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TECHNICAL APPENDIX TO BLOG POST "ANALYZING THE LIKELY IMPACT OF OVERSUPPLY ON CALIFORNIA'S CARBON MARKET MUST CONSIDER STATE'S 2030 EMISSIONS GOAL AND POTENTIAL FOR CLEAN TECH BREAKTHROUGHS"

BY CHRIS BUSCH ● JANUARY 2018

This technical note provides more detail regarding how the Borenstein-Bushnell blog, abbreviated "BBB," calculates the likely impact of adjusting for oversupply and explains the role played by the arguably overly inelastic abatement supply used. The core analytical framework used in BBB is developed in a recent research paper Borenstein, Bushnell, and Wolak 2017 (Borenstein et al. 2017).

After developing the necessary background, the extreme example of a completely inelastic abatement response due to the carbon price is illustrated. In the case of perfectly inelastic abatement supply, adjusting for oversupply would make absolutely no difference in emissions reductions. In the perfect inelasticity case, the price would be at the floor if the market is short and at the ceiling price if the market is long. Under either outcome, emissions would be the same. To set the stage for the discussion, I start by borrowing and explaining some figures (Figures 3 and 4) from Borenstein et al. 2017).

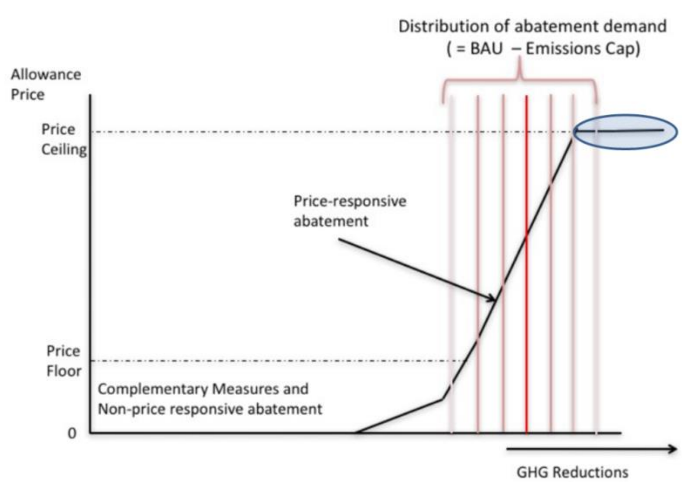


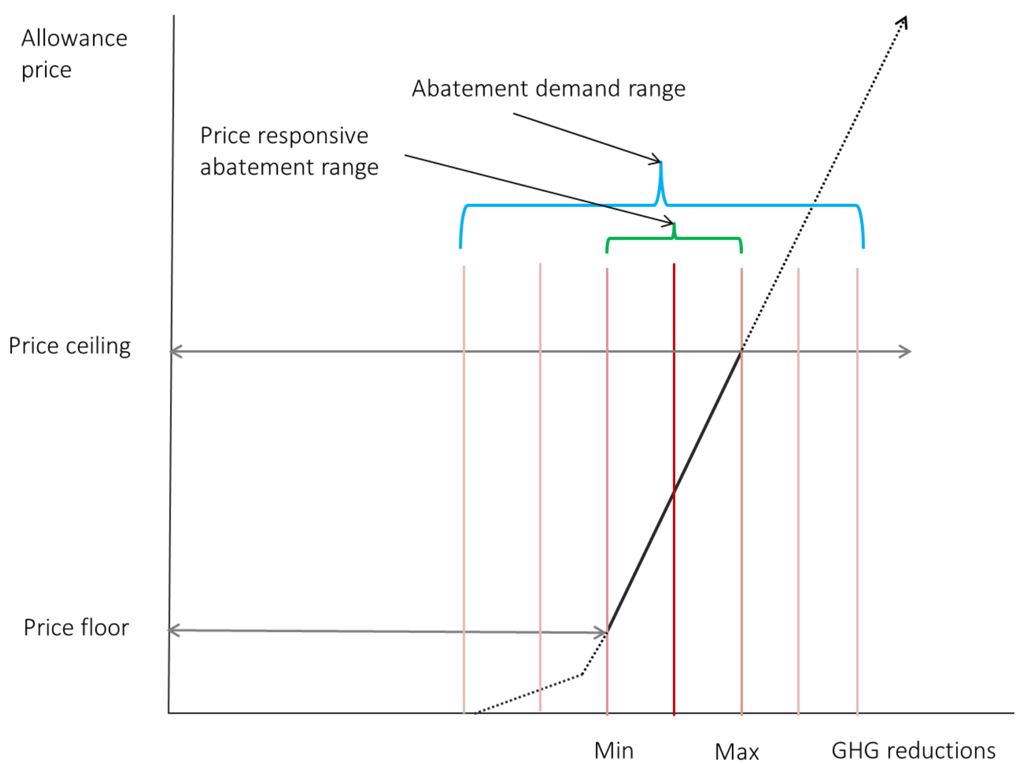
FIGURE 3. HYPOTHETICAL SUPPLY AND DEMAND FOR ABATEMENT

