Overallocation in the California-Québec Carbon Market: A Useless Cap Until 2030

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Abstract

The Western Climate Initiative cap-and-trade program is expected to contribute substantially to the climate targets set by the governments in California and Québec by gradually constraining emissions through the decrease in the number of pollution rights. Using a supply-demand model and the latest published data for the third compliance period (2018-2020), we estimate seven scenarios for future emissions and changes in the program's features, and we analyse the resulting price path for compliance instruments. We find that the observed overallocation of instruments in the past compliance periods will continue until 2030 in all the scenarios, except when covered emissions substantially increase. Only the consequent price increase induces small abatement, but it remains insufficient to reach climate targets. Our main findings show that overallocation is caused by caps being too high to foster sufficient emission reductions, and specific elements of the program such as the issuance of offset credits do not account as the main source of oversupply. If the program were to close the existing gap between compliance instruments demand and supply, government should either reduce the level of the existing allowance caps, or increase the amount of covered emissions. However, the presence of a price ceiling acts as a carbon tax, and emissions are not efficiently constrained once it is reached, unless the price ceiling is set efficiently, which is not the case at the moment.

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Key policy insights:

- In most scenarios considered, the climate objectives are not reached: emissions remain well above the established targets for 2030.
- In the current situation, only exogenous elements to the program would allow climate objectives to be fulfilled. The market on its own does not induce sufficient emission reductions, although its requirements are satisfied.
- Overallocation remains an issue until 2030 in most scenarios, and leads to prices close to the price floor. This does not effectively signal the need for emissions reductions, and consequently does not achieve expected abatement.
- The program's low emissions coverage rate is problematic and the key overallocation source. Increasing covered emissions from the current level to the one claimed by participating jurisdictions would lead to higher prices and eliminate overallocation.

Keywords: cap-and-trade, carbon pricing, carbon markets, California, Québec, Western Climate Initiative

1 Introduction

Many governments around the world have set national greenhouse gas (GHG) emission reduction targets to mitigate climate change. Economic mechanisms, such as carbon tax and cap-and-trade programs, are implemented essentially to make the environmental costs of emissions visible, and thus induce abatement. Cap-and-trade programs set a limit on the amount of emissions coming from specific sources. Emitting entities from these covered sectors need to obtain an amount of allowances (also called emission rights, permits, or more generally "compliance instruments") equivalent to their emissions. Different cap-and-trade programs exist: for instance the European Union Emission Trading Scheme (EU ETS), the Regional Greenhouse Gas Initiative (RGGI) in the United States, and the Western Climate Initiative (WCI). The WCI has three members, California (US), Québec and Nova Scotia (Canada). However, only California and Québec are linked under the WCI. Introduced in 2013, and briefly joined by Ontario in 2018, the program is expected to deliver around 40% of the emission reduction targets set by the California Climate Change Scoping Plan (CARB, 2017), and this share increases to 60% for Québec (Gouvernement du Québec, 2020). However, there are concerns about overallocation in the WCI (Inman et al., 2018; Inman et al., 2020; Bush, 2018), a situation where the supply of instruments delivered by governments exceeds the demand of instruments from emitters to cover their emissions. This can be acceptable if emissions are low and caps are not needed to incentivize reduction. But it can also lead to a situation where the abundance of instruments allows emitters to fulfill their obligations while overall emissions are beyond the established cap. The resulting low instrument prices do not induce expected emission reductions, and can thus potentially weaken climate goals. This problem has been observed in the EU ETS after the 2008 financial crisis (McAllister, 2009), as well as in the RGGI between 2010 and 2013 (Rich, 2018).

Several studies have demonstrated the presence of overallocation in the WCI. Cullenward et al. (2020) show that excessive supply has been observed in the past years, and is very likely to continue through 2030. Inman et al. (2020) study a large range of scenarios computed by a computer-based model, differing in a narrow number of settings. They show that most of them result in overallocation. In order to avoid this situation, they suggest to implement dynamic cap adjustments (Inman et al., 2018) as it has been introduced in the EU ETS. Few studies analyze the possible price of instruments under different scenarios. Generally, it has been found that it is most likely that the price will take an extreme value, either equal to the price floor or to the price ceiling (Borenstein et al., 2017 and 2019). The authors show that during the period 2013-2020, there is only a 1.1% probability that the price will end up in the intermediate region, and it increases to 19% for the 2021-2030 period, while there is a 47% probability for the price remaining at the price floor. However, no precise price path has been determined.

In light of the latest published data from the Compliance Obligation Report (CARB, 2021) for the third compliance period (2018-2020), this paper intends to determine if the program's current measures still lead to a supply-demand imbalance by the end of the sixth compliance period in 2030. Its novelty and contribution is the formulation of several scenarios that explore how a large set of components of the program might cause overallocation. By changing features in the demand and supply of instruments, we are able to determine the concrete paths for instruments prices and achieved emission reductions (or increase, in some cases) for each scenario. This allows to verify what potential policy changes can be implemented, and to confirm, or not, their ability to meet climate targets, which has not been done as precisely.

Our findings show that the market will remain overallocated if emissions follow the business-as-usual trend (Scenario 1). The price increases substantially but does not induce sufficient emission reductions to meet climate targets. If we consider scenarios where emissions either follow the historical trend (Scenario 3), which leads to lower emissions in 2030 than the business-as-usual scenario, or if they decrease due to the success of additional policies in California and Québec (Scenario 4), then even more instruments remain in the hands of the governments, and the price remains at the price floor in the last compliance period. We investigate the causes of overallocation, and find that the issuance of offset credits (Scenario 5) accounts for only a minor part of instruments oversupply, as does the unexpected drop in emissions due to the Covid-19 crisis in 2020 (Scenario 6). There is still a substantial number of instruments in circulation in the market at the end of the sixth compliance period, although the price reaches the price tiers. Emissions reductions are not important enough to fulfill the regions' objectives. Even in the case where the population would adapt its behaviour to the price increase in the long run, the WCI system does not provide the necessary incentives to meet the 2030 climate targets. The market ends up in a situation where entities comply with the system, but caps are not effective and do not efficiently constrain emissions. In order for the market to play its role, the amount of covered emissions must increase, while keeping the same caps (Scenario 2), or the caps must be reduced.

