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(OVERLY) GREAT EXPECTATIONS: CARBON PRICING AND REVENUE UNCERTAINTY IN CALIFORNIA

James B. Bushnell

California's cap-and-trade market for greenhouse gasses (GHG) began in 2013. An important feature of the California trading system was its allowance price-containment policies, intended to limit the range of allowance prices. The scope and ambition of the system had been expected to set an example for other states and countries about the efficacy and revenue potential of cap-and-trade systems. However, despite achieving its emissions reductions targets at lower than expected costs, the system has been considered a disappointment in the political arena. A major source of disillusionment with the California system has been its failure to generate the expected amount of revenues that would have contributed to a wide range of public expenditures. The design of the price-containment system, while effective at maintaining a relatively high marginal carbon price, contributes to the wide range of uncertainty over the revenue potential of allowance sales.

Keywords: cap-and-trade, price collar, carbon pricing, revenue stability

JEL Codes: Q54, Q58, H23

I. INTRODUCTION

Environmental economists have consistently advocated for some form of carbon pricing as a foundational element of climate policy, as summarized in Aldy et al. (2010). While many economists favor a carbon tax, the more common instrument in practice has been cap-and-trade. Both instruments achieve the primary environmental goal of establishing a price on carbon emissions and forcing firms and consumers to internalize the external cost of their emissions.[1] In practice, however, policymakers have usually focused on elements other than the goal of establishing an efficient carbon price. In states and regions that are inclined to pursue carbon policy, debates have focused more on the level and use of revenue generated from carbon pricing. In this dimension,

[1] A line of literature starting with Weitzman (1974) examines the ex-post efficiency of price instruments (such as taxes) relative to quantity instruments (such as caps) in the presence of uncertainty.

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carbon taxes can appear to have the advantage of stability, given the fact that the tax rate should be more stable and predictable than an endogenously determined allowance price from a cap-and-trade system. When it comes to revenue stability, however, the specific details of how an instrument, either cap or tax, is implemented can matter more than the choice of the instrument itself.

This paper examines the revenue question in the context of California's recent experience with carbon pricing. The California system of cap-and-trade for greenhouse gasses (GHG) began in January 2013 and at the time of this writing is halfway through its 5th year. As deadlines approached for renewing the system and maintaining a viable market past 2020, the system has come under intense scrutiny and criticism, primarily from the left of the political spectrum. One major source of the disillusion with cap-and-trade in California has been that state revenues have fallen well short of expectations. A June 2016 column in the *Sacramento Bee* concluded that "the meltdown of California's cap-and-trade system of reducing carbon emissions has not only thrown its climate change crusade into disarray but caused collateral damage."[2] The column noted that California Governor "Jerry Brown's $3.1 billion plan to spend auction proceeds, is now on indefinite hold." Community groups and activists focused on local pollution and environmental justice concerns have also emerged as vocal critics of cap-and-trade. These two sources of discontent are linked as allowance auction revenues were expected to help to contribute to projects that would address local pollution concerns.

The California carbon market has an allowance price floor set at a relatively high price relative to other carbon markets, starting at $10.00/ton CO2e in 2012 and rising each year at a 5 percent real rate of escalation. By contrast, the price floor in the Regional Greenhouse Gas Initiative (RGGI) in the U.S. Northeast is only $2 per ton, while the European Union Emissions Trading System (ETS) has no floor price at all. Four years into trading, the California market has rarely cleared above this floor price. This is not an entirely unexpected outcome. A combination of relatively loose early targets combined with aggressive carbon reduction policies that have been implemented through other channels implied that there could be only modest need for the abatement induced by a higher carbon price. Borenstein et al. (2016) forecasted more than a 90 percent probability that prices might settle at the 2020 floor price by 2020. Less well understood, however, is the way in which the mechanism that enforces the allowance floor price contributes to the volatility of state revenues. In this paper, I describe this interaction and quantify how it contributes to the range and uncertainty of state revenues. I also explore how alternative mechanisms may have mitigated the range of revenue fluctuations. This paper is closely related to Borenstein et al. (2016) and uses the forecasting results developed in that paper to generate revenue estimates. In Section II, I give a brief review of the literature on the role of carbon pricing in public finance. In Section III, I describe the California cap-and-trade market and how it operates within the context of

[2] "Jerry Brown's vow to slash oil use in California's cars in trouble." *Sacramento Bee*, June 21, 2016, http://www.sacbee.com/news/politics-government/politics-columns-blogs/dan-walters/article85150877.html.

a broader set of policies aimed at reducing carbon emissions. I then examine alternative approaches to carbon pricing, including a change in the price floor scheme that would share the burden of shortfalls in allowance sales more evenly between the state and other stakeholders receiving free allocations of allowances. Section VI concludes.

