby increased the opportunity for innovation relative to the regulatory policies. It had been expected that sources would need to install expensive control technologies such as Selective Catalytic Reduction. Instead many sources were able to achieve emission reductions of up to 30% through operational changes such as removing some burners from the boiler, better control systems for boilers, and shifting to natural gas and low-NOx coals.

The studies cited evaluate the impact of specific emissions trading schemes on emissions abatement technology innovation and diffusion. They do not assess the effect of specific scheme provisions, such as banking, on emissions abatement technology innovation and diffusion. The only study identified that analyzes the effect of specific scheme provisions is Cames and Weidlich (undated). They analyze the effect of alternative methods of allowance allocation and alternative treatments of new entrants and closures under the EU emissions trading scheme on the German power sector.

In summary, emissions trading schemes provide a continuous financial incentive to improve emissions abatement technology and to adopt more efficient abatement technology. Evidence from the lead in leaded gasoline, Acid Rain SO_2 and NOx Budget programs suggests that emissions trading schemes succeed in this respect. While RECLAIM appears to have been less successful in stimulating innovation, this is probably due to its smaller size and relatively shorter period with an effective emissions cap than its more restrictive banking provision. Allowance banking should enhance the technology innovation and diffusion performance of emissions trading schemes, but there is no empirical evidence to confirm this expectation.

3.3 Behavior of Participants

The literature on the behavior of affected sources covers three topics: whether the potential cost savings are achieved, the choice between emissions abatement investments and the purchase of allowances for compliance, and the behavior of affected sources in different industries.

Achievement of the Potential Cost Savings

Several ex post studies of the emission reduction actions of electric utilities participating in Phase I of the Acid Rain SO_2 program find that the potential cost savings have not been fully realized (Carlson, et al., 1998; Solomon, 1998; and Swinton, 2004). Swinton (2004) reaches this conclusion by comparing the marginal costs of reducing emissions of SO_2 for 40 of the 263 power plants required to participate in Phase I from 1994 through 1998. He finds no evidence of convergence of the marginal costs and failure by a substantial number of plants to use the market to their advantage.[25]

Such analyses exclude many factors that influence the behavior of affected sources. As Ellerman (2003) notes many Phase I plants banked allowances in anticipation of the more stringent Phase II cap. The large reduction in the allowance allocation to Phase I units from 1999 to 2000 had little effect on their emissions, which declined by 8% between the two years. This was achieved through the use of banked allowances; the emissions of Phase I units in 2000 were about 39% higher than their aggregate allowance allocation while the comparable figure for the Phase II units was 6%.

There are several other reasons to expect that ex post marginal SO_2 reduction costs would not be equalized across Phase I units, including:

- Some units were forced to install scrubbers that were not cost-effective ex post as a result of state legislation or regulatory decisions;

- Many units are subject to state or local air quality regulations that require implementation of emission controls (allowances can not be used to achieve compliance);
- The cost-minimizing strategy for meeting all environmental regulations may differ from the cost-minimizing strategy for managing SO_2 emissions;
- Regulatory treatment of electric utility operating expenses and capital expenditures might bias the emissions control strategy adopted;
- The tax and regulatory treatment of costs and revenues from allowance transactions could affect a utility's willingness to buy/sell allowances as part of its compliance strategy;
- The irreversibility of investments in emissions control equipment, such as scrubbers, compared with operational controls, such as use of low sulphur coal;
- Uncertainty about possible changes to environmental regulations for other pollutants, such as NOx, mercury and CO_2, that might affect control strategies for SO_2;[26] and
- Uncertainty about possible restructuring of the electricity industry in many states might have biased the emissions control measures implemented.

This is not intended to suggest that Phase I affected sources behaved optimally, simply to suggest that there are reasons to expect that marginal control costs might not be equalized across all sources and that a difference between the marginal control cost and the market price of allowances might not be sufficient reason to buy/sell allowances.

The Choice between Abatement Investments and the Purchase of Allowances

Hunter and Mitchell (1999) analyze the choice between investment in abatement technology and the purchase of allowances for compliance. Their model indicates that for parameter values prevalent during the early years of the Acid Rain SO_2 program, the cost of compliance by abatement investment was higher than the cost of purchasing the required allowances. This result is due to the uncertainty of allowance prices, electricity prices and production levels, and the irreversibility of abatement investments. They note that the results could be different if allowance banking was not allowed, but do not analyze the no banking case.

