Tracking banking in the Western Climate Initiative cap-and-trade program

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1. Introduction

This document is designed to provide a technical summary of the methods described in the main paper. A full accounting of the methods is contained in an accompanying spreadsheet file, which includes the primary data sources referenced in the paper, citations to additional data used, as well as all of the paper’s mathematical equations.

This document has two purposes:

- To summarize the main paper’s methodology in greater technical detail, including mapping the banking metric methods to the precise categories in the quarterly Compliance Instrument Reports (CIRs) that are used to construct those metrics; and,
- To describe the methodological details needed to address idiosyncrasies in the ways that Western Climate Initiative (WCI) governments implement their program regulations as well as to account for the temporary participation of Ontario’s cap-and-trade program in the linked WCI system.

This document is written assuming the reader is familiar with the main paper, which introduces several key concepts that are not repeated here.

2. Measuring compliance instrument holdings

Our banking metrics measure compliance instrument holdings using quarterly CIRs issued by the California Air Resources Board (CARB) [1]. Each CIR presents a snapshot of WCI-wide market holdings across all types of accounts as of a stated point in time. For example, the Q4 2018 CIR reports holdings as of January 4, 2019, and therefore can generally be used to observe WCI-wide holdings as of the end of the fourth quarter of 2018 or very beginning of the first quarter of 2019. The first CIR was issued for Q2 2014; CIRs have thereafter consistently been issued each quarter through Q2 2019, the most recent available CIR at the time of this writing.

Appendix A to this document lists the ten different account types tracked by CIRs. Three are “Entity Accounts” that report compliance instruments held by private market participants; six are “Jurisdictional Accounts” that report compliance instruments held by WCI governments; and one is a total that sums up all holdings across both private and government accounts. For convenience and consistency, our methodological descriptions here refer to the numbered list of account types in Appendix A.
The CIRs track holdings of allowances and offsets. Appendix A breaks down the specific types of instruments tracked in CIRs. Allowances holdings are reported for vintages 2013 through 2030 (#11-28 in Appendix A), inclusive, and also include two kinds of allowances that do not have vintages. The first, “Non-Vintage Early Action Allowances” (#29 in Appendix A), reports allowances issued by Québec for early actions taken to reduce emissions prior to the beginning of Québec’s cap-and-trade program. The second, “Non-Vintage Price Containment Reserve Allowances” (#30 in Appendix A), reports allowances designated by WCI governments for their respective reserve accounts. Although WCI program regulations designate specific shares of each jurisdiction’s overall program budget-years for assignment to the reserve accounts, and thus these allowances could be considered to have a corresponding vintage year, they are explicitly designated as non-vintage allowances in the program and tracked as such. Because they have no vintages, they are not subject to the program’s general restrictions on borrowing future vintages of allowances for surrender at compliance events.

Each entry in the CIR measures the number of the specific kind of allowance or offset held by a particular account type. The number reported is the sum of all holdings across all entities in the WCI of that account type, measured in metric tons of carbon dioxide equivalent (tCO₂e) [1].

In the case of allowances, CIRs do not distinguish between jurisdictional origins. Instead, allowance totals are reported as the sum across all jurisdictional holdings in circulation for a given account type—including allowances from California, Québec, and Ontario. (Although Ontario left the WCI program, many of its allowances are still in circulation and fungible for compliance purposes in the remaining WCI jurisdictions [3].)

Our banking metrics compare compliance instrument holdings against compliance obligations that private entities have incurred, but not yet satisfied via surrendering compliance instruments at compliance events. We exclude allowances with vintage years that are greater than the latest calendar year of the emissions for which the compliance obligations are measured. The primary reason for this methodological choice is to ensure our measurement of

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1 In addition to non-vintage allowances, program reserves also include vintage allowances. As of Q2 2019, Government Reserve Accounts also include ~37M vintage allowances, largely due to the fact that California allowances that remain unsold at auction for 24 months must be transferred to California program reserves; periodically, Québec also transfers allowances in and out of its program reserves as part of its annual allowance allocation process [2].
“excess” holdings involves a temporally consistent approach to observing market assets (compliance instruments holdings) and debts (outstanding compliance obligations).

Allowances with vintage years that are greater than the calendar year of the metric’s measurement are generally not available for satisfying compliance obligations incurred in that calendar year. Under this principle, all compliance instruments counted in the banking metrics for a given year can be used to satisfy the outstanding compliance obligations measured for the same year. In turn, the metrics do not capture holdings of future-vintage allowances until such time as the vintage of those allowances is equal to the calendar year of the metric in question.

This outcome is important to note because a significant number of future-vintage allowances are in circulation at any given point. See Figure 2 in the main paper for an overview of flows into private accounts, and see Figure 5 in the main paper and Figure SI-1 here for a comparison of “current” and “all vintage” metrics. For example, every quarterly auction includes an advance auction of allowances with vintages three years ahead of the current calendar year; that is, advance auctions in the year 2019 make available a limited number of vintage 2022 allowances for purchase. When private entities purchase these allowances, the allowances move into private accounts and are tracked in the CIRs. They are not included in our banking metric, however, until sufficient time passes such that these allowances become current-vintage allowances (with vintages equal to or less than the calendar year of the metric).