II. CARBON PRICING AS A SOURCE OF PUBLIC FUNDS

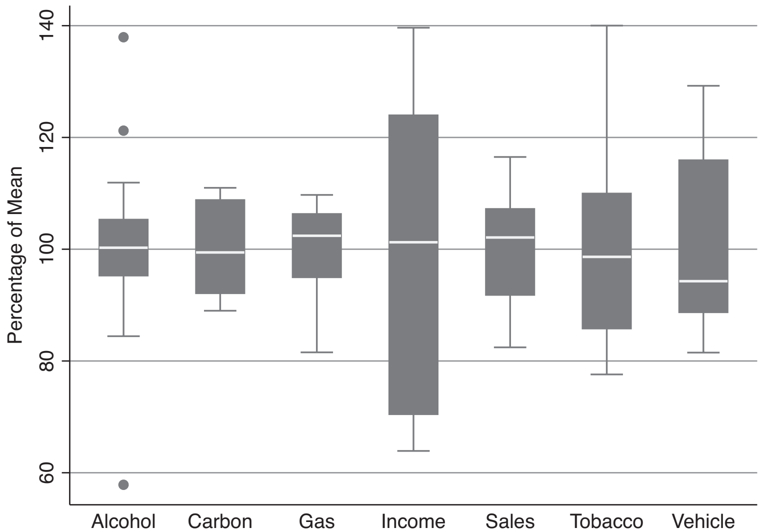
Both the public debate and academic studies of carbon pricing have been largely focused on its prospects for mitigating emissions and combating climate change. As discussed in Aldy et al. (2010), economists generally agree that carbon pricing of one form or another provides significant advantages over other policy tools. However, both policy makers and academics have long been aware of the attraction of carbon pricing (either taxation or through a cap-and-trade scheme) as a source of public funds. Much of this work, such as Bovenberg and Goulder (1996), Goulder (1995), and Fullerton (1997) focused on the so-called "double dividend," the prospect that carbon-taxes could increase welfare both through the direct pricing of the environmental externality and the indirect benefit of using the associated revenues to reduce other forms of distorting taxation.

Certainly the revenue potential of carbon pricing is significant. Metcalf (2009) estimates that a $15/ton carbon tax would raise more than $90 billion annually in the United States. During the period around 2010, when a national cap-and-trade policy seemed to be a realistic possibility, the economics literature considered more specific implementation issues. Marron and Toder (2014) examined the distributional impacts of a carbon tax, as did Williams et al. (2014). Several papers, such as Metcalf (2014) and Fowlie (2012) examine options for mitigating leakage and protection trade exposed industries.

While there has been much discussion about the potential level of revenues that could be collected under a carbon tax or cap, there has been less focus on the reliability of such a revenue stream. Metcalf (2009) notes the prospect of steady decline in revenues as the carbon price induces reductions in emissions, but does not consider the volatility of year-to-year emissions. McKibbin, Morris, and Wilcoxen (2009) study in detail the vulnerability of a global carbon pricing system to macro-economic shocks. They highlight the advantage of individual national schemes having an ability to at least insulate themselves from these shocks.

McKibbin, Morris, and Wilcoxen highlight the sensitivity of carbon emissions to economic conditions, and the long-range unpredictability of both. One implication of this fact is that revenues tied to this unpredictable source will themselves be unpredictable. Morris (2016) documents a closely related issue, the vulnerability of certain state budgets to volatility in the revenues associated with mineral extraction. In the California context, emissions have fluctuated considerably even in the absence of an explicit carbon price. Figure 1 illustrates the relative stability of different revenue streams in California compared to a hypothetical carbon tax. I use data from the California Legislative Analyst's office for revenue collection from 1990–2009 and combine this with carbon emissions data from the California Air Resources Board. California's budget

Figure 1
Volatility of CA Revenues
(Ranges of Revenue Relative to 1990–2000 Mean)



Notes: Data are available at http://www.lao.ca.gov/PolicyAreas/state-budget/historical-data.
Source: Author's calculations from California Legislative Analyst's Office data

has been notoriously reliant on a highly volatile source of personal income tax revenue, and carbon taxation would certainly provide more stability on a year-to-year basis. It is important to note that year-to-year stability is not the same thing as long-range predictability of average revenues. In fact, policy discontent in California has stemmed from both the quarterly volatility as well as the disappointing level of revenue collected from California's carbon market.

III. THE CALIFORNIA CAP-AND-TRADE MARKET

The Global Warming Solutions Act of 2006 (AB 32) called for California to reduce its GHG emissions to 1990 levels by 2020, and assigned the responsibility for developing a strategy for meeting this target to the California Air Resources Board (CARB). Between 2006 and 2010, the CARB developed a scoping plan of regulations that included a renewable electricity standard, automotive mileage standards, a standard for low-carbon fuels (LCFS), and a cap-and trade market.

