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Cost Containment for Climate Policy Requires Linked Technology Policies

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Cost containment for climate policy requires linked technology policies

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Abstract

Safety valves, discretionary advisory boards, and other cost containment mechanisms enhance the political feasibility of stringent climate policy by limiting firms' and households' exposures to higher than anticipated costs associated with reducing greenhouse gas emissions. However, cost containment comes at a price; it increases the risk of climate-related damages and it also discourages investments in low-carbon innovation. Using a highly stylized model of the cost of climate policy, this paper finds that currently proposed cost containment mechanisms will increase emissions by 11–70% by 2030. Because these clauses limit the payoffs to innovation for low-carbon energy technologies, they will reduce our societal capacity to affordably mitigate climate change through technology improvement. If cost containment measures are to be employed at levels currently being discussed in policy debates, then complementary policies to invest in technology improvement directly, such as R&D, will be needed; crucially, they also need to be linked. One way to resolve the impasse between increased risk of damages and reduced incentives for innovation is to create a technology development fund with contributions indexed to the amount by which the market price for carbon exceeds the price cap. Simulations of such a proposal are used to show some of the anticipated impacts and point to important sensitivities.

1 Introduction

Cost containment measures limit the macro-economic risks of complying with quantity based greenhouse gas reduction targets by effectively setting an upper limit on the price of carbon emissions. “Safety valves”, discretionary advisory boards, and other cost containment mechansims make stringent climate policy more politically palatable by limiting investors’ and households’ exposure to higher than anticipated costs associated with climate policy. One implication of this insurance for affected parties is that these clauses place an upper bound on the payoffs to innovation in low-carbon technologies. The application of cost containment for climate policy emerged in the late 1990s as the U.S. debated how to comply with the Kyoto Protocol’s stringent emissions targets. A variety of countries have implemented mechanisms, which, though they vary in their implementation details, fall under the rubric of efforts to limit the cost of climate policy. In the U.S., legislative proposals for cost containment mechanisms emerged in the mid-2000s as proposals in U.S. states and federal government began to attract serious political support.

A primary justification for cost containment mechanisms is that they reduce the near-term price volatility of emissions permits in nascent cap-and-trade regimes. It is difficult however to apply this justification to the wide array of currently proposed cost containment measures because of two characteristics. First, the *levels* of cost containment being proposed are stringent; these price caps are likely to become binding within a few years of beginning the cap-and-trade program. These price caps are not designed to apply to exceptional cases but are expected to become binding quickly. Second, the *duration* of these measures extends for decades, well beyond the time frame for insuring against turbulent start up conditions. This paper examines the effects of safety valves under these two conditions of high stringency and semi-permanence.

This paper begins with some background on the advantages of priced-based mechanisms and quantity based mechanisms for pollution control. It then shows how expected future payoffs are supposed to motivate investments in innovative activities. It surveys the current policy environment to show the profusion of these out-clauses. The next section looks at the effect of these clauses on the deployment of low-carbon technologies. It then discuss the risks of climate uncertainty and the need to have backstop technologies available quickly. Finally, it proposes a mechanism for triggering the necessary investments in technology while keeping cost containment measures in effect. Simulation results show some of the anticipated impacts and point to important sensitivities.

2 Debates about the need for cost containment

Vigorous debates about the appropriateness of using cost containment mechanisms for climate policy turn on a variety of differences in premises; for example, what the goals of climate policy should be and how the private sector will respond to them. This section outlines the characteristics of the policy instruments being discussed—first, generally and subsequently, specifically for climate change. It then lists the sources of disagreement about which would be best to use.

2.1 Price-based and quantity-based pollution control

Uncertainties associated with future damages and future costs to avoid those damages introduce a tradeoff in policy design. Policy makers can choose to impose a definite limit on the economic costs of a policy by imposing a tax, in which the future environmental damages are unconstrained. Alternatively, they can set firm limits on environmental damage by imposing a quantity-based constraint on the amount of pollution allowed, with unknown future costs. The optimal choice between the two depends on expectations about how sensitive the costs of abatement and the costs of damages are to changes in emissions (Weitzman, 1974). If costs of abatement are expected to rise steeply, relative to damages, a price-based instrument is preferable so that the level can be set to avoid runaway costs. If the damages are expected to rise steeply, then an emissions based target can be used to set the level of emissions below the point at which damages rise to unacceptable levels. In both cases, choosing the correct instrument reduces the probability of making costly mistakes. Because of pervasive uncertainty about the carbon cycle and the ease with which we can transform energy use, avoiding such mistakes is important for climate policy.

In the case of climate change, both quantity and price targets have been proposed, as have designs that combine features of each. Cap-and-trade systems set quantity limits on emissions of greenhouse-gases. Permits allowing pollution are distributed in one of many ways, and entities are able to buy and sell credits. With a carbon tax, price based instrument, polluters pay a tax to the federal government based on the amount of CO_2 emitted from a good or service.

So called hybrid instruments aim to combine attractive features of both types of limits (Pizer, 2002). For example, a hybrid systems might include a cap-and-trade system in which the government imposes a cap on the prices of pollution permits. This cap can be implemented in several ways so that shortages do not occur—one way is that the government can agree to be a seller of an unlimited amount of additional permits at the pre-established cap price. The level of the price cap can escalate over time to make the transition costs of meeting emissions targets more gradual. A central feature of these systems is that the price cap takes precedence over the quantity limit; once the price cap is reached the quantity limits are no longer binding.

2.2 Sources of disagreement

Preferences for carbon taxes, cap-and-trade, or hybrids are attributable in part to differences in the following premises and objectives.

2.2.1 Non-linearities

One source of the difference in preferences arises from expectations about whether we are more likely to encounter non-linearities in the marginal costs of climate damages or in the costs of abatement. Are we mainly concerned that aspects of the climate system will manifest abrupt changes as a result of incremental addition of greenhouse gases to the atmosphere? Or is the bigger worry that once inexpensive emissions reductions efforts are acheived, that further efforts to reduce emissions will impose rapidly increasing costs on consumers and investors?

It is important to note that the debate on hybrid instruments is asymmetric. In practice, proposed hybrid schemes include only quantity-based instruments with a constraint on cost; there are no proposals for price based instruments that include a limit on emissions—for example, a carbon tax that includes an emissions constraint that takes precedence over the level of the tax. In a situation in which uncertainty about environmental damages takes precedence over that of the costs of compliance, one would expect to see discourse around a carbon tax that reverts to a cap and trade system once a threshold on emissions, concentrations, or temperature change is reached. The absence of this policy option may reflect expectations among policy makers that non-linearities in the costs of emissions reductions pose a greater risk than do abrupt changes to the climate system.

2.2.2 Level of price cap relative to expected price

Under a hybrid system—such as cap and trade with a safety valve—a second source of disagreement comes from perceptions of the difference between the level of the price cap and the expected price without a cap. If the cap is set at a level that appears much lower than the expected cost, then there may be genuine concern that outcomes will fall well short of environmental objectives. If the cap is set at a level that is close to a mean or upper bound of the expected price without a cap, then arguments against the cap are weaker. Because most price cap proposals include dynamic mechanisms, both the choice of initial cap and the rate at which it escalates affect the strengths of these arguments.

Alternatively, given a policy proposing an initial price cap and escalation rate, disagreements about the attractiveness of a hybrid mechanism turn on expected costs. For example a recent exchange points to several of these reasons for supporters (Harvey, 2007) and opponents (Krupp, 2007) of a safety valve mechanism. A key difference is that whereas Harvey (2007) sees the cap as "infrequently invoked," Krupp (2007) sees the cap price being reached as "a likely scenario."