Section 2 presents the flows of instruments in the WCI and the general functioning of the program. In Section 3, we expose the methods we use to model the

WCI market and we explore several scenarios for the evolution of future emissions and potential changes in the functioning of the program. Results are discussed in section 4.

2 The Western Climate Initiative

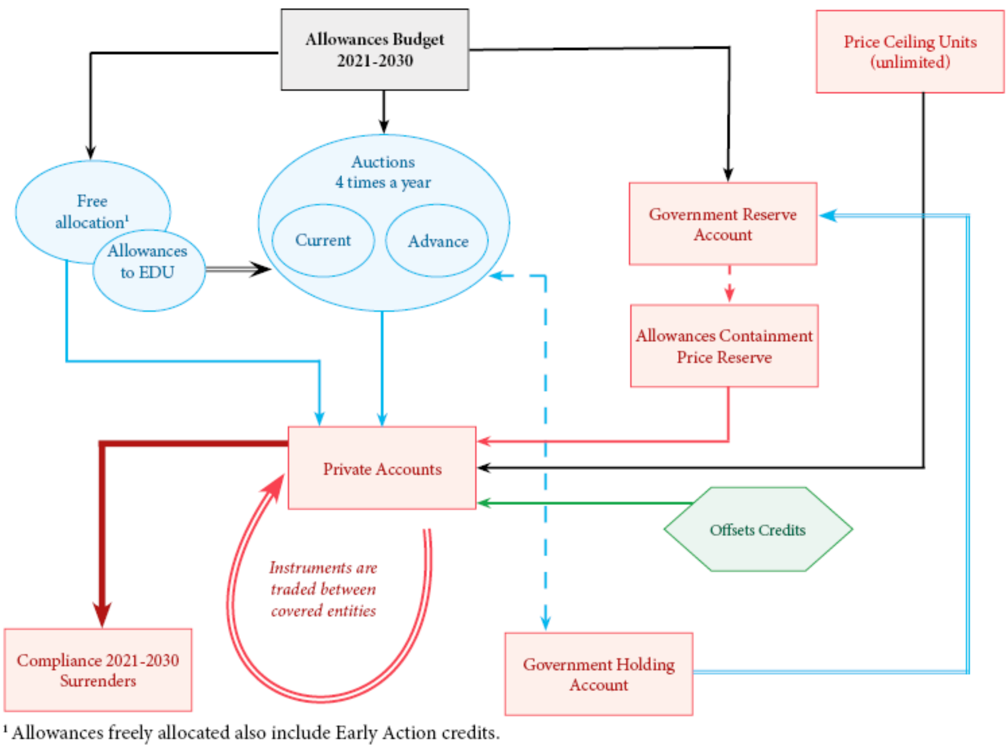
In essence, a cap-and-trade program creates a market for pollution and gives a price to emissions. The government sets a maximum level of emissions that can be released by emitters (also called covered entities), and issues an equivalent number of compliance instruments. Covered entities obtain these instruments by buying them at auctions or from other covered entities through a trading scheme, or through free allocations directly from the government. Ultimately, covered entities must fulfill their compliance obligation by surrendering to the government the number of instruments corresponding to their emissions over the compliance period. In the WCI, one compliance instrument corresponds to one metric tonne of carbon dioxyde equivalent (tCO_2e). A compliance instrument either takes the form of an allowance, or a credit (in the case of WCI, it can be an offset credit, or an early action credit), and both are considered equivalent when surrendered for compliance, although entities are limited in the amount of offset credits they are allowed to surrender in each compliance period.

The key components of the WCI and relationships between them are illustrated in Figure 1. Appendix 1 offers a more detailed explanation of the program's specific features.

The regional institutions in charge of the program, respectively the California Air Resource Board (CARB) and the Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC), defined six distinct compliance periods (periods or CP). Each region sets a carbon budget for each calendar year (California Code of Regulations, 2017; Gouvernement du Québec, 2017), that we hereafter call caps. Compliance periods and corresponding caps are displayed in Table 1. These caps are based on the 2030 climate targets of California and Québec. They are equivalent to the number of instruments issued in the form of allowances (represented by the upper grey box in Figure 1).

These allowances are then distributed to covered entities through several distinct channels represented by the black lines in Figure 1: free allocation, auctions, Re-

Figure 1: Flows of instruments in the Western Climate Initiative



serve sales and Price Ceiling sales. Entities can also receive additional compliance instruments in the form of offset credits, if they achieve verified emission reductions in a sector or location not covered by the program. These instruments can be traded among covered entities, and surrendered indifferently to fulfill the entities' compliance obligation. If entities hold instruments in excess at the end of the compliance period, they can bank them for future use. See Appendix 1 for extensive details.

3 Methods, model and scenarios

The prime objectives of this paper are to investigate the presence of a gap between the supply of instruments by the governments and the demand of covered entities to fulfill their compliance obligation until 2030, and to investigate the price path for compliance instruments. We use a supply-demand model for compliance instruments, that indicates the presence of a difference between supply and demand, and allows to estimate the resulting equilibrium price.