By setting an emissions target specifically for the year 2020, AB 32 was somewhat ambiguous about what was intended post-2020. It was widely expected that subsequent legislation would resolve this uncertainty. Senate Bill 32 (SB 32), passed in 2016 did establish a more ambitious target of a 40 percent reduction of GHG from 1990 levels by 2030, but this latter bill was notably silent on the role of cap-and-trade in achieving this goal. This lack of an explicit legislative mandate for cap-and-trade is more significant now than it was in 2006, due to a California ballot measure described later.

The question of whether the CARB's authority extended to cap-and-trade was challenged by the California Chamber of Commerce, who maintained that a cap-and-trade system constituted a form of taxation, which, under California law required a 2/3 vote of the Legislature that AB 32 did not receive. On April 6, 2017, the 3rd District Court of Appeal in Sacramento unanimously upheld CARBs authority to conduct auctions under AB 32, providing support for the current market.[3] However unlike AB 32, SB 32 is subject to California Proposition 26, passed in 2010. This measure extended the 2/3 requirement to any fee, levy, charge, or exaction as well as conventional forms of taxation.[4] The CARB still maintains that it has the authority to continue its cap-and-trade system beyond 2020, but other parties, such as the California Legislative Analyst's Office disagree with that conclusion. It was widely believed that, absent 2/3 legislative approval, the cap-and-trade system would have operated under a degree of legal uncertainty even greater than that experienced to this point. After extensive debate, and the introduction of at least three other cap-and-trade bills, Assembly Bill 398 (AB 398), a bill that authorized the extension of cap-and-trade to 2030 following a similar framework to the current program, was passed with more than a 2/3 majority in mid July. In this paper, I focus on the performance of the market up to the Spring of 2017.

A. The Cap in the Context of AB 32

The cap-and-trade program established an aggregate cap covering approximately 85 percent of the state's GHG emissions, and a system of tradable emissions allowances that regulated facilities must use to meet their compliance obligations. The program covers emissions for the years 2013–2020, and is partitioned into three compliance periods. Beginning in 2013, emissions obligations were assessed on industrial facilities and importers ("first deliverers") of electricity to the California grid. Emissions associated with fossil transportation fuels and retail sales of natural gas were included in 2015, at the start of the second compliance period. The third compliance period runs from 2018 through 2020.

Unlike the systems envisioned by economists and other advocates of market-based environmental instruments, California's cap-and-trade program was never positioned as the primary policy mechanism for achieving AB 32's goals. This was in part due to a

3 The Plaintiffs argued that the quarterly auctions constitute an illegal tax under Proposition 13 https://www.scientificamerican.com/article/court-upholds-californias-cap-and-trade-program/.

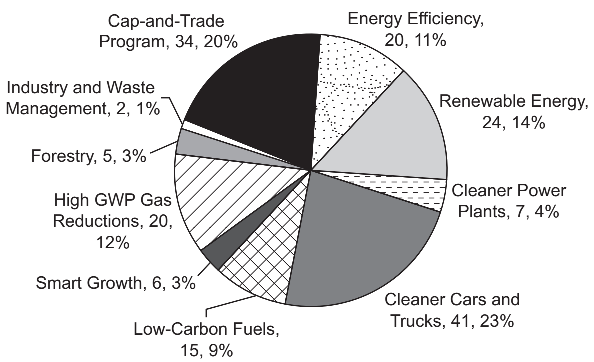
4 "Any change in state statute which results in any taxpayer paying a higher tax must be imposed by an act passed by not less than two-thirds of all members elected to each of the two houses of the Legislature." https://ballotpedia.org/Text_of_Proposition_26,_the_Supermajority_Vote_to_Pass_New_Taxes_and_Fees_Act_(California).

general mistrust of market instruments in the wake of California's 2000–2001 electricity crisis and in part due to strong support for a range of more targeted policies that were believed to produce more tangible, and easily measured, impacts. Indeed, as illustrated in Figure 2 the CARB was careful to point out that under its scoping plan of compliance options, cap-and-trade was expected to provide only 20 percent of the abatement necessary to achieve AB 32's goals. The bulk of the abatement was expected to come from a suite of what CARB has called complementary policies, including mileage standards on passenger vehicles, a renewable electricity standard, and a low-carbon fuel standard.

From Figure 2 it is also clear that many of the complementary policies are directed at industries also subject to the cap. Electricity and transportation comprise roughly 70 percent of California's GHG emissions, and the vast majority of these emissions now fall under California's cap. These sectors are also the targets of the most significant complementary policies. One implication of these overlapping policies is that, when successful, they reduce demand for emissions allowances and therefore can indirectly depress allowance prices. A second important factor to note is that, the expected reductions illustrated in Figure 2 are relative to a 2006 vintage forecast of a 2020 baseline of emissions. This comprises a single point estimate of a variable, 2020 Business-as-Usual (BAU) emissions, around which there was and remains much uncertainty. One potential implication of this, as discussed in Borenstein et al. (2016), is that allowance prices are much more likely to be either at or near the level of the auction reserve price (floor), or at levels set by the allowance price containment reserve (APCR) (ceiling) than they are to be at some intermediate level. Borenstein et al. (2016) demonstrate that when one considers the full potential distribution of BAU emissions, the probabilities of prices falling at either the APCR ceiling or auction reserve price floor could constitute a large fraction of the overall distribution of potential emissions outcomes.