The extent to which a hybrid system resembles a price or quantity based mechansims depends on the level of the price cap relative to the expected cost of abatement (Jacoby and Ellerman, 2004). Setting it low makes the scheme resemble a price instrument and setting it high makes a quantity based instrument. Stranlund (2007) argues that if non-compliance is an option, then marginal non-compliance penalties need to be increasing. As a result, one source of disagreement about preferred instrument derives not only from expectations of future marginal damages and abatement costs, but from the level at which the price cap is set.

2.2.3 Perceptions of political feasibility

Another difference is perceptions of political feasibility of passing stringent legislation (Felder and Schleiniger, 2002; Bennear and Stavins, 2007). For those that consider a cap and trade without a price cap politically unfeasible, a price cap provides a way to overcome powerful opposition by affected interest groups both domestically (Pizer, 2002) and internationally (Hourcade and Ghersi, 2002). Alternatively, some may consider that stringent price-based climate policy can be made feasible and as a result oppose price caps as an unnecessary compromise (Nordhaus, 2007; Victor and Cullenward, 2007). Expectations about the strength and effectiveness of emitter interest groups are highly uncertain and affect choice of optimal policies once political feasibility considerations are included. For those that favor a price based scheme but who consider a "tax" politically nonviable, the safety valve provides a way to create a mechanism whose outcome is likely driven by the price-based attributes of the instrument, but does not appear to carry the stigma of a tax.

2.2.4 Complementary mechanisms

The level or existence of other components of the proposed policy scheme also plays a role in preferences about instrument type. There may a much weaker case for the benefits of safety valves if other cost containment measures are included, for example, if banking or borrowing of pollution permits from one period to another is allowed. Inter-year transfers would reduce the short frequency price volatility that safety valves would dampen. With borrowing and banking provisions in place, safety valves look less necessary in achieving their short term anti-volatility objective. Although banking and borrowing are small for addressing the longer term objective, some would support safety valves in the absence of banking provisions but not with them.

2.2.5 Concerns about private costs

Support for safety valves may also be affected by concerns of the costs that climate policy might impose on individual firms or interest groups (Bovenberg et al., 2005). Given a quantity target, there are no additional costs that accrue to specific interest groups from the imposition of a safety valve, only cost savings for carbon intensive industries. Some of the disagreement may be affected by narrower private interests rather than social welfare.

2.2.6 Short-term vs. longer-term goals

Finally, differences arise based on whether safety valves are used to address short-term or long-term goals. The short-term justification is to address price volatility. The longer term is more to do with cost containment. The credibility of long term climate targets is fragile (Montgomery and Smith, 2005). Policy schemes that impose a hybrid system for the near term may lessen the credibility of long term targets that involve more stringent reductions (Hepburn, 2006).

3 Inducing innovation under climatic uncertainty

At the root of each of these debates over price versus quantity instruments is the concern that stabilizing greenhouse gas concentrations will be painfully expensive. However, it is possible that the costs of meeting emissions targets can be reduced through the introduction of new technologies, and the improvement of existing ones. Policy makers may be able to affect this outcome because of their ability to affect the price of emissions; changes in prices induce changes in behavior (Hicks, 1932), including decisions to develop new technologies (Edenhofer et al., 2006). Imposing a price on carbon emissions raises the cost of carbon-intensive energy technologies and makes low-carbon alternatives more attractive as substitutes; the expected future demand for low-carbon technologies increases with the stringency of the carbon constraint or price. As a result, when there is a price on carbon emissions, investors in innovative low-carbon technologies will expect higher payoffs if their technology development programs are successful. On the margin, they will increase their investments in innovation, deciding to develop some low-carbon technologies that would not be profitable enough to invest in without a carbon price. Climate policy can thus "induce" private sector efforts to invest in developing improvements to low-carbon technologies; it can shift the marginal cost of abatement curve downward.

3.1 Risks to innovators

Firms deciding whether to invest in innovation face a variety of risks. These include the technical risk of whether a new device will function and the competitive risk of what other firms will do, that any innovator faces. These firms also face policy risk, which is especially important in a sector in which governments' decisions about how to incorporate environmental externalities are of paramount importance to the profitability of low-carbon energy technologies. If expectations about the level—or existence—of these policy instruments several years in the future are uncertain, then firms will discount the value of these future policies and under-invest in innovation. Lags between investments in innovation and their payoffs can last several years, exacerbating the risks for investors.

To the extent that a safety valve dampens the volatility of expected future prices, it reduces the risk for future innovators since it will tend to make the size of the market for successful innovation less uncertain. Proponents of safety caps have argued that this feature of the safety valve actually provides *stronger* incentives for innovation (Jacoby and Ellerman, 2004). However, the effect of the safety valve on expected future markets is asymmetric; it cuts off the upper tail of the distribution of expected profits, but not the lower. While, ceteris paribus, a narrower distribution of expected outcomes will encourage risk averse innovators to invest more, it will not increase investment if the narrowing of uncertainty is achieved completely through the elimination of their most profitable outcomes. In comparison, note that allowing banking of permits from one period to another provides a way to reduce carbon price volatility; it does so symmetrically because it eliminate price spikes due to temporary shortages, but raises prices in times of plenty because permits hold value in future periods. The elimination of the possibility of the most profitable outcomes is particularly important when the distribution in expected payoffs is wide. These arguments are considered with respect to current proposals in Section 5.

3.2 Non-appropriable learning and climatic uncertainty

Some emerging low-carbon technologies will be profitable only at carbon prices above the price cap. Under a cap, these would not be worth investing in. One could argue that this reduced investment in climate related innovation is acceptable because imposition of the safety valve implies that we are unwilling to pay for these new technologies. However two problems remain: first, learning effects that may not be appropriable by the firms involved may delay or eliminate the diffusion of low carbon technologies that in the longer term may have cost below the price cap; the marginal costs of emissions abatement with these technologies may eventually fall below the price cap level due to economies of scale and learning by doing. If some of this leanring is not appropriable, then an innovator would not choose to pursue development of this technology.

Second, there is uncertainty in which technologies may be needed. Because there is uncertainty about climate damages (Baker and Adu-Bonnah, 2008). It is possible for marginal damage costs to rise rapidly (Keller et al., 2007). Knowledge of the carbon cycle and the effects of higher greenhouse gas concentrations on ecological and human systems is improving. Knowledge and expectations about the shape of the marginal damage curve may differ in the future given social learning about influential parameters such as feedback mechanisms that are not currently handled well by existing models. Since technologies take time to develop and diffuse, we may limit our ability to adapt to higher than excected damage functions. The existence of non-appropriable learning and uncertainty in the marginal damage cost curve suggest that the dampening of incentives for innovation created by safety valves may itself be risky. The characteristics of this uncertainty are described in Section 5.4.

4 Cost containment in current policy debates

Cost containment mechanisms feature prominently in nascent efforts to regulate greenhouse gas emissions. The prevalence of cost containment mechanisms is impressive given that the design of climate policy to date has been a heterogeneous undertaking. Greenhouse gas policies, some proposed and some already enacted, encompass a wide variety of policy instruments; they include distinct efforts by dozens of governments; and they have been attempted at almost every conceivable jurisdictional level, from local municipalities to supra-national organizations. Throughout this diversity, concern about the costs of reducing emissions has had a pervasive effect on policy making.