Table 1: Compliance Periods and corresponding regional and joint caps (in million metric tons of CO_2 equivalent, $MtCO_2e$)

CP	Calendar Year	CA Cap	QC Cap	**Joint Cap**	**CP Cap**
1	2013	162.8	23.2	**186**	**368.9**
	2014	159.7	23.2	**182.9**	
2	2015	394.5	65.3	**459.8**	**1336.9**
	2016	382.4	63.2	**445.6**	
	2017	370.4	61.1	**431.5**	
3	2018	358.3	59	**417.3**	**1209.4**
	2019	346.3	56.9	**403.2**	
	2020	334.2	54.7	**388.9**	
4	2021	320.8	55.3	**376.1**	**1084.5**
	2022	307.5	54	**361.5**	
	2023	294.1	52.8	**346.9**	
5	2024	280.7	51.6	**332.3**	**953.0**
	2025	267.4	50.3	**317.7**	
	2026	254	49.1	**303.1**	
6	2027	240.6	47.8	**288.5**	**821.6**
	2028	227.3	46.6	**273.9**	
	2029	213.9	45.4	**259.3**	
	2030	200.5	44.1	**244.7**	

3.1 Demand

The demand for compliance instruments expresses the number of instruments needed by entities to cover their emissions for a given compliance period. We thus assume that the amount of emissions equals the number of demanded and surrendered instruments. The demand primarily depends on the structural level of emissions in the economy and the price of instruments. The inverse price elasticity specifies how the demand for compliance instruments changes when the price of instruments increases. A review of carbon elasticities can be found in Appendix 2. We take the average value, -0.41. Specifications on how the demand function is derived from elasticity can be found in Appendix 3.

3.2 Supply

The supply reflects the amount of compliance instruments made available by the governments. The amount of instruments offered by the governments does not depend on the price of compliance instruments, thus the supply function is price inelastic. For each compliance period, we determine the following levels of supplies:

1. EMISSION CAP. It is the lower bound supply that includes solely the joint allowance cap determined by the program, as shown in Table 1. It can be interpreted as the conservative estimate of the theoretical supply.

2. CAP+OFFSETS. This level of supply includes the joint allowance cap and the maximum amount of offset credits that covered entities are allowed to surrender for the compliance period. This represents the high estimate of the theoretical supply.

3. AVAILABLE SUPPLY. It reflects the supply of compliance instruments actually offered to covered entities. For each compliance period, it includes the following elements:

   - Allowances that were freely allocated by California (Cap-and-Trade Program Allowance Allocation Summary; Electrical Distribution Utility and Natural Gas Supplier Allocation) and Québec ("Quantité d'unités d'émission versées en allocation gratuite et liste des émetteurs qui en ont bénéficié"),
   - Allowances offered at auctions, with a current vintage only (Summary of California-Quebec joint auction settlement prices and results). We do not include allowances offered in previous auctions that were not sold and auctioned again. Allowances offered in Advance Auction enter the accounts only when their vintage equals the calendar year. For instance, allowances with vintage 2021 offered in the Advance Auction in 2017 are not available for surrender before 2021.
   - Granted offset credits (ARB Offset Credit Issuance; Registre des projets de crédits compensatoires). Note that the number of issued offset credits is independent of the maximum amount of offsets that covered entities are allowed to surrender.
   - Granted Early Action credits by MELCC (Linked California and Québec Cap-and-Trade Programs Carbon Market Compliance Instrument Report), conceded in 2013 but also available in later compliance periods.
   - Instruments that entered Private Accounts during the preceding compliance periods but remained unused for compliance obligations (calculated as the difference between allowances freely allocated, bought at auction, granted offsets and surrendered instruments). These instruments are banked and available for future use. Note that we use the cumulative surplus of instruments.

- When buying allowances at auction, entities' bids must lie at or above the minimum allowance price (fixed at 10 USD in 2012 and increasing by 5% plus inflation every year). Because of this feature, the supply function is infinitely inelastic at the price floor.
- Allowances in the Price Containment Reserve made available at predetermined price tiers (California Cap-and-Trade Program Sale of Greenhouse Gas Allowances from the Allowance Price Containment Reserve). This creates steps in the function at the price tiers, when additional instruments are offered. From 2021, unlimited amounts of allowances are offered at the price ceiling, thus the supply function becomes infinitely inelastic.

For modeling and illustration purposes, and for each element defined above, we use the average values over each compliance period. Figure 2 shows the supply-demand model for the third Compliance Period (2018-2020), with the three supply functions and the demand function.

This graph shows that at the end of the third compliance period (2018-2020), the market was still highly overallocated, no matter which supply we consider. The equilibrium price was slightly above the average minimum price (16.26 USD).

In Figure 3, we show the market equilibrium for the first three compliance periods. For clarity, we only show the available supply for each compliance period instead of all three supply functions. Demand and supply both substantially increase from the first compliance period to the second due to an increase in the emissions covered by the program: energy distributors (selling oil products and natural gas in the transportation, commercial and residential sectors) were included in 2015. The number of issued compliance instruments consequentially increased. For all periods, demand for instruments is lower than the supply, meaning that unused instruments are banked and available for the next period. This translates into a higher supply in the next period. In each compliance period, the equilibrium is again very close to the price floor.

3.3 Scenarios for compliance periods 4 to 6

In this section, we analyze seven scenarios, exploring different emission paths in compliance periods 4, 5 and 6, as well as potential changes in the functioning of

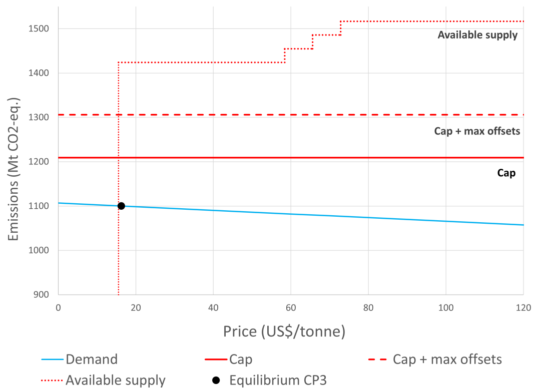


Figure 2: Third Compliance Period supply-demand equilibrium

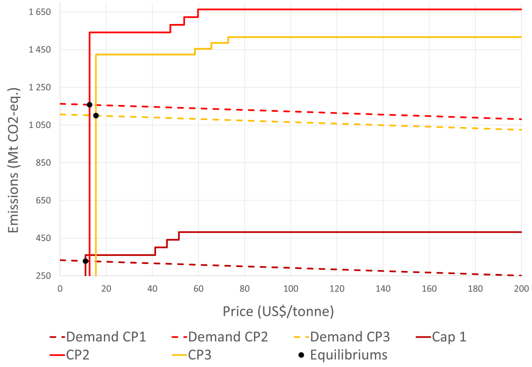


Figure 3: Supply-demand equilibrium for CP1, CP2 and CP3.