Similarly, there are a large number of future-vintage allowances in governments’ “Auction + Issuance + Allocation” and “Reserve” accounts (#5 and #8 in Appendix A, respectively). These future-vintage allowances are also excluded from our metrics for the same reason, until such time as they become current-vintage allowances.

2.1. Addressing post-2020 reserve allowances

Our methods require a consistent approach to addressing the presence of allowance reserves that are drawn from program budget years 2021 through 2030. While program regulations allow compliance entities to surrender any such allowances at any compliance events, these post-2020 allowances are held in (1) Government Reserve Accounts that are currently accessible only at prices far in excess of historical market prices (as is the case with Québec) or (2) Government Holding Accounts for which there is no mechanism to make these allowances available to private-sector entities at this time (as is the case with California).

Our analysis tracks both kinds of allowance stocks, but our metrics exclude them. The primary reason is that the overallocation issue primarily focuses on the extent to which allowances from
program budget years 2013 through 2020, inclusive, will be banked into subsequent compliance periods. Because post-2020 reserve allowances originate from post-2020 program budgets (see Table SI-1), their inclusion in banking metrics would increase the reported amount in a conceptually inconsistent manner. For the purposes of analyzing how many allowances exist under the program at any given point in time, they must be included; however, to focus our metrics on banking of pre-2021 allowances, we have decided to exclude them. We note that this decision is also consistent with our decision to exclude allowances with future year vintages from both the Private Bank and the Government Holding Accounts metrics.

Beginning in 2021 for our annual banking metrics and in the fourth compliance period (2021-2023) for our multi-year compliance period metrics, we intend to include all post-2020 reserve allowances. Until then, they are excluded from our results. Implementing this approach requires two additional steps:

- **Adjusting Government Reserve Accounts.** Beginning in Q4 2017, the CIRs include Québec’s post-2020 reserve allowances (~19.9M; see Table SI-1) in the Government Reserve Accounts. To calculate Government Reserve Accounts’ holdings of allowances that originate only from program budget years 2013 through 2020, inclusive, we subtract Québec’s post-2020 reserve allowances from the total reported in each applicable CIR. In addition, the Q4 2017 CIR included Ontario’s reserve allowances from budget years 2017-2020 (~26.7M) in Government Reserve Accounts. We exclude these allowances from our reserve metrics. They were subsequently removed when Ontario left the WCI program and do not appear in CIRs from Q2 2018 onward.

- **Adjusting Government Holding Accounts.** Also beginning in Q4 2017, the CIRs include 52.4M post-2020 California reserve allowances (see Table SI-1) in Government Holding Accounts. We exclude these allowances from our metrics. We do not know why CARB has retained these allowances in its holding account, rather than transferring them to its reserve account, but speculate that this decision may have reflected the potential for CARB to amend its post-2020 reserve volumes in response to statutory requirements. Immediately following the passage of the 2017 cap-and-trade extension bill, AB 398, CARB finalized a set of regulations that did not conform to AB 398’s requirements. This regulatory package set the post-2020 reserve allowance budget at 52.4M allowances. Subsequently, CARB approved a newer regulatory package implementing AB 398’s specific requirements in December 2018, with these newer reforms entering force as of April 2019. This new regulatory package increased the post-2020 reserve by 2,272,000 allowances in each program year 2021 through 2030, inclusive, bringing the total post-2020 reserve allowances
to ~75.1M (see Table SI-1). Up to and including the Q3 2019 CIR, however, the total number of post-2020 allowances remained at 52.4M, which were held in Government Holding Accounts. We expect that CARB will designate an additional 2,272,000 allowances for each vintage year 2021 through 2030, inclusive, as reserves; and we expect that CARB will eventually transfer all ~75.1M such allowances to the Government Reserve Accounts. No such designation nor transfer has yet occurred, as of Q3 2019, even though both changes are implied by law as of this writing. In the CIR for Q4 2017, Government Holding Accounts also include Ontario’s post-2020 reserve allowances (~52.4M), which we exclude from our metrics. These allowances were subsequently removed from WCI and do not appear in CIRs from Q2 2018 onward.

3. Annual metrics

Annual metrics are generally constructed using Q4 CIRs for each year, except as specified in more detail below.

3.1. Private Bank

The Private Bank includes all Entity Account holdings (#1-3 in Appendix A) of current and historical vintage allowances, all Entity Account holdings of non-vintage allowances (#11-28 in Appendix A, as appropriate), and offset types (#40 in Appendix A). The relevant CIR categories are shown in blue in Appendix A.

For example, the Private Bank at the end of 2018 calculates the sum of the following types of compliance instrument holdings across all Entity Accounts (#1-3 in Appendix A):

- Allowance vintages 2013 through 2018 (#11-16 in Appendix A), inclusive;
- Both types of non-vintage allowance categories (#29-30 in Appendix A); and,
- All offset holdings (#40 in Appendix A).