4.1 International

Under the auspices of the United Nations, the Kyoto Protocol (KP) is a quantity-based emissions reductions agreement, in which nearly all developed countries, including the largest emitter, the U.S., agreed to non-binding targets to reduce their emissions relative to a baseline level. A subset of these countries, not including the U.S., ratified the treaty and accepted the targets as binding commitments. These countries have committed to reduce their emissions (as an average between 2008 and 2012) to between 90 and 100% of 1990 emissions levels. While the lack of participation by the two largest emitters has made the environmental effectiveness of the KP negligible, those countries that did accept binding commitments have imposed on themselves a stringent policy requirement; they will need to make reductions of 20–30% from business-as-usual levels in 2012.

The Kyoto Protocol does not include an explicit cost containment mechanism, which in itself might provide one reason for the lack of participation among large emitters. However, it does allow for cost containment in two ways. First, the KP includes a clause that allows countries to miss their targets for 2012 and then pay a penalty in the subsequent commitment period, presumably 2013-2016. For every ton of GHG emitted above the 2012 target, a country must reduce by 1.3 tons in the next period, beyond the level it commits to in the second commitment period.

Second, individual signees can choose to implement their own cost containment measures, because the KP leaves design of national "action plans" to the discretion of the member countries. The members of the EU chose to accept their KP targets as a group and have jointly implemented a cap-and-trade scheme, known as the EU Emissions Trading System (EU-ETS) to meet them. There are no explicit cost containment measures in the EU-ETS, although like the KP itself, it includes penalties for non-compliance. These fines start at euro40/ton CO_2 in 2005 and rise to euro100 in 2008. In addition, cost containment has been managed ex ante within the E.U. through negotiations in how national governments distribute emissions credits to industry. Generous allowances in the 2006–07 period had the effect of containing costs by inflating the baseline level of emissions (Sijm et al., 2006).

4.2 National

Other KP signees have attached cost containment measures to their plans to meet their KP targets. Canada used a cost containment mechanism to secure industry support for its decision to ratify the Kyoto Protocol in 2002. Under this compromise, the Canadian government agreed to sell permits for \$C15/ton until 2012, so that industry would never see carbon prices above that level. By 2006, not coincidentally, growing acknowledgment that its emissions were accelerating led to Canada's announcement that it would not meet the 2012 goal and was abandoning the KP targets. With a more binding cap, Denmark imposed a penalty for firms that do not comply with its KP target of DKK40/tCO_2, about \$8/tCO_2. New Zealand is discussing the possibility of using a cap to limit economic risk in its national implementation plan (Kerr, 2007). While Australia only signed the KP in late-2007, it has been running an emissions trading pilot scheme in the province of New South Wales, where penalties for non-attainment are set at A\$12/tCO_2, about \$11/tCO_2. While not a general cost containment measure, Germany has delivered cost containment for some by making its coal industry exempt from Kyoto targets.

4.3 Sub-national

A variety of sub-national governments have announced plans to implement climate policies. Most consist of aspirational emissions reductions targets with little or no enforcement mechanisms and as a result, cost containment is less of a concern. But for those with the most ambitious and mature proposals, cost containment is high on the agenda.

Among the most ambitious plans is California's Global Warming Solutions Act (Assembly Bill 32), which the legislature passed in 2006; it sets greenhouse-gas reduction targets for 2020 (Nunez, 2006), and the accompanying Governor's Executive Order includes a 80% reduction target for 2050

(Schwarzenegger, 2005). Assembly Bill 32 mandates that the state implement programs such that emissions are reduced to 1990 levels by 2020, and the Executive Order announced a target of 80% below 1990 levels by 2050. The bill does not specify limits on the carbon price but a "safety valve" clause gives the Governor discretion to waive the emissions reductions requirement in any year in case of "extraordinary circumstances, catastrophic events, or threat of significant economic harm" (Nunez, 2006).

Ten states in the Northeast U.S. have signed the Regional Greenhouse Gas Initiative (RGGI), which targets reductions of 10% by 2018. The most recent version of this agreement includes a "price trigger" of $\$10/tCO_2$, which increases at inflation plus 2% per year (RGGI, 2007). When the price of emissions permits reaches this level, compliance is extended for 4 years and offsets can be used to satisfy targets.

Several other U.S. states and groups of states have proposed greenhouse gas reductions targets, as have hundreds of municipalities. However, since most of these mechanisms do not include consequences for non-attainment, cost containment has not been a concern.

4.4 U.S. federal policy

Cost containment has been a central feature of efforts to regulate greenhouse gases at the U.S. federal level. As of early-2008, the most extensive effort by the U.S. federal government to regulate greenhouse gas emissions consisted of its 2003 voluntary greenhouse gas emissions intensity target, which it achieved ahead of schedule in 2006. Cost containment was accomplished by indexing the targeted reductions to economic growth and by its being voluntary. In 2008, a much more stringent set of policies was being discussed; at least a dozen bills establishing a federal climate policy had been drafted or preliminarily discussed as of early-2008.[1] With the exception of two, these bills include various forms of cap-and-trade systems. While the timing of the proposed emissions reductions for all of these bills are not nearly as aggressive as those specified in the KP, the level of reductions in most of them go well beyond those of the KP's first commitment period. Importantly, they are not voluntary agreements but include legally binding reductions targets. As a result, most of these, and certainly those which have progressed furthest

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[1] The authors and bill numbers for these pieces of draft legislation include: Lieberman-Warner (S.2191), Bingaman-Specter (S.1766), McCain-Lieberman (S.280), Sanders-Boxer (S.309), Kerry-Snowe (S.485), Olver-Gilchrest (H.R.620), Waxman (H.R.1590), Udall-Petri (draft for discussion), Feinstein-Carper (S.317), Alexander-Lieberman (S.1198), Stark (H.R.2069), Larson (H.R.3416).

in the legislative process, include some form of cost containment clauses.

Table 1 summarizes cost containment measures included in each of the bills being discussed in Congress in early 2008. Most include a provision for limiting the costs associated with meeting the emissions reduction targets. The proposed cost-containment measures come in a variety of forms.

- *Pre-specified price caps*: Two of the bills include language about the precise level at which the price of CO_2 emissions credits is set (H.R.1766 and Udall-Petri draft). These proposals also establish at the outset a rate of escalation, usually at some rate above the consumer price index.
- *Discretionary price limits*: Two other bills include measures limiting prices but do not specify the level in advance (S.309 and S.2191). Similar to California's legislation, which gives the Governor authority to override the emissions targets, these bills give discretion to administrators to set limits on carbon prices. In the case of the bill that has advanced the furthest through the legislative process as of early 2008 (S.2191), a new entity would be established, the Carbon Market Efficiency Board, to determine whether carbon prices exceed a tolerable level and how to remedy the ensuing economic damage.
- *Taxes*: Two bills implement cost containment inherently by proposing carbon taxes, with pre-specified levels that increase over time at pre-specified levels (H.R.2069 and H.R.3416).

It is perhaps unsurprising that the bills that do not include cost containment (S.485, S.1198, and H.R.1590) have so far progressed least far through the legislative process.

The proposed bills that fall in the first and third categories, those that specify an upper limit on the price of carbon emissions, vary considerably in both their near term price limit and that for 2030. The range of price caps for 2030 possible within this set of bills is to \$17–92/tCO_2. Fig. 1 shows the price limits which would be in effect through 2030 for the various bills with quantifiable cost containment measures.

5 Effect of cost containment on investment incentives

While opportunities to reduce greenhouse gas emissions at little or no cost may be plentiful, efforts to reduce greenhouse gas emissions to the levels

Table 1: Cost containment mechanisms for climate bills in the 110th U.S. Congress.

