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Managing Uncertainty in Carbon Offsets: Insights from California's Standardized Approach

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1. Letter emailed to Yachun Chow, Ph.D., Air Resources Engineer, Stationary Source Division, California Air Resources Board, December 19, 2013, *RE: Potential market distortions caused by California's potential Rice Cultivation Compliance Offset Protocol*
2. Details of the analysis of the proportion of non-additional credits that could be generated by the Mine Methane Capture Protocol from abandoned mines
3. Details of the analysis of coal mine profits from coal mine methane capture offset projects

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December 19, 2013

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RE: Potential market distortions caused by California's potential Rice Cultivation Compliance Offset Protocol

Dear Yachun,

When our group last talked with you on the phone, Robert Heilmayr, a PhD student at Stanford whose work combines economics, ecology and remote sensing, raised several potential "perverse incentives" that could be created by the Rice Cultivation Protocol. One of his concerns was that by making rice farming more profitable, the offset Protocol might create an incentive, on the margins, for farmers to switch from the production of other crops to rice farming. Since rice farming is substantially more greenhouse gas (GHG) intensive than the production of most other crops, even when the emissions reduction practices credited under the Protocol are used, the Protocol would lead to an increase in emissions to the extent that it incentivizes crop switching to rice.

Since we talked, Robert has quantitatively examined the potential magnitude of this effect to better understand if this effect may be material enough to require further study. His results, based on conservative assumptions, are surprising. Several factors together result in potentially substantial impacts on GHG emissions from the incentives created by the Protocol to switch crop production in the mid-South region. Most importantly, since 2005, we have seen large shifts in acreage back and forth between corn and rice correlated with changing the prices of these commodities. The magnitudes of past shifts in acreage suggest that the incentives to shift crop production created by the Protocol could be large enough to need consideration. Also, rice production is estimated to emit just under four times the GHGs of corn in areas of the mid-South, while the effects of the Protocol on emissions from rice cultivation are expected to be much smaller. Robert finds that inducing even a relatively small shift in acreage from corn to rice can negate a material portion of the total emissions savings from the Protocol. We believe that this analysis suggests that further study of the potential for these effects is needed and, perhaps, that measures would need to be taken to avoid these effects or to account for them in the compliance offset protocol.

A description of his analysis and results are attached below. We would be very happy to discuss this further with you.

With best,

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Examination of potential market distortions caused by CARB's potential Rice Cultivation Compliance Offset Protocol from crop switching

Summary

By providing an additional source of revenue to rice farmers, the proposed rice cultivation offset protocol will shift the relative profitability of rice in comparison to other crops. In areas of the Mid-South, where it is common for farmers to shift between rice and corn as the prices of these goods change, material changes in profitability from the offsets program may lead some farmers to shift towards rice production. Since rice production is just under four times more emissions intensive than the production of corn in areas of the Mid-South (Nalley, 2011), and since offsets projects may reduce rice cultivation emissions in that region by substantially less than the difference in emissions intensity of the two crops, inducing even a relatively small shift in acreage from corn to rice can negate a material portion of the emissions savings from the protocol. If so, this increase in emissions would need to be prevented or accounted for by the protocol.

Through scenario analysis, we explore the potential magnitude of the effect of the rice cultivation protocol on emissions from inducing a shift in acreage from corn to rice. Our goal is to understand if such effects can materially lessen the effects of the protocol on emissions.

For the purposes of this analysis, we focus our attention on Arkansas, the state with the largest area of rice cultivation, and where farmers have demonstrated significant flexibility in cropping decisions over the past decade. We ran three scenarios which differ by the proportion of rice acreage participating in the protocol and the proportion of corn acreage that shifts from corn to rice as a result of the financial incentives created by the protocol using conservative assumptions for all scenarios. We find that under these scenarios, the crop switching induced by the protocol negates 9%, 21% and 41% of the emissions savings that would be credited by the protocol.

This initial analysis indicates that under reasonable assumptions the protocol may induce crop switching that increases emissions by material amounts. This suggests that this "perverse incentive" is worthy of more detailed analysis to assess the aggregate emissions effects of the proposed protocol on the agricultural system as a whole, rather than just at the scale of the individual participating farm. If more rigorous analysis supports these initial results, the protocol should seek to minimize the incentives for crop switching towards rice. We describe our analysis below.