Estimating the Private Bank is straightforward for most years, with two modifications needed to address data limitations. In both cases, any potential complications or errors introduced by the modifications would be limited to the results for the year in question, with no impact on future years’ calculations. This is because subsequent CIRs produce an accurate picture of WCI-wide holdings that supersedes any inconsistencies or inaccuracies resulting from data limitations in previous years.

First, there were no CIRs issued in 2013, so it was necessary to estimate private compliance instrument holdings for this year from other data sources. (The first CIR was released in Q2
Instead of using CIR data, we estimate the number of compliance instruments in private accounts from quarterly WCI auction sales and allocation reports from California and Québec (see the accompanying spreadsheet for specific data and citations). We assume that no offsets were issued in 2013; we are not aware of public data summarizing offset issuance that may have occurred in 2013. As a result, the Private Bank we report in 2013 is not strictly comparable on a methodological basis with results from other years. However, any inconsistency would be limited to this year only because subsequent years’ CIRs accurately measure contemporary compliance instrument holdings, eliminating any potential bias that this alternative method may have introduced for 2013.

Second, the 2017 Private Bank metric requires a methodological modification to address Ontario’s brief participation in the WCI program and its aftermath [3]. Ontario launched a domestic cap-and-trade program in 2017 and linked with the WCI program as of January 1, 2018. Following the election of a new government that promised to eliminate Ontario’s program, the market operator, WCI, Inc., suspended Ontario entities’ ability to trade with other WCI participants on June 15, 2018, and the Ontario government announced the withdrawal of its program regulations on July 3, 2018 [1].

Ontario’s withdrawal introduces a number of complexities related to our use of the CIRs. We use Q4 CIRs to measure private compliance instrument holdings at the end of that calendar year, but Q4 CIRs are actually released in early January of the following year and measure WCI-wide holdings as of that date. Specifically, the Q4 2017 CIR measures WCI-wide holdings as of January 5, 2018, and therefore includes Ontario entities’ holdings as part of the linked WCI system, rather than reporting only those holdings in California and Québec accounts. In contrast, 2017 WCI compliance obligations do not include Ontario compliance obligations.

To adjust for this discrepancy, we observe California-Québec-Ontario holdings from the Q4 2017 CIR and subtract the number of 2017 Ontario allowances sold at auction (96.8M) and allocated to Ontario entities in 2017 (which we calculate at 34.0M) (i.e., we subtract a total of 130.8M allowances from the Q4 2017 CIR data). This approach reasonably allows us to estimate what a California-Québec Q4 2017 CIR would have shown, had one been issued with respect to only those holdings in California and Québec entity accounts. We note that if CIRs were re-issued to provide subtotals of account-specific holdings by instruments’ jurisdiction of origin, then it should be possible to calculate 2017 holdings without introducing any potential errors.

As with the additional methodological step required to calculate the 2013 Private Bank metric, any potential discrepancy related to 2017 results would be a one-off concern because
subsequent Q4 CIRs do not include Ontario entity holdings and therefore directly report the data of interest.

3.2. Government Holding Accounts

The Government Holding Accounts metric measures the number of compliance instruments that are held in specific jurisdictional accounts—as shown in the CIRs as the “Auction + Issuance + Allocation” column (#5 in Appendix A)—using the same basic rules concerning the qualified allowance and offset types that are adopted for the Private Bank metric. This metric includes all allowances with vintages less than or equal to the reporting year (#11-28 in Appendix A, as appropriate), both kinds of non-vintage allowances (#29-30 in Appendix A), and all offsets (#40 in Appendix A). The relevant CIR categories are shown in yellow in Appendix A.

For allowances with vintages, the methods for calculating the Government Holding Accounts are identical to those used for the Private Bank. For non-vintage allowances, however, the decisions WCI governments have made about when to transfer allowances between Government Holding Accounts and Government Reserve Accounts are somewhat idiosyncratic. In order to measure only those non-vintage allowances arising from program budgets from years 2013 through 2020, two additional steps are required.

First, as described in detail in Section 2.1, we account for the presence of post-2020 reserve allowances in Government Holding Accounts. Beginning with the Q4 2017 CIR and continuing through the Q3 2019 CIR (the latest available as of this writing), there were 52.4M post-2020 non-vintage California reserve allowances (#30 in Appendix A) in Government Holding Accounts. Similarly, the Q4 2017 and Q1 2018 CIRs include ~26.7M Ontario reserve allowances (#30 in Appendix A) in Government Holding Accounts. We exclude both sets of reserve allowances from our Government Holding Account metric.

Second, it is necessary to account for Ontario’s brief participation in the WCI program. The Q4 2017 CIR includes Ontario’s holding accounts, even though our methods for the 2017 metrics require their exclusion. To address this data challenge, we reduce the number of allowances measured by the Q4 2017 CIR in Government Holding Accounts by the number of vintage 2017 Ontario allowances that went unsold at Ontario’s stand-alone auctions, which we calculate at 4.4M [4]. As with the methodological limitations discussed for the Private Bank, any potential discrepancy here would be limited to the 2017 results only, because future years’ metrics rely on CIRs that eliminate the data issue in question.
3.3. Government Reserve Accounts

The Government Reserve Accounts measure the number of allowances held across each jurisdiction’s reserves, which set aside a fixed quantity of allowances for sale at pre-determined (and relatively high) prices. This metric is measured from the “Reserve” account on the CIRs (#8 in Appendix A). As with the Government Holding Accounts, we include only those allowances with vintages less than or equal to the year of measurement (#11-28 in Appendix A, as appropriate), along with the two kinds of non-vintage allowances in the WCI program (#29-30 in Appendix A). The relevant CIR categories are shown in green in Appendix A.