Authors	Bill	Cost containment provisions
McCain-Lieberman	S.280	Borrowing for 5-year periods with interest
Sanders-Boxer	S.309	Price cap is set by cost of commercially available technologies.
Feinstein-Carper	S.317	Borrowing for 5-year periods
Kerry-Snowe	S.485	Offsets
Alexander-Lieberman	S.1198	No provisions
Bingaman-Specter	S.1766	\$12/ton CO_2 price cap, rising at 5%/yr above inflation.
Lieberman-Warner	S.2191	Gives Carbon Market Efficiency Board discretion to specify cost containment
Olver-Gilchrest	H.R.620	Borrowing for 5-year periods with interest
Waxman	H.R.1590	No provisions
Stark	H.R.2069	\$3/ton tax rising by \$3 annually
Larson	H.R.3416	\$3/ton tax rising by inflation+10% annually
Udall-Petri	Draft	\$12/ton CO_2 rising at 2–8%/yr above inflation.

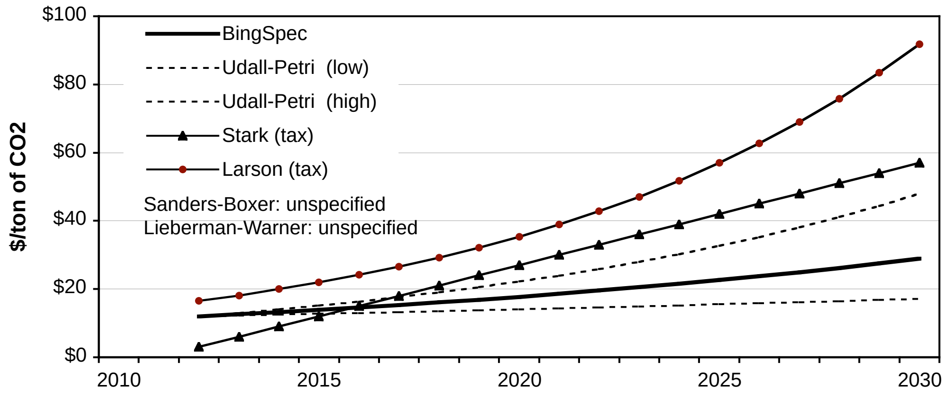

Figure 1: Proposed cost containment measures: upper limits on the price of CO_2 emissions.

prescribed in these bills will involve positive costs—on the order of low single digit percentages of GDP. Policy-induced technological change, is an attractive mechanism in that it can reduce the marginal cost of emissions abatement. This section provides reason for concern that cost containment mechanisms limit the scope for technological change by dampening the incentives for innovators. Efforts to control the cost of regulating greenhouse gas emissions may actually subvert promising technical means by which to reduce costs without abandoning emissions targets. This section uses the concept of a marginal abatement cost curve to show that some technology development projects will be abandoned due to cost containment mechanisms in climate legislation. This effect is quantified using macro estimates and is then related to the decisions that potential innovators face.

5.1 Marginal cost of emissions reduction.

Analogous to a supply curve in microeconomics, a marginal abatement cost curve relates the greenhouse gas (GhG) emissions reductions (q) that are available at each price level (p) at a given point in time. Fig. 2 shows the effect of imposing a cost constraint on the price of carbon. A climate policy, such as those discussed above, might have a quantity target, q' in one year. Meeting emissions reduction target q' would require a carbon price signal of p'. A cost containment measure would limit the price of carbon emissions, such that the price for emissions permits cannot rise above p*. As a result of the lower price, the economy will reduce emissions by q* instead of q'. Because p*<p', emissions will be larger under the price cap than they would be without the price cap. The amount q'-q* are emissions in excess of the quantity limit identified in the climate policy. This configuration creates a problem because even though the 'safety valve' limits the costs of the climate policy, it does not limit the cost of the damages associated with greenhouse gas emissions. In fact, the cost containment mechanism *enhances* these damages by allowing higher emissions than would have occurred without the cap.

With respect to technological change, technologies that would have avoided emissions q'-q* will not be deployed. Also, nascent technologies that have the potential to be effective at costs between p* and p', these are not developed either. Investments in these technologies would have "flattened out" the MAC curve, reducing p', for a given q'. In practical terms, there are technologies that are currently expensive, that would not be invested in if their expected costs are between p* and p'. One might think of a technology such as carbon capture and sequestration with current costs (>$100/ton)

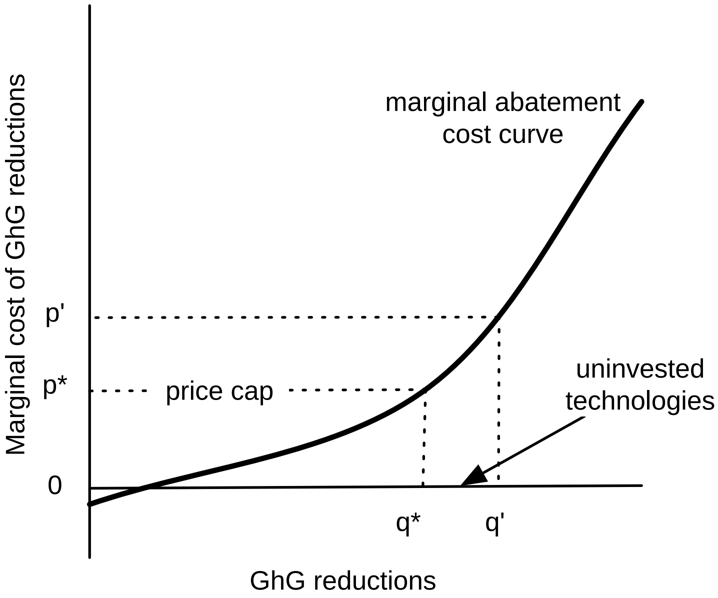

Figure 2: A marginal abatement cost curve and the effect of cost containment measures on the price of greenhouse gas emissions. “Uninvested” technologies are those that would pay off at price levels between p' and p^*.

well in excess of any carbon prices currently being discussed (Anderson and Newell, 2004), but with potential to be much cheaper (Rubin et al., 2007). A price cap on carbon that is an order of magnitude lower than the cost of reducing emissions using this technology will severely restrict the incentive for firms to build new coal plants, e.g. with gasification, which are amenable to sequestration later, never mind investing in improving the CCS technology directly. The principle concern to be highlighted in this paper is that cost containment reduces incentives for investments in technologies like this one.

5.2 Current mitigation cost assessments

Proposed safety valves would cause climate policy to miss reduction targets by substantial amounts. In the interest of sacrificing analytical detail for transparency, here highly stylized macro-economic estimates are used to estimate the extent to which these incentives are lacking.

5.2.1 IPCC meta-analysis

This analysis uses the costs of mitigation undertaken by the Intergovernmental Panel on Climate Change (IPCC) in their Fourth Assessment Report (IPCC, 2007c)(Table 3.15, SPM1, and SPM2). The IPCC used the outputs of multiple integrated assessment models to estimate the potential for reducing greenhouse gas emissions in 2030 at four levels of carbon prices (see Table 2). These estimates provide the total GhG reductions available for which the marginal cost of abatement is equal to or below each of the four CO_2 prices.[2] The mitigation potentials from Table 2 are plotted in Fig. 3 as marginal abatement cost curves, showing the range of expected reductions available at various carbon prices.

Limits on CO_2 prices for 2030 are calculated using specifications in each of the four proposals with an explicit cost containment provision (Fig.1).[3] Quantity targets for 2030 are then estimated for those policies which include GhG reduction targets. These amounts are compared to the IPCC results using the example of S.1766 (Bingaman-Specter), the one proposal that

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[2] The models used fall into one of two categories: "top-down" approaches use macroeconomic models that characterize market feedbacks and "bottom up" approaches use models that explicitly characterize individual sectors of the economy and the technologies used within them.