Figure 2

Expected Sources of Abatement Under CA AB 32



Source: California ARB 2008 Scoping Plan

B. Price Containment Mechanisms

The California GHG market is also notable for its policies that restrict the range of possible allowance prices. In recognition of the problems created by uncertain allowance prices, economists have long proposed hybrid mechanisms that combine emissions caps with price-collars that can provide both upper Jacoby and Ellerman (2004) and lower Burtraw, Palmer, and Kahn (2010) bounds on allowance prices. Such hybrid mechanisms can greatly reduce allowance price risk while ensuring a better match between ex-post costs and benefits (Pizer, 2002). While the European Union ETS has no such bounds, the trading system proposed under the never-enacted Waxman–Markey bill of 2010 included price collars of a sort, as does California's program. The fact that California's market currently has the highest price among mandatory GHG cap-and-trade programs is largely due to its relatively high floor price.

Importantly, the price-containment mechanisms in California increases the likelihood, but does not guarantee, that prices fall between an *auction reserve price* at the low end and a *containment reserve price* on the high-end. The upper limit on prices is supported by an APCR. Of the 2,508 million metric tonnes (MMT) of allowances in the California program over the 8-year period from 2013–2020, 121 MMT of allowances were originally assigned to the APCR. These allowances were only made available at allowance prices of $40, $45, and $50 (in equal proportions) in 2012 and 2013. In later years, these price levels increase by 5 percent plus the rate of inflation in the prior year. In theory, if this reserve were exhausted, there would be no other official restraint on allowance prices. As Borenstein et al. (2016) point out, however, there has been widespread belief that the political environment in California would not tolerate allowance prices above (or perhaps even reaching) the APCR price levels.

As I discuss later, the APCR has not been called into use and it now appears virtually certain that allowance supply will exceed its demand for compliance during the 2013–2020 timeframe. Absent a major shift in expectations, it is likely that allowance prices will not rise to the containment price during the 2013–2020 timeframe. The relevant price bound in California has been the floor price, also known as the auction reservation price. The floor price is enforced through automatic adjustments to the number of allowances sold in California's quarterly auctions. Only bids at or above the auction reservation price are satisfied with a supply of allowances. When the demand for allowances is insufficient to clear all of those on offer, the unsold amount remains out of circulation.[5] Therefore, despite its name the emissions cap in California is actually rather flexible. The number of allowances in circulation can be increased or decreased endogenously in response to the allowance prices.

[5] Within the unsold category treatment of allowances varies according to whether the allowances come from the share assigned to the state's electric and gas distribution utilities, or from the share assigned to the state of California. Utility allowances are offered at the next auction, while unsold state allowances are assigned to the APCR and would therefore only return to circulation if prices rose to the containment price.

C. Allowance Allocation and Auction Revenue

One last critical component of the design of California's cap-and-trade system is the distribution of allowances and the revenues associated with their sale. As described in Schatzki & Stavins (2014), when passed, the program as a whole was expected to generate approximately $10 billion in allowance value per year once all sectors were under the cap starting in 2015. Of this total roughly 60 percent were to be allocated (for free) to various entities, with the two largest categories being 40 percent allocated to electricity and distribution utilities and another 17 percent expected to go to various trade-exposed industries.[6]

The remainder of the allowances, expected to be 40 percent of total allowance value or, by the estimates of 2010, roughly $4 billion per year were to be auctioned quarterly. The proceeds would accrue to the state of California and dedicated to a wide range of purposes, including assistance to disadvantaged communities, high-speed rail investment, and other smaller scale projects.[7]

Importantly, while budget planners recognized the potential uncertainty of auction revenues with respect to the allowance price, relatively little attention was paid to potential uncertainty stemming from low auction *quantities.* Thus state budgets included spending plans based upon what were thought to be conservative estimates with respect to allowance prices, but still nonetheless assumed that all the allowances would be sold at those prices.

As I describe later, the potential uncertainty with respect to auction quantities is actually quite large, and has been exacerbated by the way in which allocation policies and enforcement of the price floor have been implemented. The direct allocations to industry described earlier were established as either fixed amounts, or in the case of trade-exposed industries were linked solely to the ongoing production of goods within the state of California. In both cases allocations to industry are unaffected by shortfalls in auction sales. The allowance price floor is maintained by withdrawing allowances from the market by means of reducing the quantities sold in the auction. The consequence is that any allowances withdrawn from circulation need to come entirely from the state share, rather than proportionately from every party receiving allowances.