Measuring the number of allowances in Government Reserve Accounts requires minor adjustments for the years 2017 and 2018. The Q4 2017 CIR measures WCI-wide holdings as of January 2018, at which point Ontario had linked with the WCI program. As a result, this CIR includes reserve allowances from Ontario’s program budget years 2017 through 2020 (~26.7 million) and also reserve allowances from Québec’s program budget years 2021 through 2030 (~19.9 million). We exclude both from the number of allowances observed in the Q4 2017 CIR.

4. Multi-year compliance period metrics

The primary data limitation with respect to our multi-year compliance period metrics is that there is no CIR issued immediately following a multi-year compliance period’s compliance event. As a result, it is necessary to estimate the multi-year compliance period metrics using Q3 CIRs, which are generally issued about a month before compliance events occur. Any potential errors could be eliminated completely in future metrics if WCI jurisdictions report CIRs immediately following major compliance events.

4.1. Private Allowances

We calculate the number of allowances banked in private accounts as the difference between private allowance holdings as of the Q3 CIRs and the number of allowances surrendered at the November compliance event in the same year. Because there are no auctions and no major free allocations of allowances in between each year’s Q3 CIR and compliance event, we would expect this method to produce a reasonably accurate estimate of what a contemporaneous CIR would report. As discussed below in Section 4.5, however, Québec occasionally draws on allowances in its Government Reserve Accounts to distribute free allowances to private emitters, so there is some potential for changes in Private Allowances in between Q3 CIRs and compliance events.
As with the Private Bank, the Private Allowances metric is measured as the total number of allowances with a vintage less than or equal to the year of measurement (#11-28 in Appendix A, as appropriate), plus the total number of non-vintage allowances (#29-30 in Appendix A), across all private Entity Accounts (#1-3 in Appendix A).

4.2. Private Offsets

We calculate the number of offsets banked in private accounts as the difference between private offset holdings as of the Q3 CIR and the number of offsets surrendered at the November compliance event in the same year. In practice, there is a temporal gap of about a month in between the Q3 CIR and November compliance submission, during which time WCI jurisdictions may issue and/or transfer additional offset credits into private accounts; if any such transfers occur, they would not be captured by our metric. As a result, this metric offers a conservative estimate of the extent of private offset banking. Any error introduced by this method is likely to be small and will be transient because subsequent compliance period metrics will automatically measure any offset transfers that occurred.

The term Private Offsets is measured as the total number of offsets of all types (#40 in Appendix A) across all private Entity Accounts (#1-3 in Appendix A).

4.3. Government Allowances

The term Government Allowances is measured as the total number of allowances with a vintage less than or equal to the year of measurement (#11-28 in Appendix A, as appropriate), plus the total number of non-vintage allowances (#29-30 in Appendix A), as held in the “Auction + Issuance + Allocation” account (#5 in Appendix A).

The same caveat that applies to Private Allowances also applies to Government Allowances: we do not expect, but cannot rule out the possibility that there might be, modest transfers of allowances in or out of the Government Holding Accounts that occur in between the Q3 CIR and November compliance event.

4.4. Government Offsets

The term Government Offsets is measured as the total number of offsets of all types (#40 in Appendix A) held in the “Auction + Issuance + Allocation” account (#5 in Appendix A).

The same caveat that applies to Private Offsets and Government Allowances also applies to Government Offsets: we do not expect, but cannot rule out the possibility that there might be,
modest transfers of offsets in or out of the Government Holding Accounts that occur in between the Q3 CIR and November compliance event.

4.5. Government Reserves

The term Government Reserves is measured as the total number of allowances with a vintage less than or equal to the year of measurement (#11-28 in Appendix A, as appropriate), plus the total number of non-vintage allowances (#29-30 in Appendix A), as held in the “Reserve” account (#8 in Appendix A).

As discussed above in Sections 2.1 and 3.2, California has 52.4 million post-2020 non-vintage allowances that are intended for its Government Reserve Account, but which reside as of this writing in its Government Holding Account. Pursuant to new regulations, we expect CARB to increase this volume to ~75.1 million (see Table SI-1). It would make sense if these allowances were eventually transferred to the Government Reserve Accounts, but for now, at least, CARB holds them in the Government Reserve Accounts. Because our metrics include only allowances from pre-2021 budget years, we exclude these post-2020 allowances from our metrics. See Table SI-3 for details.

As discussed above in Sections 2.1 and 3.3, Québec has dedicated ~19.9 million post-2020 allowances for its reserve accounts. These allowances are located in Government Reserve Accounts as of Q4 2017. Because our metrics include only allowances from pre-2021 budget years, we exclude these post-2020 allowances from our metrics. See Table SI-3 for details.