Ben-David, et al. (2000) analyze the effects of uncertainty and concomitant risk aversion on the behavior of sources in an emissions trading scheme modeled after the Acid Rain SO_2 program. They find that irreversibility of investment in abatement technology may lead potential buyers to adopt a wait and see attitude toward adoption of efficient levels of abatement technology. Sources buy allowances until the uncertainty is eliminated and then make whatever adjustments are necessary. This may lead to more costly compliance action later. The same incentive does not apply to potential sellers, but affected sources may not know whether they will be a buyer or seller due to uncertainty about future conditions in the allowance market.

Insley (2003) also develops a model of compliance decisions by affected units and applies it to the choice between investment in scrubbers and the purchase of allowances during the early years of the Acid Rain SO_2 program. Her model allows the utility to suspend construction of the scrubber and to mothball it temporarily, so the scrubber investment is more flexible than in the studies summarized above. Insley finds, given the assumed parameters for volatility and cost, that allowance prices have not been high enough to justify scrubber investment since 1993.

In short, the three studies that analyze the choice between investment in scrubbers and purchase of allowances in the context of the Acid Rain SO_2 program all conclude that allowance purchases have been the preferred option. Twenty-five scrubbers came on line between 1992 and 1996 for Phase I (starting in 1995) compliance. Several of these scrubbers were effectively mandated by state legislative or regulatory requirements. Despite a substantial decline in the capital cost, only 12 scrubbers came on line between 1997 and 1999. Thus the model predictions are reasonably consistent with the behavior of affected sources.

Phaneuf and Requate (2002) analyze firm behavior with aggregate abatement cost uncertainty. Allowance banking causes firms to invest less in emissions abatement during the pre-regulation period. Resolution of the cost uncertainty when the emissions trading system takes effect determines the additional abatement investment and allowance banking. If the allowance allocations are fixed in advance, minimization of the total social cost involves some allowance banking and delayed investment although the private banking and investment decisions do not match the social optimum. Whether allowance banking should be allowed therefore becomes a second best question based on the specifics of the regulated industry and the type of pollution.

Behavior of Affected Sources in Different Industries

Gray and Shadbegian (2002) find that estimates of the economic impact of environmental regulation based on reported abatement costs maybe understated. They also indicate that regulatory burdens differ across industries, both because they face different abatement costs and because a given abatement cost has different economic impacts across industries.[27] They estimate the economic impacts of a given abatement cost at 140% in the oil industry, 180% in the pulp and paper industry and 330% in the steel industry. Thus, affected sources in different industries that participate in the same emissions trading scheme may respond differently even though they face the same allowance price.

Khanna and Anton (2002) find that the threat of environmental liabilities, high costs of compliance, market pressures, and public pressures on firms with high on-site toxic emissions per unit output create incentives to adopt a more comprehensive environmental management system. Since affected sources in different industries face different sets of environmental issues, market pressures and public pressures, the compliance strategies they adopt in an emissions trading scheme covering a single pollutant are likely to differ.

Thus, the compliance strategies adopted by affected sources in an emissions trading scheme will be affected by numerous considerations that go well beyond the marginal costs of different abatement options. Those considerations will vary by industry and by firm within an industry. It is not surprising, then, that studies have found differences in marginal abatement costs across electric utilities participating in Phase I of the Acid Rain SO_2 program.

In general, uncertainty about costs and other developments combined with the irreversibility of investments in abatement technology will favor reliance on allowance purchases and low capital cost abatement options for compliance. Allowance banking helps reduce the total compliance cost under such circumstances, although this may not produce the socially optimal emissions profile.

4. Conclusions

Past, current and proposed emissions trading schemes incorporate allowance banking and related provisions that range from no banking to unlimited banking. An allowance life and discounting of banked allowances are the most common ways to limit banking. Emissions trading schemes for common air pollutants -- VOCs, NOx, SOx and TSP -- have a range of banking provisions. Greenhouse gas schemes tend to have relatively generous banking provisions.

Many schemes have accumulated a relatively large allowance bank quickly, predictably or unexpectedly. The appropriate size of the allowance bank depends on the variability of emissions from period to period, future changes to the emissions cap, the growth of emissions in the absence of the trading scheme, the shape of the emission reduction cost function over time, and the discount rate. If the allowance bank is too large it reduces economic efficiency and defers realization of the environmental or public health goal of the trading scheme.

Allowance banking has the potential to *increase* the rate of non-compliance if enforcement is weak. Allowance also has the potential to *reduce* the rate of non-compliance because affected sources do not try to manage compliance precisely. The experience of existing schemes suggests that the latter effect dominates; the rate of non-compliance is higher for schemes with more restrictive allowance banking provisions. A higher rate of non-compliance does not necessarily imply higher aggregate emissions. Even in the scheme with the highest rate of non-compliance, the excess emissions of the non-compliant sources are small.