I. Methods

In order to determine the environmental integrity of the offset protocol, we calculate the ratio (*E*) of net emissions reductions (*R*) to offsets credited (*O*): $= \frac{R}{O}$. For simplicity, we focus our attention on the area dedicated to two crops, the total area of rice harvested (A_r) and the total area of corn harvested (A_c). To simplify the complicated underlying market dynamics, we introduce two parameters to represent the share of rice acreage implementing changes in management practices to generate offsets (S_r) and the share of corn acreage that shifts to rice cultivation in order to receive offsets (S_c). Given an average greenhouse gas intensity for rice production (I_r) and corn production (I_c) and an average emission reduction generated by rice farms that participate in the protocol (P) we can calculate *O* and *R* as:

$$O = P(S_r A_r + S_c A_c)$$

$$R = \underbrace{S_r\, A_r\, P}_{Emissions\ reduction\ from\ shift\ in\ rice\ farm\ practices} - \underbrace{S_c A_c (I_r - P - I_c)}_{Emissions\ increase\ from\ shift\ of\ corn\ acreage\ to\ rice}$$

II. Data and assumptions

In order to estimate a reasonable range for the environmental integrity of the program, we use the following data sources to make assumptions on the different variables in our model:

1. Area of rice harvested (A_r):

   The USDA's National Agricultural Statistics Service (NASS) estimates that farmers in Arkansas harvested 1,055,000 acres of rice in 2013.

2. Area of corn harvested (A_c):

   NASS estimates that farmers in Arkansas harvested 970,000 acres of corn in 2013.

3. Emissions intensity of rice production (I_r):

   Nalley et al. (2011) estimate the non-N_2O greenhouse gas emissions intensity of rice production in Arkansas as ranging from 3.09 tCO_2e/acre to 3.34 tCO_2e/acre depending on the production practices employed. We use the median emissions intensity practice, setting the emissions intensity of rice at 3.22 tCO_2e/acre.

4. Emissions intensity of corn production (I_c):

   Nalley et al. (2011) estimate the non-N_2O greenhouse gas emissions intensity of corn production in Arkansas as ranging from 0.79 tCO_2e/acre to 0.95 tCO_2e/acre depending on the production practices employed. We use the median emissions intensity practice, setting the emissions intensity of corn at 0.82 tCO_2e/acre. This is around one fourth of the emissions of rice per acre.

5. Emissions reduction from project implementation (*P*):

   Personal communications with scientists and officials at the Climate Action Reserve have indicated that average emissions reduced from early drainage and intermittent flooding projects in the Mid-South are unlikely to exceed 0.5 tCO_2e/acre.

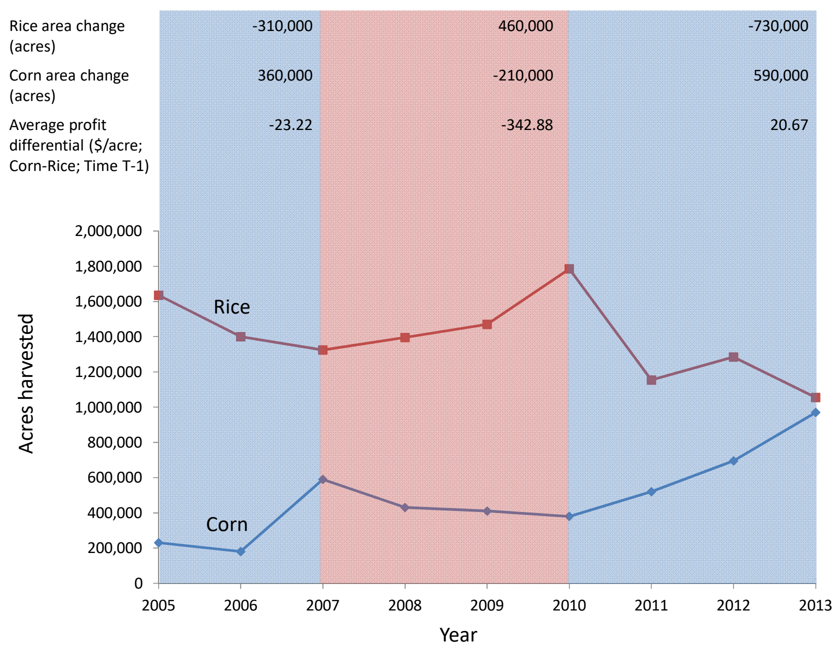
6. Share of rice acreage implementing changes in management practices to generate offsets (S_r):