IV. MARKET PERFORMANCE

One of the ironies behind the current negative public image of the cap-and-trade system is that it has been performing roughly as expected, given the conditions facing

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[6] The value associated with allowances allocated to gas and electric distribution utilities is required, through the regulatory process to flow through to utility customers, either in the form of lower rates or through the "Climate Credit," a periodic payment made to utility customers.

[7] There was considerable regulatory and legislative activity devoted to the question of how to distribute the expected revenues. California Senate Bill 535 requires that at least 10 percent of auction proceeds be invested within disadvantaged communities and at least 25 percent of the proceeds be invested to benefit those communities. California Assembly Bill 1552 required an inter-agency group develop multi-year investment plans for auction proceeds that would be aimed at investments producing GHG reductions.

the California economy shortly before it began. The process that set California's cap was finalized during the 2006–2008 time period, just as emissions from capped sectors were reaching their peak of roughly 400 MMT/year. As of late 2008, the CARB projected emissions from capped sectors during the decade of 2010–2020 to remain level at about 400 MMT, absent policy intervention. Estimates of potential revenues from the cap-and-trade system were set according to these expectations. As late as mid 2012, allowance futures prices traded in the range of $20/ton.[8] Budget planners acted according to these expectations, with estimates assuming prices in the $20/ton range or higher. The worst-case scenario was thought to be prices settling at the allowance price floor, which started at $10/ton and rose by 5 percent each year. However revenue estimates assumed that all the available allowances would be sold at these prices.[9]

The financial crisis in 2008 and ensuing economic slowdown, however, had considerably changed the trajectory of carbon emissions. Borenstein et al. (2016) calculate probabilities of prices falling either at the floor, ceiling, or intermediate range, initially using data from 2010 and subsequently updating their forecasts with data through 2012.[10] With each successive update of emissions data, forecasted emissions have declined. Using 2010 data, Borenstein et al. (2016) estimated a 92 percent probability of allowance prices settling at the floor by 2020. With 2012 vintage data, the probability of prices at the floor increased to 97 percent, indicating that the prospect of a surplus of allowances through 2020 was a near certainty.

Since 2012, the allowance market has performed in a manner that is consistent with these reduced expectations. The May 2013 auction for current vintage allowances cleared above the floor at $14/ton, but a simultaneous auction for future (2015) vintage allowances did not sell all the allowances on offer and cleared at the reserve price of $10.71/ton. Figure 3 illustrates the realized state revenues from quarterly allowance auctions relative to the "worst-case" expectation of selling all allowances at the floor price.[11] Since the first auction of future vintages in 2012, 11 of 19 auctions have failed to sell all of the allowances on offer, with demand for future vintages being particularly

[8] California allowance futures prices are traded on the Intercontinental Exchange (ICE). Five day moving average prices are reported on http://calcarbondash.org.

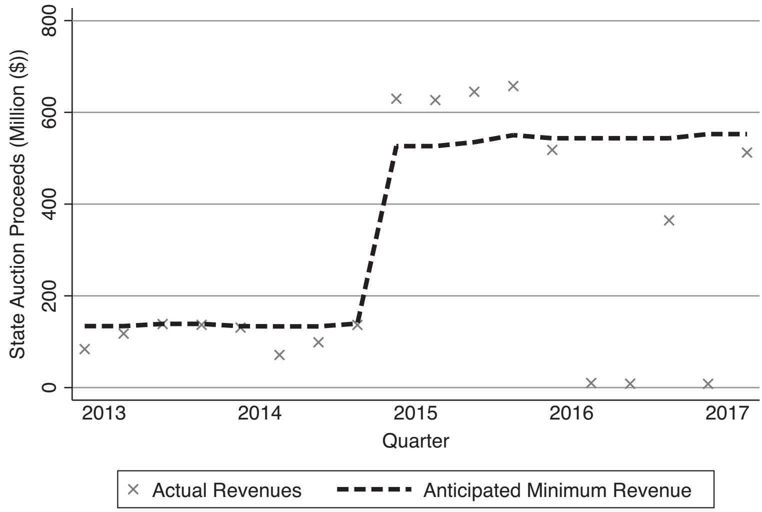
[9] The California Environmental Protection Agency (EPA) formed an external panel, the Emissions Allocation Advisory Committee (EAAC) to advise the state on options for the distribution of allowance revenues. This group was advised to use allowance prices in the $20–60 per ton range as the basis for their analysis. Schatzki and Stavins (2014) also discuss revenue implications and use $20 for the baseline estimates, while also recognizing the uncertainty in prices and reporting revenue estimates at floor and ceiling prices as well.

[10] Another complication in forecasting prices has been the existence of two separate emissions reporting datasets that each utilize distinct approaches to measuring emissions and defining the sectors from which they originate. The California Emissions Inventory, used by Borenstein et al. (2016), reports emissions dating back to 1990, making it more useful for forecasting exercises. Since 2011, the California ARB has also reported capped emissions under its mandatory reporting requirement.