Source: Borenstein et al. 2017

Figure 3 shows supply and demand for abatement in the paper's main scenario, the "base case." The black line, labeled "price responsive abatement," shows emission reductions expected at different price levels if opportunities from fuel switching are omitted. As the carbon allowance price increases, moves up the horizontal-axis, the amount of reductions increase, i.e. move further to the right on the vertical-axis. The brightest red line shows the probability weighted average for abatement demand, which a label helpfully explains is a reflection how many reductions the cap requires below BAU (business-as-usual) emissions, i.e., emissions expected in the absence of a cap-and-trade program. So, abatement demand equals BAU emissions minus the cap. (Borestein et al. 2017 treats 2015-2030 as a single cumulative cap, hence the use of cap singular, representing the sum of annual caps.)

A range of possible abatement demand levels are possible, reflecting uncertainties about future economic growth and other variables, and this reality is indicated by the vertical lines of various shades of red in Figure 3. As these move farther away from the bright red probability weighted average at the center, their coloring becomes less intense, reflecting the lower probability that they will happen. Since the abatement demand curves shown barely intersect with the price floor (the minimum auction price) and price ceiling (if prices reach this level, CARB will auction more), it seems this is a stylized representation. Since the most likely outcomes are actually at the price floor or ceiling, the actual distribution of abatement would appear to be much larger than the range shown. There is nothing problematic about this, just worth noting for readers wishing to understand the geometry of the graph.

Figure 3 is shown exactly as in the original research paper, with the exception of the light blue oval, which appears to show greenhouse gas emissions continuing to accumulate at the price ceiling, but this is not consistent with the analysis. In an email exchange, Professor Borenstein agreed that the graph could be made clearer. I've attempted to do that with the graphic below, in order to set the stage for the discussion that follows.



A1. Modified graphic of base case result in Borenstein et al. (2017)

The black line shows the price-responsive abatement supply within range of the price collar (price ceiling and price floor). The dotted line extension of the black line in Figure A1 shows price-responsive abatement supply outside of the price collar. Reductions to the left of where the dotted line intersects the horizontal axis are due to complementary policies (i.e. policies other than cap-and-trade). Different abatement demand outcomes under different values for uncertain variables are shown with the red (probability weighted average) or pink vertical lines, as in the original Figure 3. Abatement demand that intersects abatement supply outside of the price collar forces reductions to the level implied at the price floor or ceiling. This implies the maximum or minimum greenhouse gas emission reduction levels labeled along the horizontal axis, which is shown above with a green bracket (labeled "price responsive abatement range").

The intersections of supply and demand in Figure 3 (and reproduced in this document as Figure A1) produce a probability distribution of outcomes around price and quantity of greenhouse gas reductions under different economic growth, different travel demand (vehicle miles traveled), and other uncertain variables. Figure 4 depicts the resulting probability distribution of prices.