Additional steps are needed to account for the fact that the Québécois government periodically accesses reserve allowances, distributing these allowances as part of free allocations to covered entities in Québec. At Québec’s second compliance period event in November 2018, Québécois covered entities surrendered 47,454 “Non-Vintage Price Containment Reserve Allowances” (#30 in Appendix A) that had previously been held in the Government Holding Accounts (“Auction + Issuance + Allocation”; #5 in Appendix A) in addition to another 1,214,683 non-vintage “Early Action” allowances that had previously been held in private Entity Accounts (#1-3 in Appendix A) and tracked in our private banking metrics. The 47,454 non-vintage allowances in question first entered Government Holding Accounts in the Q3 2018 CIR (measuring WCI-wide holdings as of October 5, 2018), shortly before the second compliance period compliance event (November 2018), and were gone as of the Q4 2018 CIR (measuring WCI-wide holdings as of January 4, 2019). We confirmed that the transfer out of Government Holding Accounts perfectly corresponds to the difference between the total number of non-vintage allowances
Québécois entities surrendered in this event and the reduction across all Entity Account holdings (#1-3 in Appendix A) from the Q3 to Q4 2018 CIRs.

Because these 47,454 allowances originate from Government Reserve Accounts—even though they temporarily migrated through Government Holding Accounts in Q3 2018—we assign their surrender as a reduction to the Government Allowances category for the purposes of our multi-year compliance period metric for the second compliance period.

5. Comparing California vs. WCI-wide data

Data limitations generally prevent analysis that disaggregates market-wide holdings by the compliance instruments’ jurisdiction of origin. CIR data report only WCI-wide holdings of allowances such that one cannot determine how many allowances of a particular type originated from program budgets in California, Québec, or Ontario.

Because all compliance instruments are equally valid for satisfying compliance obligations under cap-and-trade regulations in California and Québec, the WCI program’s fundamental supply-demand balance is best captured by measuring the bank of allowances and offsets across all WCI jurisdictions, rather than the bank of allowances from one specific jurisdiction or another. For this reason, we report banking metrics on a WCI-wide basis, counting all of the allowances and offsets issued by all participating WCI jurisdictions from the CIR data. Nevertheless, there may be important reasons to be able to disaggregate compliance instrument holdings by their jurisdictional origin and the jurisdictional identity of their holders.

The jurisdictional origin of allowances can be relevant to monitoring program outcomes. For example, we have previously argued that identifying the breakdown of allowances by origin would provide important information about the extent of cross-border trading in the lead-up to Ontario’s departure from the WCI program. The CIR data only provide a single point estimate of ~13.2 million net Ontario allowances remaining in the WCI program after Ontario’s departure. A deeper analysis of CIR data by vintage indicates a significant amount of cross-border trading that can be distinguished from the acquisition of Ontario allowances at joint WCI auctions and therefore indicates the degree to which secondary market trading increased the extent of WCI-wide oversupply as traders anticipated and reacted to the outcome of provincial elections in Ontario and transferred Ontario allowances to buyers in California and Québec [3]. These events eventually led the market operator, WCI, Inc., to suspend trading with Ontario [5]. Recognizing the value of being able to monitor and assess these outcomes, the 2018 Independent Emissions Market Advisory Report recommended that ARB report disaggregated compliance instrument holdings by jurisdictional origin [6].
The jurisdiction identity of private entities can also be relevant to monitoring program outcomes. Projections of banking vary between those that project WCI-wide banking conditions and those that focus specifically on California-specific outcomes. For example, the California Legislative Analyst’s Office projected private holdings in California of 200 million (±100 million) excess allowances at the end of 2020 [7], whereas CARB projected that no more than 150 million excess California allowances of vintages 2013 through 2020 would be held in California entities’ private accounts by the end of 2020 [8]. These projections cannot be compared directly against the data reported in the CIRs because the CIRs report only the total holdings of California, Québec, and Ontario allowances, without subtotals by jurisdictional origin of allowances nor the jurisdictional identity of allowance holders. A complete comparison requires more data than are currently disclosed in CARB’s CIR data releases.

Recognizing the need for CIR data disaggregated by jurisdictional origin, a group of California legislators requested CARB report second compliance period private banking metrics including subtotals of allowance holdings from California, Québec, and Ontario program budgets [9]. CARB refused to provide any information beyond the existing CIR data, however, stating in an April 2019 letter that it “cannot publish the jurisdiction of origin of allowances (outside of non-vintage Quebec Early Action allowances) for legal jurisdictional reasons” [10]. We are not aware of any further description of these reasons.

Table SI-2 reports the information provided by CARB, which is identical to what is measured in what we call Private Allowances and Private Offsets accounts in the Q4 2018 CIR.

As a result, the available public program data do not permit a direct, apples-to-apples comparison between observed WCI-wide market conditions and California-specific banking projections made by CARB and the California Legislative Analyst’s Office. Both of these projections are reported in terms of the number of excess allowances that are expected to be held in California entities’ private accounts at the end of 2020. In contrast, the CIR data shows the total number of allowances from all WCI jurisdictions, not just California.