[11] Data taken from https://www.arb.ca.gov/cc/capandtrade/auction/auction.htm#results. At each auction, the ARB offers a combination of both current vintage and future vintage allowances. Both sets of allowances are linked to the same current floor (reserve) price. The revenues reported in Figure 3 reflect the combined revenue from both sets of allowance sales.

Figure 3

Actual and Anticipated Quarterly Allowance Auction Revenue



Notes: Includes sales of both current and future vintages. Anticipated minimum revenues assume sales of all allowances available at price floor. Actual revenues taken from https://www.arb.ca.gov/cc/capandtrade/auction/auction.htm#results.

Source: Author's calculations

weak. The weakness in the market intensified through 2016, when the state sold *zero* current vintage allowances in June and August auctions.

The weakness in auction demand has been attributed to several factors in addition to the likelihood of excess allowance supply through the end of the current trading regime in 2020. California's cap-and-trade program has operated under the cloud of several legal challenges, including the California Chamber of Commerce suit described earlier. In addition, AB 32 created considerable ambiguity over the fate of the program after 2020. While it was initially taken for granted in some circles that ARB would be able to continue operating its program, at least at 2020 cap levels, under the authority of AB 32, now many believe that a supermajority vote in the California legislature is necessary for an extension of the program.[12] This uncertainty over the fate of the program post-2020 also had significant implications for the value of current-vintage permits.

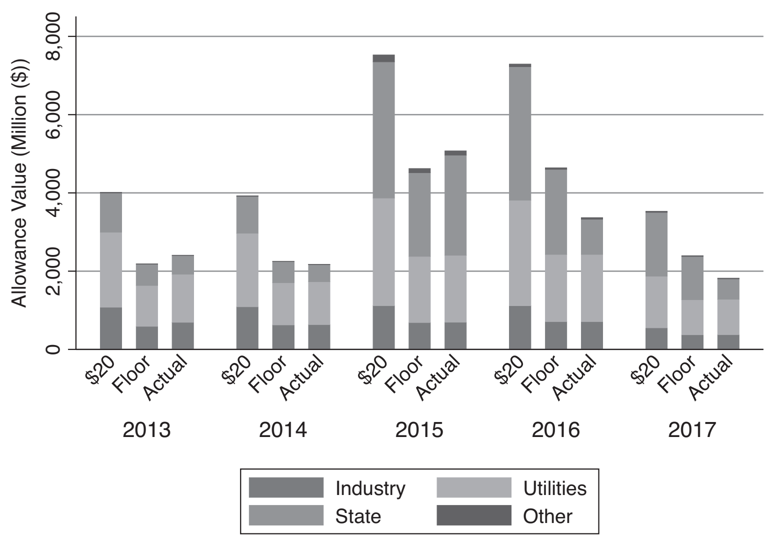
[12] The current political and legal situation is summarized in "California's climate debate heats up behind closed doors as Gov. Brown pushes to extend cap and trade." *Los Angeles Times*, June 21, 2017, http://www.latimes.com/politics/la-pol-sac-california-climate-talks-20170623-story.html.

Current prices for allowances that are bankable into the post-2020 program, could be supported by expectations over a higher future value. However, if the program had not been renewed, or had been extended in a manner that does not allow current vintage allowances to be used after 2020, those allowances would have had no value after 2020.[13]

The legal and political uncertainty therefore combined with the likelihood of at least modest over-supply of allowances through 2020 to produce revenues that have fallen well below expectations. However, another important element that has not been widely recognized is the role of California's allocation policy. As described earlier, the allowance price floor is enforced by establishing a reserve price in the quarterly allowance auctions. However, because the allocations to industry, utilities, and other groups are effectively guaranteed, any shortfall in allowance sales is taken entirely from the state's portion. Figure 4 illustrates the impact of this policy on the distribution of allowance value. This figure depicts the share of allowance value distributed between different recipient groups, including state public revenues, under different assumptions of market

Figure 4

Actual and Anticipated Allowance Value by Sector



Note: Data through May 2017.
Source: Author's calculations from California ARB data

[13] Proposed California Senate Bill 775 would establish a trading regime post 2020 that would differ dramatically from the current program and would not allow the use of any allowances sold prior to 2021 to be used after 2020.

outcomes. The left-hand side bar uses the 2010 vintage assumption of $20 carbon prices and full permit sales, the middle bars illustrate what was expected to be the "worst-case" outcome (with respect to revenues) of prices at the floor. These estimates, however, did not consider the revenue impact of low sales quantities. The right-hand bars illustrate the overall allowance value received by each group.[14] While auction sales have been relatively week in 2016 and 2017, the reductions in revenues are almost exclusively impacting California state revenues alone.

Ironically, the disappointment in the revenues generated by the cap-and-trade system posed a significant barrier to a renewal of the program after 2020. The revenue shortfalls have created a vicious cycle in which lower revenues decrease the political appeal of cap-and-trade, making it less likely to be extended, which in turn further depressed allowance values. In early 2017, the President Pro-Tem of the California State Senate noted his frustration with revenue uncertainty by stating that California government "needs a program that both reduces pollution and provides stable funding to clean up climate emissions." This comment was interpreted as signaling his preference for a carbon tax, as in DeVore (2017).