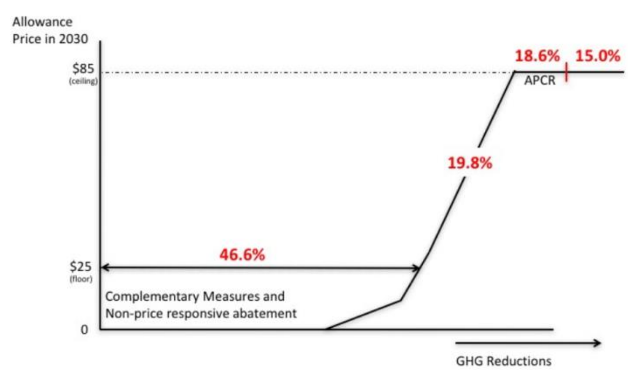
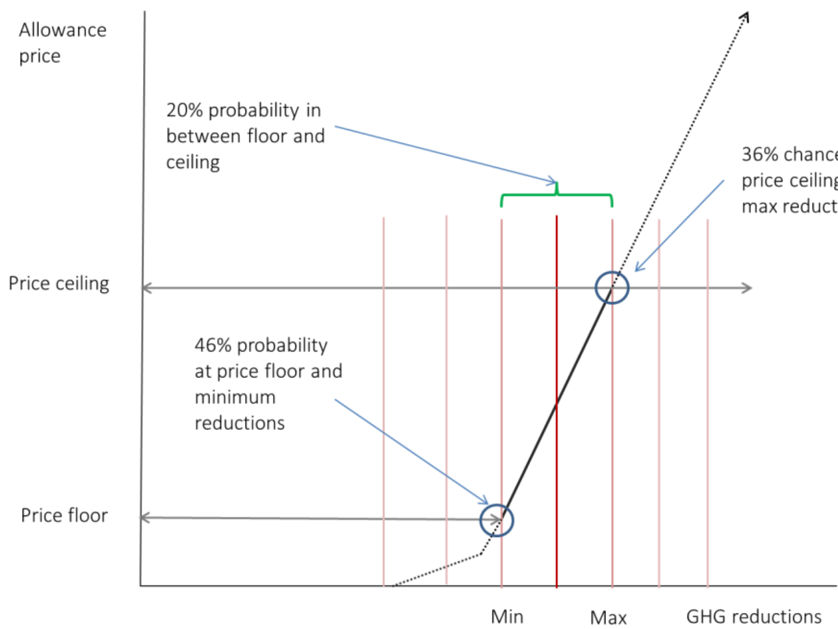


FIGURE 4. DISTRIBUTION OF OUTCOME PROBABILITIES WITH HARD PRICE CEILING, NO STEPS

Source: Borenstein et al. 2017

For ease of explanation to non-economists, I present the same results building on the modified graphical framework developed in figure A1. Figure A2 shows how the probability distribution for prices emerges from the intersection of abatement demand and abatement supply.



A2. Probability distribution of prices in base case for Borenstein et al. 2017. [1]

As in the original Figure 3 from Borenstein et al. 2017, where the pink abatement demand line intersects the abatement supply line to the below the level of reductions at the price floor, the price floor kicks in, driving reductions to the "min" level, the minimum amount of reductions from cap and trade. Where the abatement demand line intersects abatement cost above the price floor, the price ceiling kicks in, resulting in emission reductions at the "max" level.

In figure A3, we show how the Borenstein and Bushnell blog (BBB) arrives at their conclusion that adjusting for oversupply would have an effect of 42 million metric tons (MMT).