   In the absence of detailed economic modeling, it is extremely difficult to predict the rate of participation in the Protocol among farmers. Further, there is little existing precedent from which to estimate the rate of participation of farmers in a rice methane offset program. Australia's Government anticipates that its Carbon Farming Initiative will yield no emissions reductions from rice cultivation practices through 2020 (Commonwealth of Australia, 2011). Similarly, the Climate Action Reserve currently has no registered or listed projects under its voluntary rice methane protocol. Higher rates of participation of rice farmers would mean more real reductions from the protocol and a higher level of environmental integrity. In order to generate a conservative estimate of the environmental integrity of the program, we choose relatively high values for participation. In our first and last scenarios we assume 5 percent of Arkansas rice farmers will participate in the program. In our second scenario, we assume 10 percent of Arkansas rice farmers will participate.

7. Share of corn acreage that shifts to rice cultivation in order to receive offsets (S_c):

Experts familiar with rice cultivation in the Mid-South have highlighted the willingness of farmers to shift acreage between rice and corn in response to recent corn price volatility. Three distinct periods over the past 8 years seem to support these anecdotes: 1) During the period 2005-2007 rice cultivation dropped by 310,000 acres (19%) while corn area increased by 360,000 acres (157%). According to the USDA's Economic Research Service, the typical rice field along the Mississippi was only $23 more profitable than the typical corn field in the Southeast; 2) From 2007-2010 rice shifted to being $342 more profitable than corn and a corresponding flip in acreage trends was seen - rice expanded by 460,000 acres (35%) while corn contracted by 210,000 acres (36%); 3) Finally, in the period 2010-2013, rice acreage dropped dramatically (730,000 acres, 41%) while corn once again expanded (by 590,000 acres (155%)). During this period, corn was $20.67 more profitable than rice. These results are summarized in the figure below.

Figure 1: Trends in Arkansas crop profitability and acreage



Recognizing the limits of such a crude analysis, the data seem to support three conclusions: 1) Arkansas farmers do shift between rice and corn; 2) these shifts seem to be in response to the relative profitability of the two crops; and 3) the big swings in profitability have been met by correspondingly large shifts in acreage devoted to each crop.

While we can be fairly certain that the net effects of the offset protocol will be to expand rice area while decreasing the area of other crops, it is more difficult to determine the magnitude of these effects. Economic crop models (e.g. FAPRI's US Crop Model) could provide insights into the magnitude of these effects.

However, in the absence of rigorous modeling, we use the conservative estimates of 0.5% and 0.1% as the share of corn fields that shift to rice to participate in the protocol in our three scenarios. We consider these values to be conservative based on past trends. For example, at offsets profits of $10 per tCO_2e, rice cultivation projects are anticipated to generate around $5 per acre in profits. In Figure 1, the large shifts in corn acreage (-210,000 acres in the second period and 590,000 acres in the third) correspond with changes in in the relative prices of corn and rice of -$320 between the first and second periods, and $364 between the second and third periods. This corresponds to 3,285 and 8,114 acres per dollar shift in relative profits of rice and corn during the second and third periods. If the elasticity of corn acreage is constant, then an increase in profitability of rice over corn of $5 per acre from an offsets protocol would correspond with a reduction in corn acreage of 1% and 2%. In contrast, our assumptions of 0.5% and 0.1% are relatively low.

III. Results

Table 1 describes the results of this model exercise for our three scenarios.