However, a carbon tax can perform better than cap-and-trade market when the problem is price volatility. That, by and large, has not been the problem in California. The issue rather, has been the uncertainty over the amount of carbon subject to the price, a dimension in which a carbon tax is not obviously better positioned to provide more stable revenues.

V. ALTERNATIVE DESIGN OPTIONS

In this section I evaluate the potential performance of different potential market designs with regards to revenue uncertainty. I adopt the perspective of Borenstein et al. (2016) and simulate the expected revenues from different market designs from the vantage point of 2012. In other words, to avoid the benefit of hindsight, I simulate potential allowance revenues using their forecast which utilized data through 2012. Recall that these forecasts found a 97 percent chance that allowance supply would exceed demand by at least some amount from 2012–2020. Because all options perform relatively the same when allowance prices are above the floor, I therefore focus on the preponderance of cases where prices are at their lower bound.

As described earlier, an underappreciated source of California's revenue shortfalls has been the priority given to distributing allowances to industrial and utility groups over state revenues. A natural counter-factual to consider therefore would be changes

[14] Since allowances distributed to industry and to other groups are freely distributed and therefore not explicitly priced, the average auction price for current vintage allowances auctioned in each respective year are used to value the allowances received by these groups. While some utility allowances, which are consigned to the state auction, did go unsold in specific auctions, those allowances are offered immediately into the next auction and therefore regain priority over unsold state allowances.

to this order of priority of allowance sales. The "pro-rata share" scenario considers the policy where a shortfall in allowance sales is borne proportionately by all recipients of free allowances as well as the state. In other words, if only 80 percent of allowances are sold at auction, the other groups also receive only 80 percent of the allowances they would have been allocated if the market were not oversupplied. The "state priority" scenario considers the option in which free allocations are made only after the state sells the entirety of its expected share. One last scenario considers a hypothetical carbon tax in which the tax rate is set to $14.00, about the average level of allowance prices at the current trajectory of the price-floor.

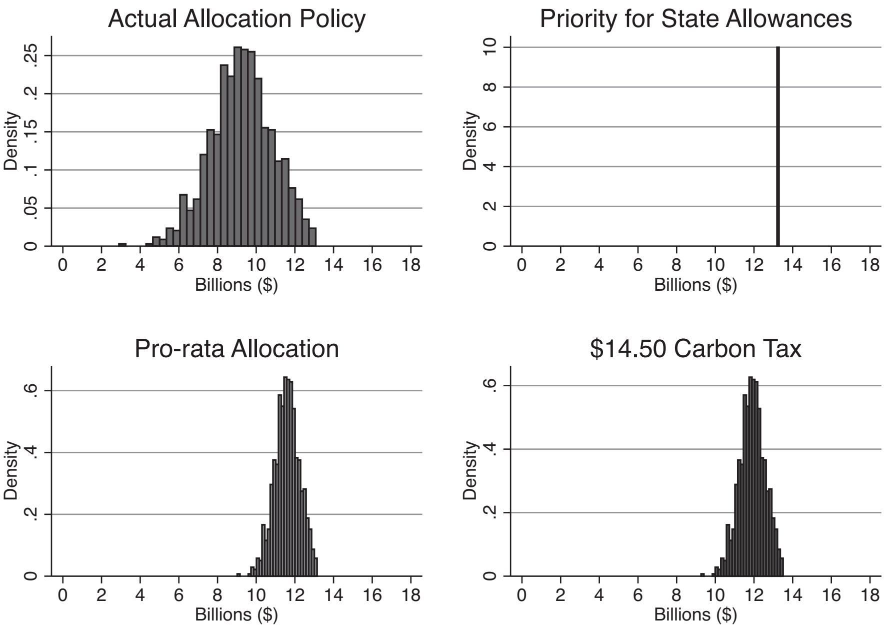
In order to normalize these comparisons, in each case the state is assumed to receive the same expected share of revenues in the event that all permits (not including the 121 MMT in the containment reserve) are indeed sold. Under the original California design, this share is roughly 40 percent of the total allowance revenues. Therefore, the maximum number of allowances that could be sold for state revenues in any scenario is 968 MMT. Under the tax, there is no upper bound on the amount of emissions that would be sold, but abatement of emissions from both the carbon price and other California policies are included in the estimate.

The results of this analysis are summarized in Figure 5. Each panel displays a histogram of potential realizations of revenue, using different allocation assumptions, that is based upon 1,000 draws of 2012–2020 emissions and abatement taken from the forecast in Borenstein et al. (2016). The upper left-hand panel describes what should have been the expectations for revenue under the current policy for allowance allocation. While the "worst-case" revenue projection was thought to be in the range of $12 billion, in fact the potential for low allowance sales, combined with a policy where the state bears the full risk of shortfalls, produces a mean revenue projection of $9.37 billion, with realizations ranging from $1 billion to $13 billion.