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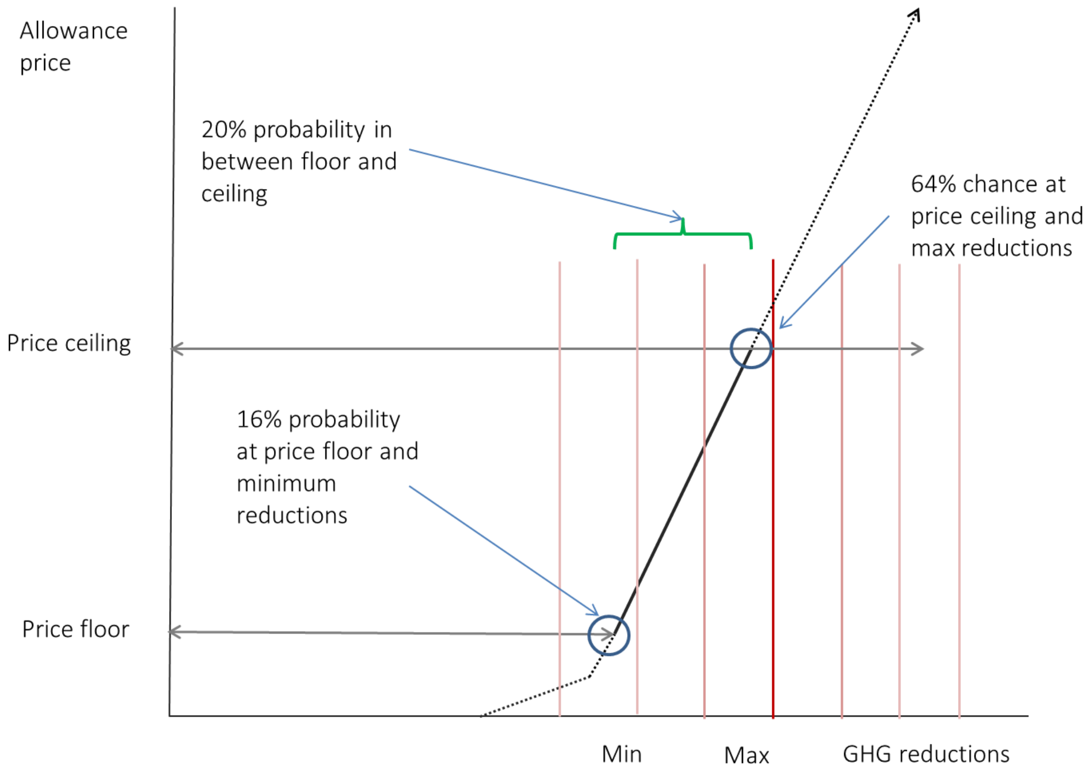
[1] For simplicity, this presentation rounds their probability estimate downward from 46.6 percent so that the total for percentage outcomes adds to 100 percent.



A3. Probability distribution of prices after adjusting for oversupply in base case for Borenstein et al (2017). [2]