Table 1: Environmental integrity of offset program under different adoption scenarios

	Scenario 1		Scenario 2		Scenario 3	
Assumptions	S_r	S_c	S_r	S_c	S_r	S_c
	5%	0.5%	10%	0.5%	5%	0.1%
True reductions to offsets generated *(E)*	**59%**		**79%**		**91%**	

S_r = Share of rice acreage participating in the protocol
S_c = Share of corn acreage shifting to rice cultivation to participate in the protocol
E = Ratio of true reductions to offsets generated

In our three conservative scenarios, only 59 to 91 percent of the payments made for emissions reductions are matched with net reductions from the program. This suggests that CARB should perform a more detailed analysis to assess the aggregate emissions effects of the proposed protocol on the agricultural system as a whole, rather than just at the scale of the individual participating farm. If more rigorous analysis supports these initial results, the protocol should seek to minimize the incentives for crop switching towards rice, or account for it with a discount factor in the protocol.

It should be noted that additional factors will further confound this analysis. While we have focused all our attention on Arkansas, global markets will counterbalance the effects we have discussed. For example, if corn farmers in the Mid-South shift towards rice production as a result of the offset program, the corresponding drop in rice prices may encourage rice farmers elsewhere to shift away from rice production.

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Nalley L, Popp M, & Fortin C (2011) The Impact of Reducing Greenhouse Gas Emissions in Crop Agriculture: A Spatial and Production-Level Analysis *Agricultural and Resource Economics Review, 40*(1), 63-80. doi:10.1017/S1068280500004524

2. Details of the analysis of the proportion of non-additional credits that could be generated by the Mine Methane Capture Protocol from abandoned mines.

Table SM-1: U.S. Abandoned Mine Methane (AMM) Projects (1993-2012)

MSHA ID	Mine Name	Coal Company	Project Developer	Date Mine Abandoned	Project Start	Mine Captured Methane when Active?	Voluntary Carbon Registry	Emissions Avoided (tCO_2e/yr)
	5 mines	various	Grayson Hill Farms	1950-1971	2011		CCX	57,094 [a]
11-00600	Orient 3	Freeman	DTE Methane	2/1/84	2009		VCS	19,052
11-00599	Orient 6	Freeman United Coal Mining Co.	DTE Methane	3/13/97	2008		VCS	15,596
42-02028	Aberdeen	Andalex Resources Inc.	Blue Tip Energy	9/25/08	2008	Yes	VCS	67,324
	Cambria 33[b]	ArcelorMittal Pristine Resources	Vessels Coal Gas	1994	2008		VCS	202,156
	5 mines	various	DTE Methane	1950-1971	2007		VCS	— [c]
11-02392	Old Ben 25	Old Ben Coal Co.	DTE Methane	9/10/96	2007		VCS	15,435
46-01482	Valley Camp 3	Valley Camp		1/10/83	2007			12,295
46-01286	Windsor Mine	Windsor Coal Co.	Consol Energy	3/22/05	2007			9,748
01-01322	Blue Creek 5	Jim Walter Resources Inc.	Jim Walter Resources Inc	4/26/07	2007	Yes	CCX	46,690
44-03795	VP 8	Island Creek Coal Co.	Consol Energy	6/26/06	2006	Yes		888,475
	3 mines	various	Grayson Hill Farms	1950-1971	2003		CCX	— [a]
46-01438	Ireland	Consolidated Coal Co.	Consol Energy	6/10/94	2003			21,819
11-00589	Old Ben 24	Old Ben Coal Co.	DTE Methane	7/10/98	2002		VCS	19,265
11-00590	Old Ben 26	Old Ben Coal Co.	DTE Methane	7/10/98	2002		VCS	25,686
11-00588	Old Ben 21	Old Ben Coal Co.	DTE Methane	11/13/95	2002		VCS	21,256
12-00323	Kings	Kings Station	small developer (Roy Farmer)	10/29/73	2001			2,852
01-00758	Blue Creek 3	Jim Walter Resources Inc.	Jim Walter Resources Inc	4/26/00	2000	Yes	CCX	— [d]
36-00906	Gateway Mine	Gateway Coal Co.		12/9/92	1999			33,990
44-01520	VP 3	Consolidated Coal Co.	Consol Energy	3/10/98	1998	Yes		148,572
44-01009	VP 2	Island Creek Coal Co.	Consol Energy	12/11/96	1997	Yes		88,092
46-01455	Osage 3	Consolidation Coal Co.	Consol Energy	5/25/96	1997	Yes		95,175
46-01452	Arkwright 1	Consolidation Coal Co.	Consol Energy	5/24/96	1997	Yes		105,744
46-01867	Blacksville 1	Consolidated Coal Co.	Consol Energy	6/10/93	1997			68,574
46-05722	Consol 20	Consolidation Coal Co.		10/1/82	1997			14,964
46-01434	Consol 9	Consolidation Coal Co.		9/10/78	1997			59,224
05-02820	Golden Eagle	Basin Resources Inc.	XTO	5/30/96	1997			117,023
44-00246	VP 1	Consolidated Coal Co.	Consol Energy	3/10/94	1995	Yes		141,128
44-04517	VP 6	Consolidated Coal Co.	Consol Energy	6/27/94	1995	Yes		146,362
44-02134	VP 4	Island Creek Coal Co.	Consol Energy	8/9/93	1994	Yes		23,657
33-00967	Nelms 1	Harrison Mining Corp.	CBM Ohio	6/10/77	1993			24,442