the program. Note that the Californian Regulation (AB 398) altered the cost containment features from 2021 by introducing a price ceiling, at which an unlimited number of allowances would be sold for entities that do not hold enough instruments to cover their compliance obligation. The first scenario assumes business-as-usual emissions as estimated by governments. A second scenario explores the resulting equilibrium if covered emissions were indeed at the level claimed by the WCI, and not at the level observed in compliance periods 2 and 3. The third one assumes that emissions follow the historical observed trends (2000-2019), namely a 1% yearly reduction in California and a 0.5% yearly reduction in Québec. The fourth scenario explores the consequences of emission reductions from complementary policies in both region, achieving some of the targeted emission reductions. The fifth scenario analyzes the consequences of eliminating offset credits from 2021, to assess if they cause the overallocation of instruments. The sixth scenario considers the fictive situation where the Covid-19 crisis would not have happened, in order to determine whether the drop in emissions in 2020 is the source of allowances oversupply in later periods. Finally, the seventh and last scenario explores a hypothetical situation where emitters are more price elastic, i.e. they adapt their behavior to price increases more easily, and switch quicker to less emission-intensive alternatives as the cost of emissions increases.

For future compliance periods, demand depends on future emissions. We will specify how we estimate them for each scenario. For the supply functions, unless stated otherwise, we estimate all future values of the elements of the "available supply".

- We calculate the mean rate of allowances freely allocated and offered at auction with respect to the allowance cap for compliance periods 2 and 3. We use the allowance caps displayed in Table 1 to derive the supply of allowances for Periods 4, 5, and 6.

- In the past compliance periods, the mean rate of granted offset credits was almost equivalent to the maximum rate of credits that entities were allowed to surrender. We assume that the number of granted offset credits for future periods is equal to the maximum number of credits that entities are allowed to surrender for compliance (8% in Québec, 4% from 2021 to 2025 and 6% from 2026 to 2030 in California).

- The steps of the function represent the number of allowances available for sale at each reserve tiers. We assume that no more allowances will be placed in the Reserve Account, as it was the case from 2013 to 2018, and take the same number of allowances as in 2021.

- The tier prices increase by 5% plus inflation every year. We assume that inflation is equal to 2%.

- We estimate unused instruments as the difference between allowances entering Private Accounts and surrendered compliance instruments.

- We assume that entities surrender the maximum allowed offset credits, which is equal to the number of granted credits. Therefore, in the calculation of the cumulative surplus of instruments, starting from 2021 we calculate it as the sum of the net surplus of unused allowances only, instead of the sum of the net surplus of instruments. Allowances entering Private Accounts are calculated using the mean rate of allowances entering Private Accounts (freely allocated and bought at auction) with respect to the number of allowances offered at auction and freely allocated by the governments. From the number of allowances offered in future periods that we derived earlier, we can determine the number of allowances entering Private Accounts for compliance periods 4, 5 and 6. Subtracting from this the number of surrendered instruments, we get the net surplus of instruments for each future compliance period, which allows us to derive the cumulative number of unused instruments. All these estimates allow us to formulate the supply functions for compliance periods 4, 5 and 6.

3.3.1 Scenario 1. Business-as-usual

In this scenario, we assume that total emissions of each region follow the business-as-usual path as estimated respectively by CARB in the Scoping Plan (2017) and by Dunsky and ESMIA (2021) for Québec. In 2030, the level of emissions reaches approximately 79 Mt in Québec and 389 Mt in California. Using the number of surrendered instruments from the Compliance Obligation reports (CARB, 2021; 2018; 2015), and historical emissions for each region (CARB, 2021; Gouvernement du Québec, 2021), we calculate the mean historical rate of emissions that are covered by the program in compliance periods 2 and 3 (some emission-intensive sectors were not covered during the first compliance period). From this coverage rate and estimated future emission levels, we derive the estimated number of surrendered instruments for compliance periods 4 to 6. The mean settlement price for estimated future emissions is calculated as a linear trend of past settlement prices. These two elements allow the estimation of the demand functions for all future periods, as defined in Appendix 3. Emissions in Québec are stable until 2030, while they slightly decrease in California, thus the demand functions are almost superimposed on each other.

Figure 4 shows future demand and supply function for compliance periods 4 to 6. We can see that the resulting price does not reach the first tier in the last compliance period, and settles around 65 USD, just below the first tier price. No allowance from the Reserve tiers is supplied in the market. Although the price increases, the resulting emission reductions are limited (jumping from the average minimum price to the first tier price decreases the demand for emissions by only 14.6 $MtCO_2e$ for the entire last compliance period). Some allowances remain unsupplied, in the hands of governments. If needed, the governments could still sell further instruments to emitters. We can thus consider that the market is overallocated with compliance instruments, despite the significantly higher price.

Total emissions in scenario 1 reach 1,057 $MtCO_2e$ for compliance period 6 (2027-2029), well above the emission level (776 Mt for the three-year compliance period) that would lead to the 2030 California and Québec joint target in 2030: 310 Mt (for that single year). This illustrates the paradox of the WCI: missing the target while still complying with a program that was meant to induce reduction to meet the target. This situation is pictured in Figure 5, that shows the gap between the official allowance caps and covered emissions that leads to instruments oversupply in the market.