[3] Note that two proposals that involve carbon taxes are treated as cost containment policies because that is one of the primary reasons for choosing a tax over a quantity-based target.

Table 2: Range of economically available greenhouse gas emisions reductions available at various carbon prices. Survey of model results by the IPCC (IPCC, 2007c).

Carbon Price ($/ton CO_2eq.)	Reductions (%) "bottom-up"	Reductions (%) "top-down"
$0	7-10%	n/a
$20	14-25%	13-27%
$50	20-38%	21-34%
$100	23-46%	25-38%

specifies both emissions reductions levels and safety valve levels for 2030.[4] The goal of returning U.S. GhG emissions to 1990 levels by 2030 specified in S.1766 represents a 37% reduction from BAU levels. This quantity target and the safety valve level in S.1766 are compared to the IPCC range in Fig. 3. One can observe that the quantity target (vertical dashed line) does intersect the IPCC range of emissions reduction possibilities below the price cap; the minimum cost of reducing emissions to the S.1766 quantity target is just under $50/ton ($48). The upper end of the range of costs estimates for meeting the quantity target is $>$ $100 ($337). The midrange value is $125. The main point is that even for the least expensive MAC, the safety valve will be a binding constraint on the carbon price. At the safety valve level of $28.88/ton, the IPCC MAC implies that we can expect reductions of 15% to 30% (midpoint -22%), well short of the quantity target of -37%. While this result depends heavily on our assumption of marginal abatement costs, it is found in other, more detailed models, as well.

5.2.2 EIA and EPA analyses

As a comparison, consider two other analyses of this bill. The Energy Information Administration's (EIA) analysis of S. 1766 used its National Energy Modeling System (NEMS) (EIA, 2008). They project that emissions with a price cap in place will be approximately 26% higher in 2030 than in the case without a price cap (page 9). Similarly the EPA's analysis of S. 1766 (EPA,

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[4] Note that the IPCC economic potential figure are worldwide. Previous studies show that marginal abatement costs for 2030 are more expensive in the OECD than in the rest of the world (see for example Table 11.3 in IPCC (2007c)). We thus treat this curve as a lower bound on the costs of making emissions reductions for the U.S.

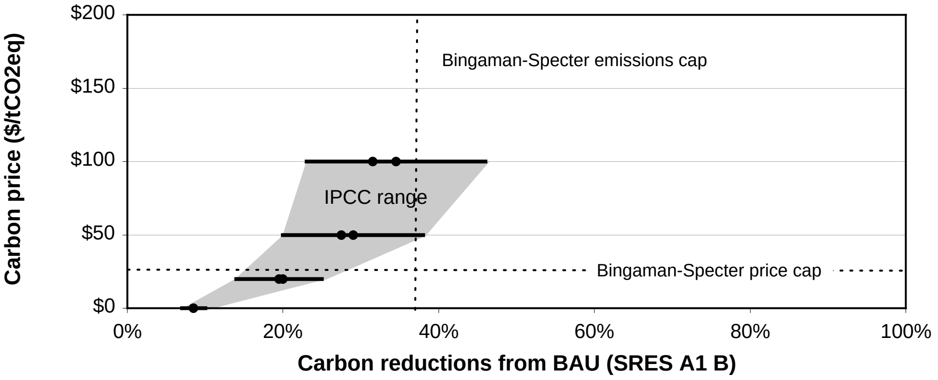

Figure 3: Range of marginal abatement cost curves for 2030 using IPCC AR4 cost estimates. Dashed lines show emissions targets and safety valve level under S.1766 (Bingaman-Specter).

2008b), using the models ADAGE and IGEM, finds that emissions will be 23% above the cap when a price cap is in place. The EIA forecasts that market prices will exceed the price cap in 2020 (page 12). The EPA finds that market prices will exceed the price cap from the beginning of the program, even under the case where 10% of reductions can be achieved through purchasing international offsets.[5] Table 3 shows how these figures compare with each other and with our simulation of the IPCC results.[6] Relative to these two models the simple model used in this analysis (IPCC) has lower marginal abatement costs in the early years, 2015–20 and higher abatement costs from 2030 onwards. We take the full range of estimates into account in the simlations to follow.

5.3 The climate innovation investment decision

Under safety valves levels such as these, innovators, who decide whether to make investments in innovation for low-carbon energy technologies, will invest less. The payoffs to innovators' investments are affected by both technical uncertainty and policy uncertainty. They decide whether to proceed with a project if the net present value of the revenues (R) equals or exceeds the costs (C). The expected revenues (R) decrease with the marginal costs of

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[5] Allowing unlimited international offset purchases keeps the price below the cap.

[6] Note that the delayed crossover years are due to provisions for banking in the early years, which this analysis does not take in to account.

Table 3: Comparisons of future emissions and marginal abatement costs across models for a proposal targeting 37% reductions from BAU by 2030.

	Year at which $p^* \geq p'$	Emissions above cap 2020	2030	MAC ($\$/tCO_2$) 2015	2020	2030	2050
IPCC (mid)	2023	–	24%	-6	11	125	483
IPCC (low)	2027	–	11%	-5	5	48	292
IPCC (high)	2019	3%	35%	-5	26	337	994
EIA	2020	5%	26%		≥ 15	≥ 25	
EPA	<2015	14%	23%	27–29	35–37	57–61	149–162

production (M) and increase with the government-imposed price of carbon (p'):

$$R = f(-M, p') \tag{1}$$

The costs of the new technology are the sum of the R&D investment (D) required to develop the technology, and the marginal costs involved in production.

$$C = D + M \tag{2}$$

The marginal cost is determined by the success of the R&D program in creating costs savings (S) from the original marginal cost, M_o. The size of the cost savings is defined by an exogenous technical opportunity which the investing firm knows ex ante. The probability of achieving those savings is defined by a function, (σ) and increases with the size of the R&D investment.

$$M = M_o - S\sigma D \tag{3}$$

The investment is made if revenue is equal to or exceeds costs:

$$f(M, p') \geq M_o + D(1 - S\sigma) \tag{4}$$

If a price cap p^* is imposed such that $p' > p^*$, firms will make fewer investments in new technologies. The cap would reduce the incentives for investing in new technologies that might enable very large reductions in emissions, but whose costs are expected to be above the price cap. One could still argue that investment in those technologies would be wasteful because their costs exceed the damage avoided by their deployment. However, there are risks associated with abandoning such investments; we may eliminate backup technologies, or at least drastically reduce their investment in development and commercialization.

5.4 Climatic uncertainty and backstop technologies

The promising low carbon technologies that do not get invested in because of the price cap are a concern for two reasons. First, there are substantial uncertainties in the damages that will result from future emissions of GhGs. Second, developing, commercializing, and deploying new energy technologies takes time; lags between policy-led price signals and sufficient technological diffusion to ameliorate environmental damages are difficult to shorten. The ability to respond relatively quickly to changes in risks of climatic damages depend on the availability of "backstop" technologies (Popp, 2006).