TABLE SM-1 NOTES: Unless otherwise noted, all emissions avoided figures are averages of data for 2012 and 2015 from U.S. EPA (2016) and its update in 2017, and all other project data are from Collings (2013). MSHA - U.S. Mine Safety and Health Administration. CCX - Chicago Climate Exchange. VCS - Verified Carbon Standard.

[a] Emissions avoided data for the eight Grayson Hill Farms mines are presented together and are the average for 2003 to 2008 from their CCX project report.
[b] Cambria project data are from its VCS project documents.
[c] Methane capture from these five mines are reported with the DTE Methane Old Ben No 25 project.
[d] Ruby Canyon Engineering lists this mine as having an active methane recovery project in 2013, but EPA does not list this mine as capturing methane in 2012 or 2015.

Table SM-1 lists all abandoned mine methane projects implemented in the United States during 1993 to 2012. We use these data to examine the amount of new business-as-usual (non-additional) methane capture that would be built in the future if rates of project development during 1993 to 2012 continue unchanged.

Table SM-2: AMM projects 1993-2012

	Projects not participating in voluntary market		**All projects**	
	mtCO2e/yr*	% of feasible capture**	mtCO2e/yr*	% of feasible capture**
At mines that captured methane when active	0.82	36%	0.88	38%
At mines with no previous methane capture	0.18	8%	0.37	16%
All projects	1.00	44%	1.25	54%

* Annual business-as-usual methane capture is estimated as half of the sum of annual methane capture for the 41 projects listed in Table SM-1 and that were implemented over a 20-year period. This is based on two assumptions. First, the MMC protocol applies 10-year crediting periods that may be renewed and we assume that all projects renew their crediting period. Second, we assume that projects are built evenly over time so that the average project built during a twenty-year period would capture methane for ten years.

** Feasible methane capture at the current pool of abandoned mines is assumed to be 2.3 $mtCO_2e/yr$ as per analysis in Ruby Canyon Engineering (2013).

Table SM-2 presents total annual methane emissions captured for the abandoned mine methane capture projects listed in table SM-1, for all projects, and for the following sub-categories: those that did and did not capture methane when they were active, and those that did not participate in the voluntary market. These sub-tallies indicate the expected generation of credits from non-additional projects if ARB had allowed all new projects at abandoned mines to participate (their initial proposal), and under the adopted protocol that only allows participation at mines that did not capture methane when they were active. We assess non-additional crediting as a range between the annual emissions from projects that did not participate in the voluntary market and all projects. This is because of uncertainty in whether the projects that participated in the voluntary offset market are additional. Table SM-2 presents these figures in both $mtCO_2e/yr$ and as a percentage of total feasible methane capture.