The evidence suggests that allowance banking improves economic efficiency. It:
- improves price stability,
- facilitates adjustment to a change in the emissions cap, and
- increases liquidity and trading activity,

all of which should improve economic efficiency.

Transaction costs can reduce the economic efficiency of an emissions trading scheme. Allowance banking can affect marginal transaction costs in ways that reduce efficiency but also reduce transaction costs by improving liquidity. Overall, the economic efficiency gains due to allowance banking are likely to be much larger than the losses due to its impact on marginal transaction costs.

In general, uncertainty about costs and other developments combined with the irreversibility of investments in abatement technology favor reliance on allowance purchases and low capital cost abatement options for compliance. Allowance banking helps reduce the total compliance cost under such circumstances.

The compliance strategies adopted by participants are affected by numerous considerations that go well beyond the marginal costs of different abatement options. Those considerations vary by industry and by firm within an industry. For participants emissions trading scheme compliance is a part of its production, investment and environmental compliance decisions. As a result it is unlikely that the marginal abatement cost for the pollutant regulated by the emissions trading scheme will be equalized for all participants.

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Notes:

[1] In the case of credits the vintage is usually the compliance period during which they are approved by the regulatory authority.

[2] Descriptions of these schemes can be found in Anderson, et al., 1990; Cook, 1996; Ellerman, et al., 2003; Environmental Law Institute, 2002; Fowler, 2004; Haites, 2002; Kim, et al, 2003; Kim and Haites, 2005; Schwarze and Zapfel, 2000; and Solomon, 1999.

[3] VOCs are volatile organic compounds, precursors for ground-level ozone which is a constituent of smog. The Northeastern Illinois VOM (volatile organic material) scheme addresses VOCs. TSP is total suspended particulate.

[4] If the marginal cost to society of reductions to meet the emissions cap is higher than the marginal value to society of the environmental and public health damages avoided, the cap is too stringent. If the emissions cap is too stringent for both periods, banking could increase the net cost to society.

[5] Given the necessary conditions, sunlight and sufficiently high temperatures, ozone formation depends on both the absolute and relative concentrations of NOx and VOCs in the atmosphere. In some places, such as northeastern Illinois, ozone formation is more effectively controlled by limiting VOC emissions while in other places it is more effectively controlled by limiting NOx emissions. To reduce the number of episodes, the appropriate pollutant needs to be controlled and the emissions of that pollutant need to be reduced by an appropriate amount.

[6] Since an emissions trading scheme regulates the total emissions of affected units, accurate and reliable measurement of the actual emissions by each source is essential for determining compliance.

[7] An affected unit concerned only with maximizing profits would incur emission reduction costs, including the net cost of allowance purchases and sale, only if they were lower than the expected cost of non-compliance. The expected cost of non-compliance is the non-compliance penalty multiplied by the probability of non-compliance being detected. Affected sources do not know the probability of non-compliance being detected, so they can not make this calculation accurately. Firms also are concerned about the effect of non-compliance on their reputation. As a result compliance tends to be high in practice.

[8] Since the number of allowances needed to cover the reported emissions is easily determined, non-compliance tends to take the form of under reporting actual emissions. If all of the allowances are auctioned, a non-compliant source saves the cost of the emission reduction measures and the cost of buying allowances. If, as is usually the case, allowances are distributed free to affected sources, a non-compliant source saves the cost of the emission reduction measures and can obtain revenue from the sale of allocated allowances.

[9] Newell and Rogers (2003, p. 1) also note that "the flexibility of the program likely increased the amount of violations, …and added an unexpected monitoring and enforcement burden." Loeb reports that the number of violations prior to the introduction of trading reached a peak of 12 during the third quarter of 1982. With the introduction of trading, but no allowance banking, the number of violations rose to 19 during the third and fourth quarters of 1983. With the introduction of allowance banking the number of violations peaked at 33 during the third quarter of 1985. Loeb (fn. 21, p. 9) reports that the excess lead use due to the violations during the third quarter of 1982 amounted to 7.57% of national lead use. Corresponding figures for the magnitude of the violations during 1983 and 1985 are not provided. A significant level of non-compliance for this program should not be a surprise given that EPA relied on unverified reports by affected sources of their leaded gasoline production, lead use, credits generated and credits used. In addition the program included hundreds of firms that quickly entered and exited the business of "refining" leaded gasoline. Anderson et al., 1990, Table III-3, p. 30 shows that the number of refiners increased from 265 in the third quarter of 1983 to 849 in the third quarter of 1985 and then fell to 547 in the fourth quarter of 1987. About 250 of these refiners were refineries that produced leaded gasoline from crude oil. The others added ethanol to leaded gasoline, thus "manufacturing" leaded