The human damages that will result from emissions of greenhouse gases, while the central concern of climate policy, are the most uncertain aspect of the climate change problem, because they lie at the far end of the cascade of uncertainties to do with emissions, the carbon cycle, and terrestrial, oceanic, and atmospheric responses. While scientific understanding of the climate system and the carbon cycle has progressed, the uncertainty around the estimate of future damages generally has increased, rather than decreased. This increase in uncertainty has been observed in surveys of expert judgement (Morgan and Keith, 1995). The persistently large, and in some cases growing, uncertainty is also visible in comparing the conclusions in the last two reports from the IPCC, cf. Houghton et al. (2001) and IPCC (2007a). The projected range of temperature change for 2100 in the Third Assessment Report was 1.4 to 5.8°C, while that reported in the Fourth Assessment Report was 1.1 to 6.4°C (Houghton et al., 2001; IPCC, 2007a).[7] One degree of warming would have modest effects, while 6.4 would likely include catastrophic human impacts (IPCC, 2007b). In addition, there is recent evidence of current developments exceeding high cases in the models, for example for the extent of arctic sea ice (Maslanik et al., 2007), emissions (Raupach et al., 2007), and the fraction of GhG emissions remaining in the atmosphere relative to the oceans and terrestrial systems (Canadell et al., 2007). Further, technological change assumed in business-as-usual scenarios may grossly underestimate the magnitude of the change required (Pielke

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[7] While the treatment of likelihood makes these not directly comparable, there is little evidence that uncertainty is disappearing.

et al., 2008). Finally, a major reason for concern about the high range of the bounds on damages is due to the lack of characterization of complicated positive feedback mechanisms in existing models, which can have large effects on damages (Torn and Harte, 2006). The notion that a price-based or hybrid mechanism is advisable over a quantity-based climate policy because uncertainty in compliance costs is of greater concern than uncertainty in damages is difficult to reconcile with the large uncertainties in current climate science.

The uncertainty in future damages raises the value of having technologies available as "backstops," technologies that can provide additional emissions reductions, but at generally higher than expected costs. And, because developing and deploying emerging technologies takes time (Grübler et al., 1999), it is worthwhile to invest ahead of time in backstop technologies. The problem is that a cap on the price of emissions credits provides no incentives for private sector actors to invest in technologies that are useful for stringent emissions reductions. In any case, targets for 2050 are likely too low if we are going to stabilize the climate (Weaver et al., 2007). Intermediate term policies need to be oriented to reducing emissions to zero - a goal that both recent policy (Conover, 2005) and science (Matthews and Caldeira, 2008) have embraced.

5.5 Adaptation

Increasing damages means that additional investments in adaptation will also be needed. However, the imposition of a price cap on carbon affects incentives for adaptation differently than those for mitigation. If one assumes that individuals, households, firms, and governments determine their investments in adaptation based on the anticipated future damages, then demand for adaptation *rises* with increasing damage costs. Because cost containment mechanisms allow emissions in excess of the price cap, they *increase* the private incentives to invest in adaptation measures to protect themselves from these damages (Table 4). The issue then is not one of weak incentives, but rather, whether vulnerable populations should be left to their own resources to protect themselves from the excess emissions that result from cost containment. One could argue that equity and "polluter pays" principle concerns justify investments in adaptation for the most vulnerable. One should be explicit that it is these concerns and not incentive problems that motivate public investment in adaptation from such a fund.

Table 4: Adaptation and mitigation: the effect of a price cap on the social need and private incentives for each.

	Social Need	Private Incentives
Adaptation	↑	↑
Mitigation	—	↓

6 Simulations of a linking mechanism

This paper has argued that not only is technology policy needed to complement carbon policy, but that cost-containment clauses create a need for a mechanism that links the two. Here one possible mnechanism is described.

6.1 The goal of the linking mechanism

Imposing a price cap is not cost-free. The distortionary effects of cost-containment measures in climate policy exacerbate the market failures that already exist for developing technologies to address environmental problems (Jaffe et al., 2005). Distortions occur regardless of whether the cap is set ex ante, is indexed to economic activity, or is set by the discretion of a Federal Reserve-like oversight board. These unfavorable effects can be ameliorated by policies to create incentives for technological innovation and build capacity for adaptation. Because the size of the distortionary effect of cost containment measures increases with the how binding the price cap is, the stringency of the complementary technology and adaptation efforts should be determined by the size of the distortion. The more heavily we rely on a price cap to reduce the cost of climate policy, the more we need to invest in complementary policies. In practical terms, when the price cap is reached, and the government starts printing more emissions permits to reduce the market price, it also needs to invest in technology development for mitigation. This fund would be used for activities such as investments in research and development, creation of technology prizes, funds to pay for inappropriable learning investments through buy downs and demonstration projects. Precedents for such societal trust funds exist (Pena and Rubin, 2008).

6.2 Implementing the mechanism

This paper proposes that one way to remedy this distortion would be to (1) create a fund for mitigation and adaptation and (2) index contributions to that fund to the amount by which the market price for carbon exceeds the price cap.

The price cap benefits polluters by allowing them not to pay for the pollution they would have had to pay for if the original quantity limit were met. As Fig. 4 shows, the price cap restricts emissions reductions to level q^* instead of q'. The damage that will be caused by the additional emissions, $q' - q^*$ is the societal cost of the cost containment insurance. The notion behind this mechanism is that the government invests a portion of the payments for emissions credits that polluters do not make. As a result of the cost reductions derived from the technology program, the marginal abatement cost (MAC) curve would shift downward. This shift would increase the scope of emissions reductions that would be affordable under the price cap, so that the new level of emissions reductions would be q_t rather than q^* and the social cost of the cost containment measure would be reduced to $q' - q_t$. To be sure, for a given level of cost containment, this scheme does introduce additional cost into the climate policy program. But it is important to note that there are serious risks associated with 'costless' insurance against cost increases. One way to mitigate those risks is to invest in the capacity to mitigate them in the future, through R&D, and deal with those that we do not avoid, through adaptation.

The following describes how this mechanism might work in practice. The price cap gets set exogenously at level p_c while the cap and trade agreement is being negotiated. It may be set to rise at a level above that of the general price level. Each year, the cap on emissions allowances becomes more stringent relative to the business-as-usual case. At some point, the marginal cost of abatement for that emissions reduction level increases to a point above the p_c. In order for this mechanism to function, the cap-free emissions price, p' must be determined.[8] The savings to polluters (σ) that result from the cost containment scheme are equal to the difference between the costs that polluters face with a price cap in place and without one.

$$\sigma_t = \int_{q^*}^{q'} M(q)\, dq \tag{5}$$

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[8] This might be done using shadow prices of demonstration markets or prices from other countries without price caps. The issue is similar to that of defining a business-as-usual case from which reductions are compared; assumptions are needed.

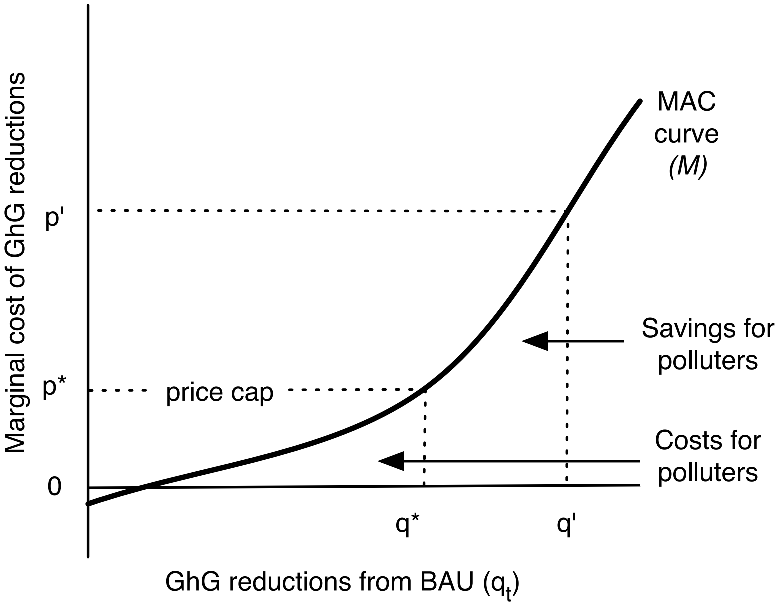

Figure 4: Marginal abatement cost curve showing the effect of a price cap on the costs faced by polluters under a carbon constraint. The savings are the difference between the costs faced by polluters with and without a price cap.

where q is the level of emissions reductions. A blunt proposal is to devote a fixed percentage of the cost savings (α) toward the technology and adaptation fund (F):

$$F_t = \alpha\sigma_t \tag{6}$$

As long as $\alpha < 1$, the benefits of cost containment will be maintained. The net benefits of the program will be a result of the productivity of R&D in reducing the marginal cost of abatement M as a result of investments, F.