References

Collings RC (2013, August 19) [Personal Email] to Ms. Jessica Bede, ARB from Vice President of Ruby Canyon Engineering, Inc, Subject: California Air Resources Board: Proposed Compliance Offset Protocol Mine Methane Capture Projects. https://www.arb.ca.gov/regact/2013/capandtrade13/5rcecomm.pdf

Ruby Canyon Engineering (2013) *Abandoned Coal Mine Methane Offset Protocol: Background Information on Performance Standard and Additionality*, Grand Junction. https://ww3.arb.ca.gov/cc/capandtrade/protocols/mmc/rce_amm_background.pdf

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3. Details of the analysis of coal mine profits from coal mine methane capture offset projects

Table SM-3: Estimated Offsets Profits from Coal Mine Methane Capture Projects

				Estimated offset profits as % of mining profits at offset price:		
Mine	State	2016 status	2012 coal production (mill tons)	$10/tCO_2e$	$20/tCO_2e$	$50/tCO_2e$
Bailey	PA, 85% bituminous, 15% anthracite	Operating at reduced rate[a]	10.1	1%	2%	7%
West Elk	CO	Operating post layoffs[b]	6.9	7%	18%	49%
Robinson Run	WV, northern	Operating post sale[c]	5.0	2%	6%	18%
San Juan South	NM	Operating post sale and layoffs[d]	5.0	2%	9%	29%
Bowie #2	CO	Idled[e]	3.4	-	-	6%
Elk Creek	CO	Closed[f]	3.0	15%	38%	107%
West Ridge	UT	Closed[g]	2.4	17%	44%	127%
Pinnacle	WV, southern	Operating post sale and layoffs[h]	2.4	3%	10%	30%
		Production-weighted average:		3%	8%	23%

Table SM-3 notes: 2012 mine production data from Fiscor (2013). Offset project NPV estimated as 10-year annuity using EPA's Coal Mine Methane Project Cash Flow Model v 3.0 (U.S. EPA 2016a), assuming enclosed flare, methane GWP = 21, no royalty/severance taxes, and default model values. Methane availability taken as EPA-reported 2012 drained gas volumes less utilized volumes (U.S. EPA 2016b). Mine profits from coal sales assumed to be 9.4% of coal sales revenues (the average 2008-2012 profit margin of the coal mining-focused companies with publicly available annual reports that are listed in U.S. EPA (2009) as owners of large gassy underground U.S. coal mines: Alliance Resource Partners, Alpha Natural Resources, Arch Coal, CONSOL, Patriot Energy, and Walter Industries. Coal sales prices taken as EPA-reported state or sub-state average values for 2012 (U.S. EIA 2013, table 33).

Table SM-3 sources:

[a] http://triblive.com/business/headlines/9799455-74/coal-consol-company

[b] http://www.denverpost.com/2016/06/02/colorados-leading-coal-mine-cuts-jobs/

[c] http://www.murrayenergycorp.com/corporate-overview/

[d] http://www.daily-times.com/story/money/industries/oil-gas/2016/03/09/westmoreland-lays-off-workers-san-juan-mine/81532714/

[e] https://www.gjsentinel.com/news/western_colorado/buyers-back-out-of-deal-for-mine/article_f2d2ab16-d401-11e7-9c59-10604b9ffe60.html

[f] https://www.gjsentinel.com/news/western_colorado/oxbow-shifts-to-permanent-shutdown-of-elk-creek-mine/article_765ec9bd-ad46-5b4f-b4a8-fa6e543c1456.html

[g] https://www.sltrib.com/news/environment/2017/08/21/firm-wants-to-burn-methane-leaking-from-utah-coal-mine-creating-credits-to-sell-to-carbon-emitting-companies/

[h] http://wvmetronews.com/2016/01/03/pinnacle-lays-off-nearly-200-miners/

Table SM-3 presents the potential effects of California's Mine Methane Capture Protocol on coal mine profits at eight active underground coal mines. EPA identified these as the U.S. mines that have methane drainage wells that vented the majority of drainage methane to the atmosphere in 2012 and that did not already have pipeline injection systems. We perform this analysis using EPA's Coal Mine Methane Project Cash Flow Model version 3.0 (U.S. EPA 2016a), which EPA developed to allow coal mine operators and others to evaluate the potential economic viability of coal mine methane capture systems (U.S. EPA 2016c). This quantitative analysis is not meant to be a detailed assessment of potential methane capture projects at each mine, but rather an exploration of the scale of the effect California's offset protocol might have on coal mine operations.

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