gasoline equal to the amount of ethanol added. They were obviously able to enter and exit the business quickly. The net increase of almost 600 refiners between 1983 and 1985 followed by the net decrease of about 300 refiners between 1985 and 1987 understates the entry and exit of individual firms. Such large and rapid changes in the population of affected sources obviously complicate compliance enforcement.

[10] Weak enforcement means that some non-compliance might not be detected. So it may not be possible to detect this effect from the non-compliance data for specific trading schemes.

[11] The bank might have been higher since banked allowances would have an economic value which might have encouraged earlier emission reductions.

[12] Reported by Anderson, et al., 1990, p. 29. See Newell and Rogers, 2003, p. 11 as well.

[13] With no banking, actual emissions are less than the emissions cap each year. With banking, actual emissions are lower than the emissions cap through 1999 and exceed the emissions cap thereafter. With banking the actual emissions are lower than those without banking through 1999 and higher than those with no banking thereafter. The report does not indicate whether with banking actual emissions drop after 1999. But the banking scenario reflects the actual program and aggregate emissions have declined since 1999.

[14] Brokers were used for virtually all trades initially and charged fees of about 3%. Currently brokers are used for less than half of the volume traded and the fees are about 0.2%. Swift (2001) discusses the transaction costs of implementing a tradable permit system.

[15] Affected units are assumed to receive allowances free and to hold them for compliance purposes. Non-emitters seek to earn a return on their investment. Since allowances do not pay interest or dividends, they can only earn a return on their investment if prices rise over time. If the spot market price in the future is expected to be the same as the spot market price today, then the price of a forward contract would be lower than the current (and future) spot market price. In effect the price of the forward contract would be the present value of selling an allowance at the current spot price at that future date.

[16] The price should rise until it induces enough costly, short-term reductions, such as curtailing production, to meet the overall cap or until it is equal to the non-compliance penalty. The impact of the California electricity crisis on RECLAIM NOx prices is probably the best example of such a situation.

[17] The proposed Clean Air Interstate Rule would reduce the cap by 50% in 2010 and a further 50% (67% total) in 2018. A participant will need one banked allowance with a pre-2010 vintage or two 2010 allowances (which have already been issued) to cover 1 ton of 2010 SO_2 emissions. This caused allowance prices to rise from $200 in November 2003 to $700 in December 2004 (see Figure 3) and probably reduced the number of banked allowances used for compliance from what it would have been in the absence of that proposal.

[18] See Madea, 2001 and Ellerman and Montero, 2003, Figure 2, p. 13.

[19] Emissions during the ozone season in the case of the NOx Budget program.

[20] The first two years in the case of the Ozone Depleting Substances program.

[21] In the case of the NOx program the high volume is due to the transfer of allowances associated with the sale of electricity generating units being treated as a trade.

[22] Typically technological developments that reduce the cost of emissions control are rewarded by both market-based instruments and conventional regulations while developments that reduce the abatement performance of such technologies are rewarded by market-based instruments but not and conventional regulations.

[23] A smaller number of participants provides a smaller market for any technological innovations, hence a weaker incentive to develop new abatement technologies.

[24] Scrubbers were designed for compliance with conventional regulations which typically specified a minimum removal efficiency and minimum utilization. To ensure that the minimum utilization level could be achieved the scrubber design included features to provide added reliability. With no requirement for minimum utilization under the Acid Rain SO_2 program, the scrubber design could be simplified leading to lower capital costs. The capital cost savings would be offset by the cost of the allowances needed to cover any extra emissions due to the lower reliability. In practice utilization was higher than the minimum typically specified for scrubbers in conventional regulations because the higher utilization enabled allowances to be sold or banked.

[25] This is defined as the failure to buy allowances if the plant's marginal cost was higher than the auction price or the failure to sell allowances if the plant's marginal cost was lower than the auction price.

[26] Lee and Alm (2004) find, in the context of conventional regulation, that the likelihood of a regulatory change affects an average firm's investment in pollution abatement capital.

[27] Gray and Shadbegian (2003) find similar results for different process technologies within the pulp and paper industry.