The polar opposite policy is summarized in the upper right-hand panel. This policy assumes that all state allowances be sold before *any* allowances are allocated to other parties. Under this policy, emissions need to only exceed 40 percent of capped levels for the state to be guaranteed its revenues. As Figure 5 illustrates, this policy does indeed provide a near-guaranteed revenue stream of more than $13 billion. The lower left-hand panel assumes that the burden of allowance sale shortfalls is born equally among all parties receiving permits, including the state. Under this seemingly equitable policy, expected state revenue rises by $2.3 billion relative to the current policy, and the range of potential outcomes is considerably narrower. Finally, the lower right-hand panel assumes a $14.00 carbon tax, with the state retaining a proportional 40 percent share of the revenue collected. This policy produces a range of potential revenue outcomes similar to that of the pro-rata allocation policy, but with a higher upper bound on revenue since there would be no cap to limit the amount of carbon to be subject to the tax. These calculations illustrate how, with variations in allocation policy, a cap-and-trade system could achieve greater stability than a tax, at least if the price-containment bounds are relatively tight. More generally, however, adjustments to a taxation policy could

Figure 5

Range of Expected Revenue by Allocation Policy



Notes: Figure depicts cumulative eight-year revenues conditional on cap prices being at price floor in each year. Emissions quantities from Borenstein et al. (2016).
Source: The calculation is described in Section V

in theory be added that could achieve similar certainty over the quantity of emissions subject to the tax.[15] In practice, such adjustments have been less common under taxation schemes.

VI. CONCLUSIONS

Carbon pricing policies offer an alluring combination of efficient incentives for reducing carbon emission and the generation of significant revenue, reaching nearly $100 billion under a hypothetical national carbon-pricing regime. This potential revenue has long been recognized as providing opportunity for either reducing other distortionary taxes or focused investment in infrastructure. However, while carbon pricing offers a

[15] A tax could, for example, be applied only to a fraction of emissions, excluding emissions above a certain threshold. Or tax credits or rebates could be made contingent upon certain revenue targets being reached.

huge source of revenue, there is also substantial uncertainty associated with the size of the potential windfall. When carbon pricing systems are marketed primarily as sources of revenue, they risk potential backlash if those revenues fail to materialize.

The experience to date with California's cap-and-trade system provides a cautionary tale of exactly this kind of dynamic. There were high expectations about the revenues that could be generated from this allowance market, and plans to support projects ranging from low-income energy assistance to high-speed rail infrastructure. However, emissions allowance sales have substantially underperformed expectations, clearing at substantially lower prices and quantities than were anticipated just five years ago.

California's choice of a cap-and-trade mechanism over a carbon tax could be expected to contribute to the uncertainty of revenues. Research has illustrated the potential for small swings in emissions to yield large changes in allowance prices. However, California has mitigated the price uncertainty by placing relatively tight (if not fully robust) price bounds on its allowance market. Indeed, prices have not been at all volatile, but have instead rested on the price floor for most of the last four years.

The main source of revenue uncertainty has therefore been a policy of allowance allocation that placed the entire burden of low allowance sales upon the state of California. By contrast, utilities and other industries that receive over half of the allowances created in California through direct allocation are virtually guaranteed to receive their shares. While low allowance sales could be viewed as good news for the environment, they have been a substantial disappointment for budget planners.

In this paper I demonstrate how uncertainty could be substantially reduced, if not eliminated, by changing the priority ordering of allowance allocation and sales. In the extreme policy, where no allowances were allocated to industry before California's share of allowances were fully sold, the combination of price-floor and allowance priority virtually eliminates risk of revenue shortfall. More generally, allowance allocation policies, combined with price collars could be used to substantially smooth revenue uncertainty to a point where it could be even more reliable than a tax. If fewer allowances are allocated at lower prices, and more allowances given away at higher prices, then the state essentially sells higher quantities when prices are lower, smoothing its expected revenues.

It is important to recognize that revenue shortfalls are not the only source of disillusion with California's climate policy. Concerns over the extent of emissions leakage, costs to local industry, and the perceived lack of benefit in the form of reduction in locally harmful co-pollutants are all controversial topics under debate at the time of this writing as California struggles with the question of what to do next.

It is also important to recognize that some of the policy alternatives described in this paper decrease the uncertainty of state revenue by *increasing* the uncertainty in the value of allowances received by other parties. However many of the related objectives that made climate policy attractive to Californian's depend upon the generation of state revenue to support them. To the extent that increasing the reliability of this revenue is important for the program to succeed, it can be accomplished within the general framework of the current program.

DISCLOSURES

James Bushnell has advised the California Air Resources Board on various aspects of allowance trading and was a member of the Emissions Market Assessment Committee from 2011–2014.

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