6.3 Simulations

We ran simulations from 2010 to 2030 to examine the effect of a price cap on emissions, carbon prices and the financial impact to emitters. Because our objective is to understand the sensitivity of emissions and prices to the level of the price cap, we intentionally use a combination of a quantity-based limit and cost containment mechanism from two separate bills in the U.S. Congress. As a result, this analysis is not intended to analyze any specific policy. We use the full range of estimates from the IPCC for the marginal abatement cost curves (Fig. 5). It is important to note that this range fully encapsulates the assumptions on emissions abatement costs under the analyses by the EPA and EIA discussed earlier. We are especially interested in the effects on emissions when the price cap is set low, relative to the expected price, as is the case in recently proposed legislation.

The results of these simulations are summarized in Table 5. These results are for 2030, at which point the price cap we are using (S.1796) will have risen to \$29/ton. To show the effect of the emissions cap, we present results for two quantity-based emissions limits, -37% (S.2191) and -50% (S.1796). We use the midpoint and high and low values for the stylized marginal abatement cost curve and calculate values for each. Column 1 shows the marginal price for carbon permits if emissions were reduced to the quantity limit, in the absence of a price cap. The large dispersion in values is a function of uncertainty in the MAC curve. Column 2 shows the emissions reductions from BAU that would be expected if the price cap is included. The difference between the values in column 2 and the specified emissions limits in each of the bills leads to “excess emissions”’ which are shown in column 3. These are emissions that would not be allowed under the quantity cap but which are allowed if the price cap is in place. Emitters benefit financially from the price cap because they do not have to pay for these excess emissions. The annual savings are shown in Column 4. The savings in 2030 alone range from tens of billions to hundreds of billions of dollars. Column 5 shows the

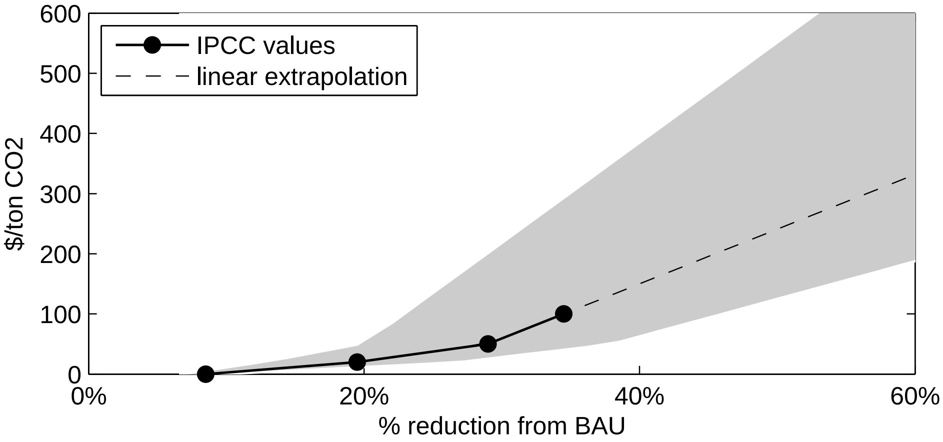

Figure 5: Marginal abatement cost curves derived from IPCC values. Data: IPCC (2007c)

contributions that would be made to a technology development fund if 10% of the emitters' savings are dedicated.

The following figures show the path of these values over time. For these figures, we use only the recently proposed quantity based target from S.2191 and a cost containment mechanism from S.1796. The black line shows the outcomes based on the midpoint value for the marginal abatement cost curve. The gray area shows the range of values defined by the high and low MAC values. Fig. 6 shows business-as-usual emissions, the emissions expected including a price cap (including uncertainty), and emissions under a quantity cap in the absence of a price cap. Note that the price cap becomes binding between 2013 and 2019. Fig. 7 shows the range of prices generated by the MAC curves in order to meet the quantity-based target. The solid line shows the level of the price cap over time. Fig. 8 and 9 show "excess emissions" over time. By 2030, between 1.6 and 2.8 gigatons of excess CO_2 are being emitted as a result of the price cap mechanism. This leak means that emissions will be 40% to 70% higher than they would have been without the price cap.[9] Finally, Fig. 10 shows the annual savings to polluters over time that result from the price cap. The left axis shows the revenues available if 10% of these savings are devoted to a technology fund.

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[9] A similar analysis of S.1796 shows excess emissions of 11% to 35%, due to a less stringent reduction target. Combining the results for S1796 and S.2191, we get an overall range of excess emissions of 11% to 70%.

Table 5: Policy simulation results for 2030. Assumes a price cap for carbon permits of $29/ton in 2030.

	1 Price at qty. cap (\$/tCO$_2$)	2 Qty. at Price cap (%)	3 Excess emissions (GT CO$_2$)	4 Savings to emitters (\$b)	5 Contrib. to Tech. Fund (\$b)
Bingaman-Specter (S.1766): -37% by 2030					
Low MAC	48	-0.30	0.5	21	2
Mid MAC	125	-0.22	1.2	78	8
High MAC	337	-0.15	1.7	281	28
Warner-Lieberman (S.2191): -50% by 2030					
Low MAC	124	-0.30	1.6	106	11
Mid MAC	240	-0.22	2.2	261	26
High MAC	548	-0.15	2.8	724	72

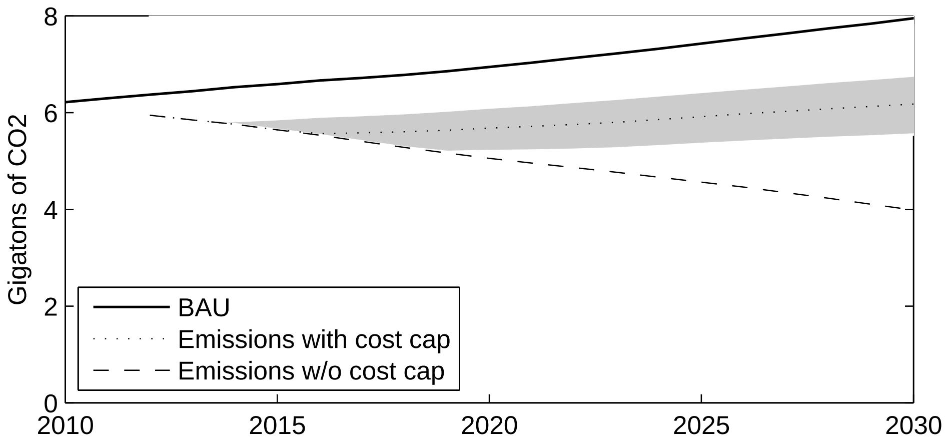

Figure 6: Emissions: business-as-usual, specified quantity targets, and projections under price cap.