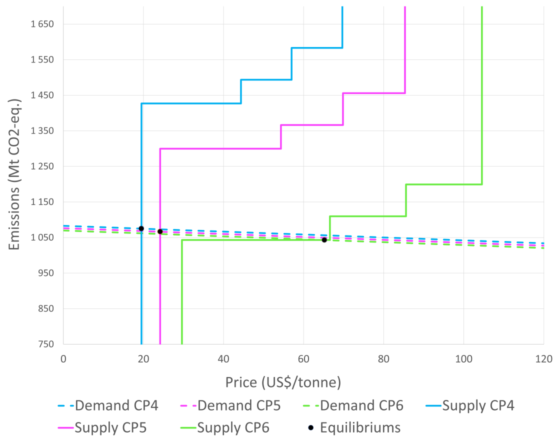


Figure 4: Scenario 1. Business-as-usual

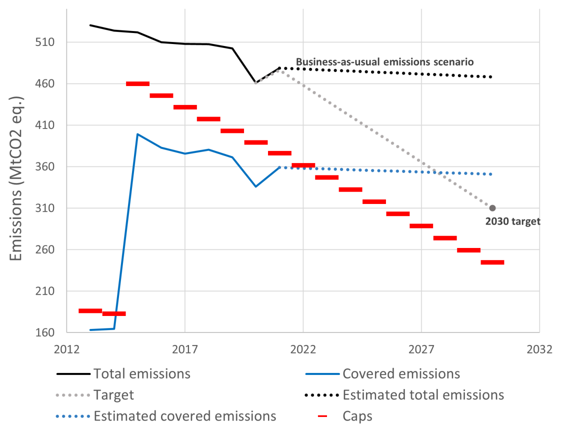


Figure 5: Scenario 1. Caps and emissions

3.3.2 Scenario 2. Official Emission Coverage

The period 2 and 3 compliance reports provide the number of tonnes of emissions for which an instrument was needed in each period. Comparing these numbers to the actual emissions reported for these periods (and estimated for 2020), we notice that only approximately 72% of the total emissions in Québec and 75.5% of emissions in California are covered by the program. However, it is claimed that the program covers around 80% of total emissions in California and 78% of total emissions in Québec (WCI Inc, 2021). The overallocation observed in scenario 1 might come from the difference between the estimated coverage rate and the one reported by WCI Inc. Therefore, using the coverage rate from WCI Inc, we estimate the demand function using future surrendered compliance instruments needed by entities to cover their emissions. The number of unused instruments is affected by the increase in emissions to be covered, but the other elements of demand and supply remain identical to the previous scenario. Resulting demand and supply functions are displayed in Figure 6a.

In that case, entities need to cover more emissions, and thus demand more compliance instruments. That leads to the end of overallocation. The settlement price reaches the ceiling at approximately 103 USD in the last compliance period, and is high enough to complete the sale of all allowances from the last Reserve tier. Emissions increase by 52 $MtCO_2e$ in the last compliance period compared to the scenario with a 75% coverage rate. This scenario shows that for the program to play its role, in the sense that caps partially constrain emissions, the level of emissions covered by the program must be higher than what it currently is. However, the presence of the price ceiling, and the consequential unconstrained emissions, show that the level of the ceiling must be carefully set. In this scenario, the price is at its maximum but emissions are not at the targeted level, meaning that the ceiling should be much higher to be an efficient economic mechanism of emission restriction.

3.3.3 Scenario 3. Current emission trends

For this scenario, we assume that emissions from covered entities follow the same trend than the one observed in earlier compliance periods. We first estimate future total emissions of each region with a linear trend, using emissions data from 2000 to 2020 (California Greenhouse Gas Emission Inventory, 2021; Inventaire québécois des émissions atmosphériques (IQÉA), 2021), excluding emissions of 2020 because of the exceptional fall due to the Covid-19 crisis. In California, estimated emissions decrease by 1% per year, and by 0.5% per year in Québec. We assume that the introduction of the program in 2013 did not have a significant impact on emission trends, since the price of instruments remained constantly low and emission abatement is not very sensitive to allowance price changes (Borestein et al., 2017). We use the mean rate of emissions covered by the program in compliance periods 2 and 3 (as estimated in the business-as-usual scenario), and multiply the estimated future emissions by this rate to get the number of compliance instruments covered entities will need. Only the number of instruments in excess are affected, all other features of demand and supply keep the same values.

The graph for all future demand and supply functions for the current emission trends Scenario is displayed in Figure 6b. It can be seen that the market remains overallocated until the end of the program, as demand in Period 6 is below the first step of the available supply function, meaning that entities hold sufficient compliance instruments to cover their emissions without being in need of allowances from the Reserve tiers. The price of instruments is very likely to remain at the minimum price level for all compliance periods (respectively around 19.50 USD, 24.17 USD and 29.61 USD).

3.3.4 Scenario 4. Complementary policies

Both California and Québec have additional policies to reach their emission reduction targets, respectively a 40% emissions reduction in 2030 compared to 1990 levels, and a 37.5% emissions reduction over the same period. In order to achieve this ambition, the Scoping Plan (CARB, 2017) states that from the 621 $MtCO_2e$ cumulative emission reduction target from 2021 to 2030, 385 $MtCO_2e$ will be completed by other policies. In Québec, the "Plan pour une économie verte 2030" (Gouvernement du Québec, 2020) also establishes specific targets through additional policies supposed to reduce emissions by 12.4 $MtCO_2e$ in 2030 compared to the business-as-usual scenario. It is thus expected that structural reductions will result from complementary policies (such as the Low Carbon Fuel Standard, the California Sustainable Freight Action Plan, ect), and will decrease the number of instruments entities must surrender for compliance.

We estimate future emissions as a result of expected reductions from additional policies. For Québec, emissions in 2030 are 12.4 $MtCO_2e$ lower than in the business-as-usual, and we assume that they follow a linear trend between the 2020 known emission level and the 2030 estimated level. On the other hand, we know that the cumulative difference between 2021-2030 California business-as-usual emissions and these emissions is 385 $MtCO_2e$, and we assume they follow a linear trend. Resulting demand and supply functions are shown in Figure 6c.

Since emissions are lower, the number of instruments left in excess at the end of each compliance period is higher, which increases the available supply of instruments in the next compliance periods. The gap between supply and demand is therefore even more substantial than in the business-as-usual scenario, and prices remain at the average price floors. Due to these very low prices and little-responsive demand, emissions do not decrease much further. The expected contribution of the cap-and-trade program to close the difference between emissions reduction achieved by complementary policies and emissions reduction targets has very little chances to materialize.