The main paper presents unadjusted comparisons between the results of the annual banking metrics and various projections of the expected private bank at the end of 2020. That is, the main paper does not attempt to correct for the differences between projections of excess California allowances versus projections and measurements of WCI-wide banking. It bears emphasizing that CARB has the necessary data to permit an apples-to-apples comparison but that, without additional data disclosures, one can only speculate as to what a disaggregated CIR would indicate.
To provide an additional perspective to help facilitate a comparison of observed market conditions with California-specific projections, we adjust those projections in Table SI-4.

Specifically, we increase the California-specific projections for excess allowances in 2020 by a factor of 1.1638, which is the ratio of the WCI-wide program cap in 2020 (388,940,000 tCO₂e) to the California program cap in 2020 (334,200,000 tCO₂e). This adjustment reflects what one would expect if the California and Québec programs are equally stringent relative to domestic demand, such that excess allowance supplies in one jurisdiction are perfectly proportional to excess supplies in the other. It is a modest adjustment because Québécois emissions and program caps are much smaller than those in California—about 1/6 the size on an annual basis.

Under these assumptions, one can compare our results for the 2018 Private Bank’s minimum number of allowances (186.2M) with the adjusted CARB projections (174.6M). The central estimate for the 2018 Private Bank’s minimum number of allowances is 12.7M higher than the adjusted CARB projection for 2020, but the lower end of the uncertainty range in our results for the 2018 Private Bank’s minimum number of allowances overlaps the adjusted CARB projection for 2020. Similarly, the central estimate of the 2018 Private Bank’s minimum number of allowances is 45.5M lower than the central estimate from the adjusted California Legislative Analyst’s Office projection for 2020 (232.8M, ±116.4M).

We emphasize that these adjusted projections do not provide a superior means of evaluating the extent of program overallocation. California covered entities can use Québécois allowances to satisfy compliance obligations, and vice versa; and excess supplies in one jurisdiction can be sold to covered entities in another. It is therefore necessary to evaluate the extent of WCI-wide banking on the basis of WCI-wide holdings, rather than focus myopically on any one jurisdictional allowance origin or holdings in any one jurisdiction. Similarly, projections should focus on the availability of WCI-wide supplies across all WCI jurisdictions if the goal is to estimate the expected emission reductions from the program at a given point in time.

A final point of comparison can be made with the Q2 2019 CIR, which reports 195.5M allowances with vintages 2013 through 2017 and non-vintage allowances in private accounts. If we assume that the share of California allowances in private accounts is 0.8590—that is, the ratio between the California program cap in 2019 (346,300,000 tCO₂e) and the WCI-wide program cap in 2019 (403,150,000 tCO₂e)—that would imply that there are 167.9M California allowances in private accounts as of July 2019. This is more than the 150M excess California allowances with vintages 2013 through 2020 that CARB projected for the end of 2020.
The calculations presented here show how even a deferential reading of CARB’s projections does not alter the conclusion that observed banking behavior in 2018 exceeds CARB’s expectations for the worse-case 2020 scenario.

6. Current vs. all-vintage Private Bank metrics

The annual Private Bank metric presented in the main paper focuses on current vintage allowances—that is, it includes allowances with vintage-years that are equal to or less than the year of the metric’s measurement. Thus, the 2018 Private Bank measures the private holdings of allowances with vintages less than or equal to 2018, along with all offsets and non-vintage allowances. The intuition behind this approach is to measure private holdings of allowances and offsets that could be used to satisfy outstanding WCI-wide compliance obligations. Future-vintage allowances generally are not eligible for compliance purposes until they become current-vintage allowances, and therefore excluding them from a banking metric provides an instantaneous measure of the number of immediately-eligible compliance instruments held in excess of outstanding compliance obligations.

However, this is not the only methodological approach one could use to evaluate the program’s supply-demand balance. Private parties also hold a significant number of future-vintage allowances that were acquired at advance auctions and/or allocated by WCI governments to private parties. A banking metric could include these allowances to provide a second perspective on market supply-demand balance. This is the approach the European Union takes in its banking metric; for example, see [11]. Figure 5 in the main paper includes an estimate of what we call the “all vintage” Private Bank, which uses the same data sources as the “current vintage” Private Bank except that it includes all vintages of allowances, rather than restricting the vintage-year of allowances counted in the Private Bank metric.

The main Private Bank metric can be adjusted to match the scope of the European Union’s banking metric by including future-vintage allowances. However, some important differences remain owing to the timing of WCI CIR data releases. The European Union provides calendar-year accounting data, with allowances, offsets, and emissions measured at the very end of each calendar year. In contrast, although WCI emissions are also evaluated on a calendar-year basis, the CIRs measure market-wide holdings on a quarterly basis that does not align with the calendar year. Specifically, Q4 CIRs measure WCI-wide holdings as of early January of the following year—for example, the Q4 2018 CIR measures WCI-wide holdings on January 4, 2019.
The timing of the CIR measurement and the movements of allowances according to WCI program regulations impacts the number of measured future-vintage allowances. We review three important concepts that affect this measurement here.