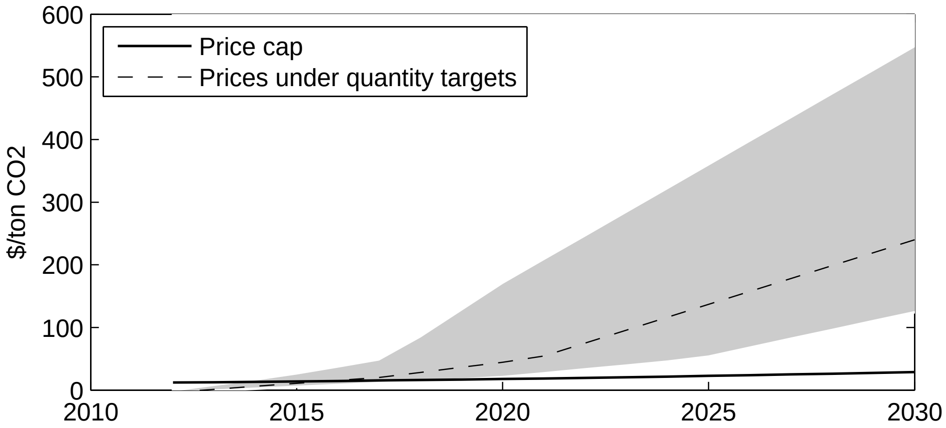

Figure 7: Carbon prices and proposed price cap.

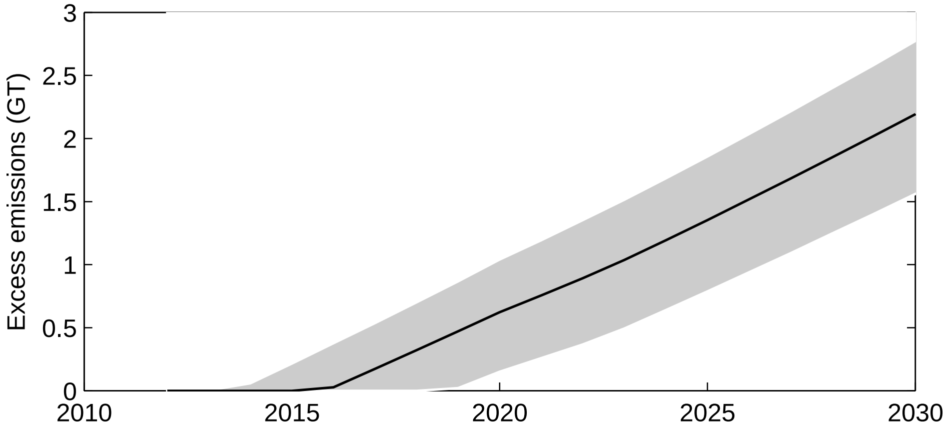

Figure 8: Amounts by which price cap causes emissions to exceed the quantity cap (Gigatons).

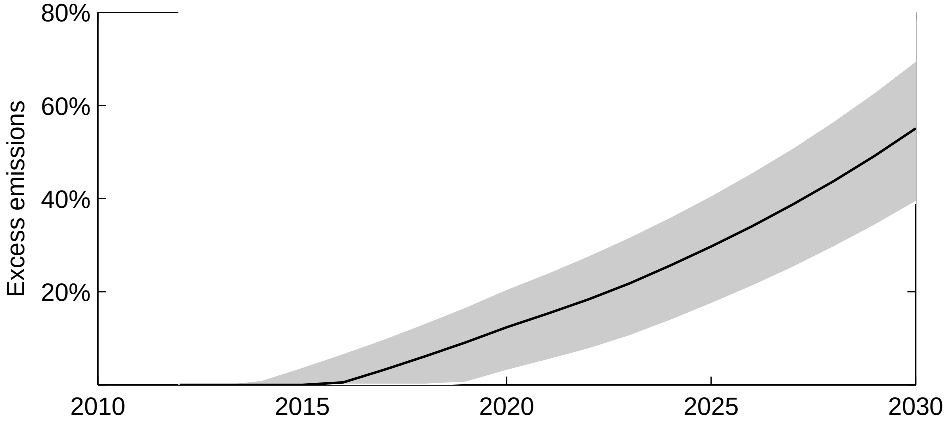

Figure 9: Amounts by which safety valve causes emissions to exceed the quantity cap (excess emissions under a safety valve relative to emissions under quantity based emissions limit).

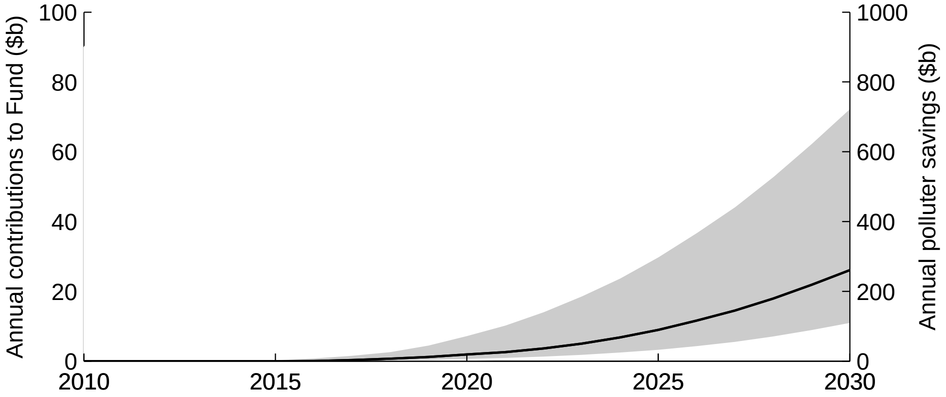

Figure 10: Benefits to emitters. Annual savings to emitters resulting from cost containment measures are shown on right axis. Contributions to a technology and adaptation fund are on the left axis, assuming contributions of 10% of savings.

A proposed Technology Accelerator Payment (TAP) in S.1766, includes many positive features that this proposal would provide. It allows polluters to purchase excess emissions at the price cap and devotes the revenues from those sales to technology programs. The order of magnitude of those revenues are similar to those of a 10% cost fund proposed here. However, since the TAP does not take into account how expensive excess emissions reductions may be, it may be under-sensitive to the amount of investment required. A TAP will be most effective at generating revenues for investment when the price cap is close to the actual price, which this analysis shows is not the case given current proposals. Still, it is a policy innovation that captures many of the benefits of the mechanism proposed here.

7 Summary

Cost containment mechanisms can limit exposure to near term price volatility under nascent cap and trade schemes. But setting cost containment mechanisms at low levels and putting them in place for many years, as is currently being discussed, introduces substantial environmental risk while discouraging innovation. Simulations produced by the highly stylized model introduced here show that cost containment measures being discussed will lead to much higher emissions of greenhouse gases; these measures will increase emissions by between 11 and 70 percent. These excess emissions will introduce additional damages. At the same time, cost containment reduces the incentives for innovation in low-carbon technologies by eliminating the upper tail of the payoffs to innovation. We should not expect a regime of stringent, but *avoidable* targets to stimulate investment in technologies that only pay off at high carbon prices. Relying on ‘contained’ price signals as the primary source of incentives for innovation limits our ability to reduce emissions later, should the damages become more severe than anticipated. This effect will increase the long term cost of climate policy and put substantial pressure on efforts to adapt to a changing climate. Resolving this impasse between higher expected damages and weakened incentives will require an alternative mechanism to reduce and adapt to these damages. A technology development fund that is linked to the price cap provides a means by which to retain our ability to mitigate climate change while retaining insurance against high costs.

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