3.3.5 Scenario 5. End of carbon offsets in 2021

One could argue that overallocation in the business-as-usual scenario is due to the allocation of offset credits, which increases the supply of instruments beyond what was originally planned. Taking the allowance cap solely, the corresponding number of instruments made available by the governments could only cover a level of emissions lower than the Scoping Plan and Québec target levels. In this fifth scenario, we thus consider the case where the governments would stop granting offset credits to covered entities, starting from 2021. Other elements of instruments supply and future emissions remain identical to the business-as-usual scenario. The change in the number of granted offsets affects the number of instruments offered by the governments and the number of unused instruments. The resulting demand and supply functions for compliance periods 4, 5 and 6 are displayed in Figure 6d.

In that case, in the last compliance period, some allowances from the second Reserve tier are sold to entities, and the price reaches approximately 85 USD. This reduction in the supply of instruments induces little emission reductions (8 $MtCO_2$) for the whole last compliance period, compared to the business-as-usual equilibrium. That remains quite far from the program's objectives.

3.3.6 Scenario 6. Business-as-usual without Covid-19

Overallocation in the market in the business-as-usual scenario can also be explained by the unexpected drop in emissions due to the Covid-19 crisis in 2020. For instance, emissions in the transport sector decreased in the same proportion as fuel sales: 20.7% in California (US Energy Information Administration,2021) and by 11.5% in Québec (Statistique Canada, 2021). Therefore, entities had less emissions to cover and surrendered less compliance instruments, thus holding more instruments in their Private Accounts by the end of compliance Period 3 than what would be expected by the program regulations.

In this scenario, we estimate what emissions would have been without the Covid-19 crisis in 2020, and keeping future business-as-usual emissions as estimated by the governments. The number of instruments offered at auction and freely allocated does not change compared to the first scenario. Only the number of unused instruments at the end of each compliance period is affected, through the number of surrendered instruments to cover emissions. The resulting demand and supply functions are displayed in Figure 6e.

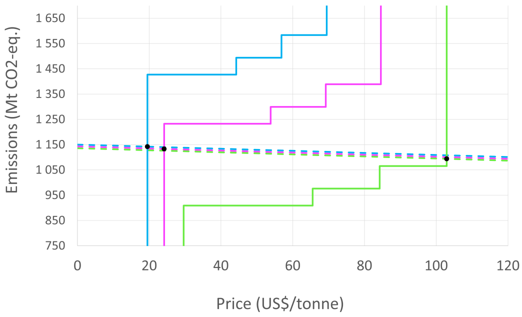
The price reaches the first price tier (around 66 USD) in the last compliance period. Due to this increase in the instruments demand, overall emissions increase by 6.5 $MtCO_2e$ during the last compliance period, compared to the business-as-usual scenario. Almost all allowances in the first Reserve tier are sold to regulated firms, but allowances in the second Reserve tier remain in the hand of the governments. The market is thus still overallocated, despite the increase in covered emissions. We can conclude that in the absence of unexpected events, the program does not provide sufficient incentives to reduce emissions to target levels.

3.3.7 Scenario 7. Increased adaptability

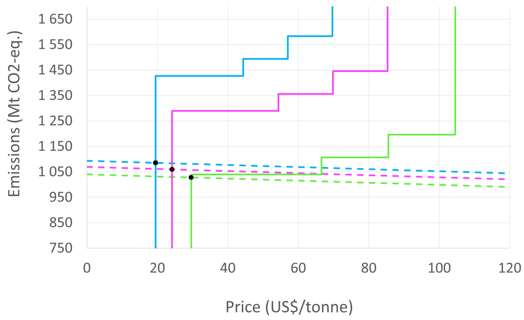
The progressive increase in the price of instruments may induce the general population to adapt their behavior in the long run. This can be explained by the increasing sensibility to climate change related topics (Bergquist and Warshaw, 2019) as well as the growing availability of less polluting alternatives such as electric cars (Battery Electric Vehicles stock increased by 140% between 2013 and 2020 in the Unites States (IEA, 2021)). Emissions being more and more expensive, people can turn more easily to less emitting and consequently less expensive alternatives. For instance they can take public transports instead of using their individual car on a daily basis, travel to a closer place instead of taking a long-distance trip by plane for their holidays, etc. These structural changes could translate into a higher elasticity of demand: as the price of emissions increases, or equivalently as the cost of emission-intensive activities becomes higher, people use less emitting substitutes, and emissions decrease at a greater rate than before. In this scenario, we assume that the demand elasticity increases constantly until it reaches the estimated elasticity in Sweden, around -1.3 (Andersson, 2017 ; Brännlund and Nordström, 2004). In Sweden, 15% of all trips were made by public transports in 2015 (Sveriges officiella statistik, 2015), whereas 4.4% workers use public transports in the West of the US in 2019 (U.S. Census Bureau, 2019). Also, 0.7% cars in circulation in the US are electric cars (Elgin and Chapman, 2021), when in Sweden it reaches 4% (European Alternative Fuels Observatory, 2021). We assume that in this scenario, the American population becomes "more Swedish". The elasticity is the only element of the demand that changes from the previous scenarios. We assume that it follows a linear trend for each year, starting from -0.41 in 2020, and reaching -1.3 in 2030. We take the average value for each compliance period to derive the demand functions. Figure 6f shows the demand-supply equilibrium for this scenario.

Compared to the business-as-usual scenario, we can see that the demand functions become steeper and steeper: the higher the price, the more the quantity demanded decreases. The equilibrium price in the last compliance period decreases, and total emissions remain at the same level, in the first step of the supply function. There is still an oversupply of instruments. While increased responsiveness is probably preferable in the fight against climate change, the resulting lower price observed in this scenario slows down the efficient functioning of the program.