First, by the time of the Q4 CIR measurement CARB will have issued its annual allocations, including consignment allocations, to covered entities for the following year. That is, by the time of the Q4 2018 CIR is measured in January 2019, CARB has issued its 2019 free allocations to private emitters and these future-vintage allowances are included in the private holdings as measured by the Q4 2018 CIR. Conceptually, governments allocate these allowances in relation to 2019 calendar-year emissions, but 2019 emissions are not included in a 2018 banking metric even if the 2019 allocations are included as a result of the timing of CIR measurement.

Second, some of the consignment allowances that were allocated to private parties by early January are designated for auction prior to the CIR measurement. As a result, these allowances are transferred from private entities’ Limited Use Holding Account (CA) (#3 in Appendix A) to the government Auction + Issuance + Allocation Account (#5 in Appendix A). Thus, a portion of the freely allocated allowances transferred from Government Holding Accounts to Private Accounts will have been transferred back by the time of the Q4 CIR measurement. Historically, this portion is similar (but not identical, in some years) to consignment allowances offered in the subsequent Q1 auction held in February.

Third, our understanding is that while California makes its allowance allocation and consignment allowance adjustments by the time of the Q4 CIR measurement, Québec does not. That is, the free allocations Québec provides to some of its covered entities are not yet made by the time of the Q4 CIR measurement, and therefore the “all vintage” Private Bank metric does not include these allowances.

The “all vintage” Private Bank metric can be estimated using CIR data for all years except 2013, when no Q4 CIR was available. Thus, the results for all years of the “all vintage” Private Bank metric are observed directly from CIR data except for 2013, which we estimate.

As a result of these methodological issues, one can think of the “all vintage” Private Bank metric as representing the instantaneous measure of total compliance instrument holdings as of early January relative to outstanding emissions through the end of the previous December. Because a significant share of the future-vintage allowances come from allocations for the following year (i.e., for the 2018 metric, 2019 allocations), however, this metric should be interpreted carefully because it does not represent the supply-demand balance on a fully consistent calendar-year basis. Nevertheless, it does provide an accurate accounting of what private entities hold as of
the point of measurement and therefore what the actual conditions are in the market at that point in time. This information can be helpful to ascertain how many surplus allowances and offsets are held by private parties at a given point in time, even if caution should be exercised in using the “all vintage” Private Bank metric to evaluate supply-demand balance on, say, a calendar-year basis. See Figure SI-1 and tab “Figure SI-1” in the spreadsheet for details.

**Figure SI-1: Comparing "current" and "all vintage" Private Bank metrics (MMtCO₂e)**

This figure shows the results for the “current” and “all vintage” Private Bank metrics and disaggregates the contribution of three sources of future-vintage allowances to the “all vintage” metric. A significant number of future-vintage allowances come from annual allocations, including consignment allowance allocations, for the subsequent year, which California has transferred to private accounts by the time of the Q4 CIR measurement underlying both metrics. However, a sizable number of allowances purchased in advance auctions, which are unrelated to the next year’s allocation process, are also present at the time of measurement. These three types of holdings can be calculated manually from program data and closely reproduce CIR measurements. Because no CIR exists for Q4 2013, we estimate the “all vintage” 2013 Private Bank using these manual calculations and include an error bar of ±5%.
Table SI-1: Post-2020 reserve allowance budgets (tCO$_2$e)

| Program year | California regulations (pre-AB 398) | California regulations (post-AB 398) | Québec regulations |
|--------------|-------------------------------------|-------------------------------------|--------------------|
| 2021         | 10,500,000                          | 12,272,600                          | 2,210,400          |
| 2022         | 9,300,000                           | 11,572,600                          | 2,160,800          |
| 2023         | 8,100,000                           | 10,372,600                          | 2,111,600          |
| 2024         | 7,000,000                           | 9,272,600                           | 2,062,000          |
| 2025         | 5,800,000                           | 8,072,600                           | 2,012,400          |
| 2026         | 4,700,000                           | 6,972,600                           | 1,963,200          |
| 2027         | 3,500,000                           | 5,772,600                           | 1,913,600          |
| 2028         | 2,300,000                           | 4,572,600                           | 1,864,400          |
| 2029         | 1,200,000                           | 3,472,600                           | 1,814,800          |
| 2030         | 0                                   | 2,272,600                           | 1,765,000          |
| Total        | 52,400,000                          | 75,126,000                          | 19,878,800         |
Table SI-2: WCI-wide private compliance instrument holdings at the end of the second compliance period, as reported by CARB (MMtCO$_2$e)