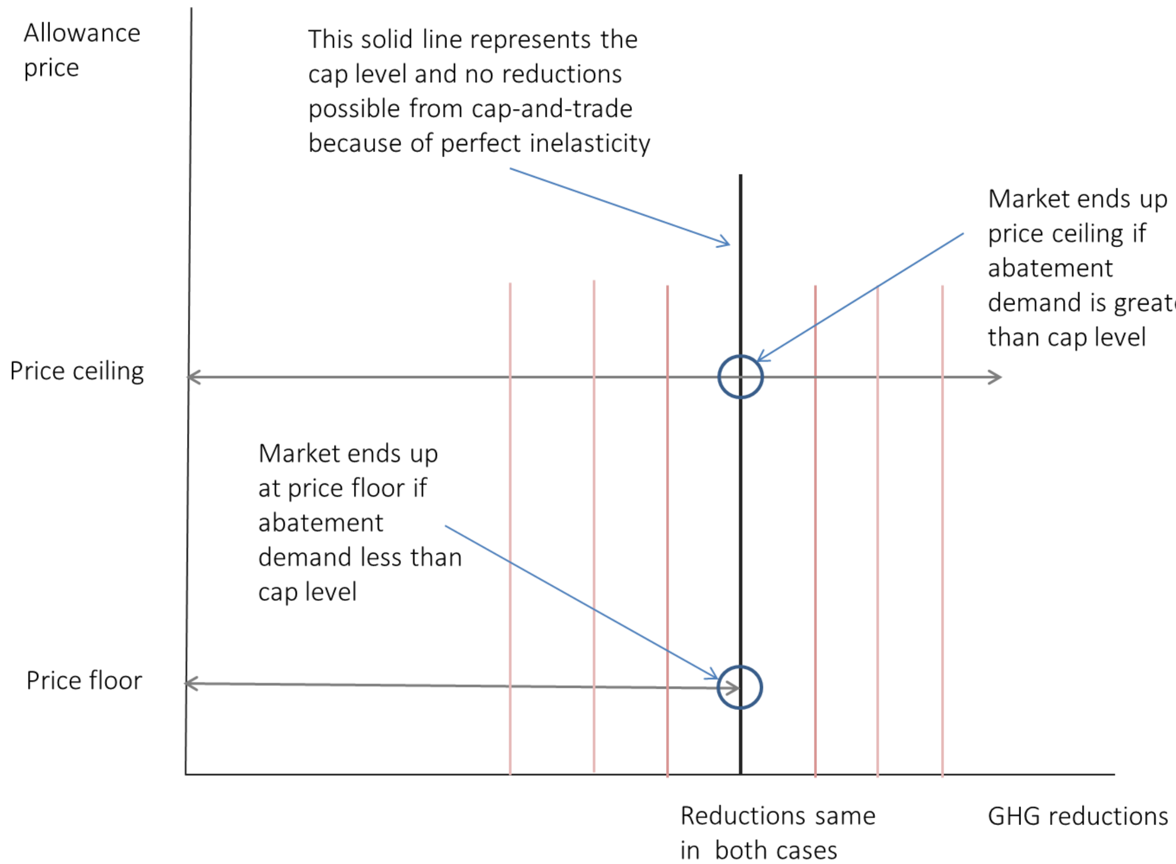
Adjusting for oversupply results in increased abatement demand (more reductions are required). This shifts the abatement demand probability distribution to the right. The result is a 30 percent shift in probability to the ceiling from the floor. Table 1 of Borestein et al. shows their estimated reductions at the price floor equal 78 MMT and estimated reductions at the ceiling as 218 MMT.

So, the impact estimate equals the effect of the increased likelihood of ending up at the ceiling plus the effect of the decreased likelihood of ending up at the price floor, which implies:

Impact of oversupply adjustment = 0.3 * 218 – 0.3 *78 = 42 MMT

Having explained how Borenstein, Bushnell and Wolak arrive at the results in their base case, next we show how the inelasticity of abatement supply helps to drive this result. Figure A4 shows how adjusting for oversupply would make zero difference if abatement supply is perfectly inelastic. If this is the case, the market ends up at the price floor if the market is long or the price ceiling if the market is long. In either case the amount of reductions is the same.

[2] For simplicity, this presentation rounds their probability estimate downward from 46.6% so that total for percentage outcomes add to 100 percent.



A4. Implications of a perfectly inelastic abatement supply curve for carbon allowance market

The vertical solid black line indicates a completely inelastic curve. No emission reductions happen because carbon pricing makes no difference. If abatement demand is to the left/below the cap level, the price is at the floor. If abatement demand is to the right/above the cap level, the price is at the ceiling. Under such circumstances, adjusting for oversupply makes no differences in the level of emissions. The impact of adjusting for oversupply would be to move the abatement demand curves to the right, affecting the expected price, but having no effect on the level of emission reductions.

This discussion has shown that the inelastic supply curve developed in Borenstein et al. (2017), which we argue is overly constrained in terms of the possible abatement response, plays an important role in the conclusion from BBB that adjusting for oversupply would not affect greenhouse gas emissions as much as a straightforward consideration of the change in allowance supply would indicate.