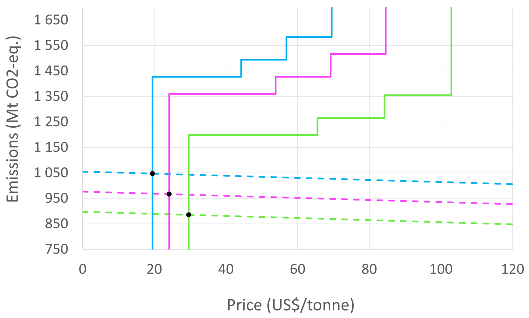
Figure 6: Market equilibrium for each scenario



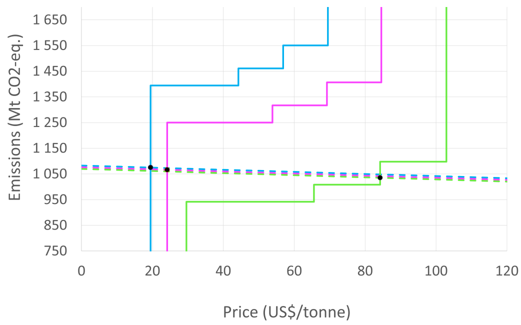
(a) Scenario 2. Official emission coverage rate



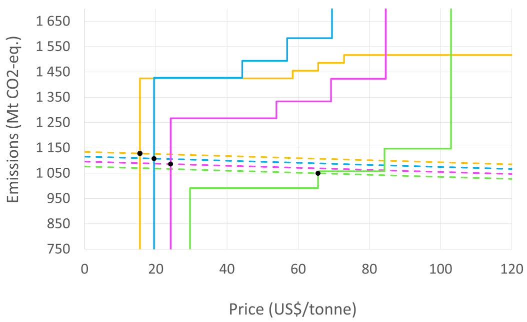
(b) Scenario 3. Current emission trends



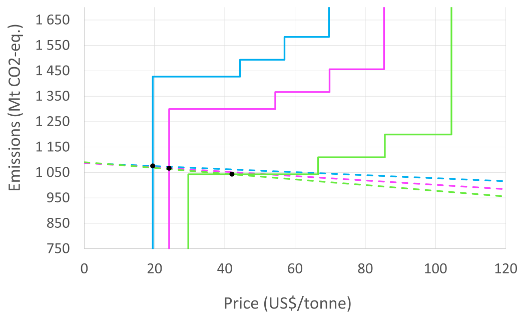
(c) Scenario 4. Complementary policies



(d) Scenario 5. End of carbon offsets in 2021



(e) Scenario 6. Business-as-usual without Covid-19



(f) Scenario 7. Increased adaptability

4 Results and discussion

The essential goal of the program is to accomplish emission reductions to contribute to the 2030 target for California and Québec. It is supposed to constrain covered emissions thanks to the lowering of the caps. Yet, in the case where no further policy is implemented, the governments supply enough compliance instruments to enable regulated firms to cover their emissions throughout the whole program, without ever being constrained by the lack of instruments. In the case where emissions would follow the same trend as in the past, the cap-and-trade program would allow overall emissions to decrease by only 12% at the end of the last compliance period, compared to 1990 levels. This is much lower than the 40% and 37.5% reduction targets fixed by the governments. Even in the case where emissions would decline due to the success of additional policies, overall emissions would decrease by only 21% in 2029 compared to the 1990 levels.

The allowance budget of the last compliance period (Table 1) should theoretically provide a sufficient incentive to meet climate goals set by the Scoping Plan in California. Because of the possibility for entities to bank instruments from one compliance period to the other, and because earlier caps were set too high compared to emissions, entities were able to bank an excessive number of allowances. It allowed them to cover a larger amount of emissions than what was initially intended by the program. Therefore, oversupply is not due to specific features of the program such as offset credits, or to the unexpected drop in emissions during the Covid crisis, as it can be derived by the last scenarios. This leads to the paradoxical situation where the system's requirements are satisfied, but the program's objectives are not fulfilled, since insufficient emission reductions occur.

The market therefore acts like a carbon tax: it does not foster any emission reductions due to the limited amount of supplied compliance instruments, but it increases the cost of emissions. Although this allows to generate funds to invest in programs outside the WCI, the market loses all the complexity of a cap-and-trade program, and is not driven by the allowance caps as it should be. Although conceptually valid, we showed that caps are empirically absent from the market.

As suggested by Inman et al. (2018), if the climate goals were to be met, governments would have to make significant cap adjustments to put an end to overallocation, and enable the program to function as it has been designed to. For instance, as shown in the business-as-usual scenario with a 80% coverage rate by the program, if more emissions were to be covered while keeping the caps equal to their current level, the market could regulate emissions and fulfill its objectives.

5 Acknowledgments

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7 Appendix

7.1 Appendix 1

Emission Caps in the WCI

California and Québec created their respective cap-and-trade programs in 2012 and joined them in 2014, under the WCI system. They are the two main "Participating Jurisdictions" with Nova Scotia, although instruments cannot be traded between Nova Scotia and California and Québec. The functioning of the program is legally defined by the California Code of Regulation (Subchapter 10 Climate Change, Article 5, Sections 95800 to 96023, Title 17), and by the Québec Loi sur la Qualité de l'Environnement (RLRQ c Q-2).

Starting in 2013, the program originally lasted until 2020, and was extended to 2030 in 2017. Each region sets a carbon budget for each calendar year, as shown in Table 1, and represented in the upper grey box in Figure 1.

Distribution of allowances

Governments distribute allowances to covered entities through four different channels, pictured as the black lines in Figure 1. First, covered entities may be entitled to a free allocation of allowances. Covered entities facing high emissions intensity and international competition can benefit from free allocations, in order to preserve their competitiveness and avoid carbon leakage. Californian Electrical Distribution Utilities (EDU) also benefit from free allocations, and these allowances are said to be in consignment. Each consigning entity (EDU) is required to offer for sale at auction all the received allowances, and to allot the value of free allocations to ratepayers. In Québec, the government conceded Early Action credits to some covered entities that achieved verified emissions reduction between 2008 and 2011. These credits were issued once in 2013. In all these cases, governments do not receive any revenue from the allocation of these allowances.