| Type                  | California | Québec   | Ontario | Total    |
|-----------------------|------------|----------|---------|----------|
| Vintage 2013          |            |          |         | 1,408,541|
| Vintage 2014          |            |          |         | 4,901,858|
| Vintage 2015          |            |          |         | 10,592,014|
| Vintage 2016          |            |          |         | 53,291,321|
| Vintage 2017          |            |          |         | 107,635,826|
| Non-vintage Québec Early Action |          | 19,221   |         | 19,221   |
| Non-vintage Reserve Allowances |            |          |         | 38,317   |
| Subtotal, Allowances  |            |          |         | 177,887,098|
| Offset Credits        | 40,538,499 | 77,534   |         | 40,616,033|
| Total Compliance Instruments |            |          |         | 218,503,131|
| Jurisdiction | Allowance Type          | Number of Allowances | Location (As of Q2 2019 CIR) |
|--------------|-------------------------|----------------------|------------------------------|
| California   | Non-Vintaged Allowances | 52,400,000           | Column [5] Row [30]          |
|              | Vintaged Allowances     | 22,726,000           | Column [5] Rows [19-28]      |
|              | Total                   | 75,126,000           | N/A                          |
| Québec       | Non-Vintaged Allowances | 19,878,800           | Column [8] Row [30]          |
|              | Vintaged Allowances     | 0                    | N/A                          |
|              | Total                   | 19,878,800           | N/A                          |
Table SI-4: Adjusted results (MMtCO$_2$e)

| Series                                      | Year | Accounting                                      | Main paper results | Adjusted results (see Section 5) |
|---------------------------------------------|------|------------------------------------------------|--------------------|----------------------------------|
| Private bank                                | 2018 | Compliance instruments, WCI-wide               | 226.9              | N/A                              |
| Private bank                                | 2018 | Minimum allowances, WCI-wide                   | 186.2              | N/A                              |
| CARB                                        | 2020 | Allowances, California only                     | 150                | 174.6                            |
| California Legislative Analyst’s Office     | 2020 | Allowances, California only                     | 200 (±100)         | 232.8 (±116.4)                   |
| Busch                                       | 2020 | Allowances, WCI-wide                            | 270 (±70.0)        | N/A                              |
| Environmental Commissioner of Ontario       | 2020 | Allowances, WCI-wide                            | 335                | N/A                              |
7. References

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[6] Independent Emissions Market Advisory Committee. 2018 Annual Report of the Independent Emissions Market Advisory Committee. California Environmental Protection Agency; 2018.

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[9] Allen B, Friedman L, Monning WW, Garcia E, Wieckowski B, Garcia C. Letter from Senator Ben Allen, et al., to Secretary Jared Blumenfeld, et al. 2019.

[10] Nichols M, Blumenfeld J. Letter from Chair Mary Nichols and Secretary Jared Blumenfeld to Senator Ben Allen, et al. 2019.

[11] European Commission. Publication of the total number of allowances in circulation in 2018 for the purposes of the Market Stability Reserve under the EU Emissions Trading System established by Directive 2003/87/EC. 2019.
Appendix A – Compliance Instrument Report details

Account Categories

Entity Accounts

1. General
2. Compliance
3. Limited Use Holding Accounts (California only)

Jurisdictional Accounts

4. Voluntary Renewable Electricity (California only)
5. Auction + Issuance + Allocation
6. Retirement
7. Invalidation
8. Reserve
9. Environmental Integrity (Québec only)

All accounts

10. Total

Compliance Instrument Categories

Allowances

11. Vintage 2013
12. Vintage 2014
13. Vintage 2015
14. Vintage 2016
15. Vintage 2017
16. Vintage 2018
17. Vintage 2019
18. Vintage 2020
19. Vintage 2021
20. Vintage 2022
21. Vintage 2023
22. Vintage 2024
23. Vintage 2025
24. Vintage 2026
25. Vintage 2027
26. Vintage 2028
27. Vintage 2029
28. Vintage 2030
29. Non-Vintage Early Action Allowances (Québec only)
30. Non-Vintage Price Containment Reserve Allowances

31. Allowances Subtotal

Offset credits – California

32. U.S. Forest Project Offset Credits
33. Urban Forest Project Offset Credits
34. Ozone Depleting Substances Offset Credits
35. Livestock Manure Digesters Offset Credits
36. Mine Methane Capture Offset Credits
37. Rice Cultivation Project Offset Credits

Offset credits – Québec

38. Destruction of Ozone Depleting Substances Offset Credits
39. Landfill Site Methane Destruction Offset Credits

40. Offset Credits Subtotal

All compliance instruments

41. Total
| Vintage       | Entity Accounts | Jurisdictional Accounts | All Accts. |
|--------------|----------------|-------------------------|------------|
|              | [1] General    | [2] Compliance          |            |
| [11] 2013    |                |                         |            |
| [12] 2014    |                |                         |            |
| [13–27] (2015-2029) |            |                         |            |
| [28] 2030    |                |                         |            |
| [29] Non-Vintage Early Action (QC) |             |                         |            |
| [30] Non-Vintage Reserves          |             |                         |            |
| [31] Allowance subtotal             |             |                         |            |
| [32] US Forest (CA)                |             |                         |            |
| [33] Urban Forest (CA)             |             |                         |            |
| [34] ODS (CA)                       |             |                         |            |
| [35] Livestock (CA)                |             |                         |            |
| [36] Mine CH4 (CA)                 |             |                         |            |
| [37] Rice (CA)                      |             |                         |            |
| [38] ODS (QC)                       |             |                         |            |
| [39] Landfill (QC)                 |             |                         |            |
| [40] Offsets subtotal               |             |                         |            |
| [41] Total                            |             |                         |            |