The second channel is auctions. CARB and MELCC hold four joint auctions per year. At each auction, governments offer allowances from the current budget, known as current vintage allowances, and allowances from consigning entities, at the Current Auction. Some future vintage allowances (three calendar years in advance) are offered at the Advance Auction. Bids at auction must lie at or above the minimum allowance price, fixed at 10 USD for the first auction in November 2012, and increasing by 5% plus inflation each year. If allowances remain unsold, they are transferred to the Government Holding Account. CARB makes them available again at the following auction, whereas MELCC re-offers them if the settlement price is above the minimum price for at least two subsequent auctions. If allowances remain unsold for more than 24 consecutive months, they are transferred to the Government Reserve Account (California Regulation). Once allowances are sold and enter entities' Private Account, they can be traded among participants in the system. These two first channels are represented with blue circles and blue full lines in the left-hand side of Figure 1.

The third channel is Reserve sales. The governments assign a part of the budget (Table 1) to the Government Reserve Account, and then transfer these allowances to Allowance Price Containment Reserves. If the price of allowances reaches a given pre-determined level, the governments hold a Reserve sale where covered entities can buy these allowances, only if they lack compliance instruments for their compliance obligation. These allowances cannot be traded among covered entities. From 2013 to 2020, allowances in the Reserve could be offered at three tier prices (but haven't, due to the lack of demand), and starting from 2021, they can be offered at two tier prices, respectively 41.40 and 53.80 USD. These prices are increasing by 5% plus inflation each year.

Finally, California can also hold a Price Ceiling sale. If at least one entity does not have sufficient compliance instruments to fulfill its compliance obligation and no allowance from the Reserve tiers is available, the governments offers for sale an unlimited number of allowances at price 65 USD in 2021, increasing by 5% plus inflation each year. In order to keep emissions in the program's reduction targets, CARB guarantees that it will invest in sectors and locations outside of the program to induce an equal amount of emission reduction than the number of additional sold allowances.

An additional core feature of the program is the concession of offset credits in addition to the period's budget. Approved projects that achieve verified emissions reduction in a sector or a location not covered by the program receive compliance instruments in the form of offset credits. These offset credits can be traded and are equivalent to other instruments to satisfy the program's obligations. All these flows can be found on the right side of Figure 1.

Compliance obligation for covered entities

At the end of each period, covered entities must surrender instruments (allowances and/or offset credits) to fulfill their compliance obligation. The number of instruments corresponds to the amount of their emissions in sectors covered by the program. Some types of emissions are exempted from the obligation to surrender an instrument. Emissions from farms, landfills and inter-regional transport are indeed not covered. The WCI estimates that 80% of emissions in California are covered by the program, while in Québec this proportion is estimated at 78% (Western Climate Initiative, 2021). Some initial estimates were even as high as 85% (CARB, 2015; The World Bank, 2020). However, the number of surrendered instruments for past compliance periods in the official Compliance Obligation reports (CARB, 2021; 2018; 2015), corresponds to approxiamtely only 72% of total emissions in Québec (Gouvernement du Québec, 2021) and to 75.5% of total emissions in California (CARB, 2020), as reported in official GHG inventories. This indicates that the coverage of the cap-and-trade is actually much smaller than claimed by governments.

Compliance instruments must have a vintage corresponding to past or current calendar year. Entities can surrender instruments issued in California or Québec, indistinctly. The number of offset credits that entities can surrender must not exceed 8% of their covered emissions for the Compliance Period. In California, this rate drops to 4% from 2021 to 2025, and increases to 6% from 2026 to 2030. In Québec, entities must surrender the number of instruments covering all their emissions from the compliance period once, on November 1st following the end of the compliance period. In California, entities must surrender the equivalent of 30% of their yearly compliance obligation each calendar year, and the remaining part plus the full compliance obligation of the last calendar year of the compliance period in the last year of the compliance period. Once a compliance instrument is surrendered, governments permanently remove it from the market.

When a compliance period ends, if covered entities still hold compliance instruments in their Private Accounts, these allowances and credits can be kept for future compliance obligations.

7.2 Appendix 2

We exclude the estimates found for transports in Sweden given the substantial differences in public transport usage with California and Québec (American Community Survey Reports and Transport Research Institute, 2019).

Table 2: Review of elasticities

Authors	Elasticity	Context
Andersson (2017)	-0.51	Carbon tax effect on transport fuel demand in Sweden
Andersson et al. (1990)	-0.56	Carbon tax effect on coal demand in the US
	-0.7	Carbon tax effect on oil demand in the US
	-0.52	Carbon tax effect on natural gas demand in the US
Bernard & Kichian (2019)	-0.11	Carbon tax in British Colombia
Brännlund & Nordström (2004)	-1.18	Carbon tax effect on petrol demand in Sweden
	-0.65	Carbon tax effect on public transport demand in Sweden
	-1.3	Carbon tax effect on other transports demand in Sweden
Dahl & Sterner (1991)	-0.26	Meta-analysis - Carbon tax effect on short run demand
	-0.86	Meta-analysis - Carbon tax effect on long run demand
Espey & Espey (2004)	-0.35	Carbon tax effect on short run residential electricity demand
	-0.85	Carbon tax effect on long run residential electricity demand
Goodwin (1992)	-0.27	Meta-analysis - short run time series
	-0.71	Meta-analysis - long run time series
	-0.28	Meta-analysis - short run cross section
	-0.84	Meta-analysis - long run cross section
Goodwin et al. (2004)	-0.25	Meta-analysis - Carbon tax effect on short term fuel consumption demand
	-0.64	Meta-analysis - Carbon tax effect on long term fuel consumption demand
Lin & Prince (2009)	-0.101	Meta-analysis and estimation for energy in California - OLS
	-0.041	Meta-analysis and estimation for energy in California - partial adjustment
	-0.068	Meta-analysis and estimation for energy in California - VMT OLS
	-0.065	Meta-analysis and estimation for energy in California - VMT IV GMM
Mori (2012)	-0.62	Meta-analysis - Carbon tax effect on gasoline demand
	-0.44	Meta-analysis - Carbon tax effect on diesel fuel demand
	-0.23	Meta-analysis - Carbon tax effect on jet fuel demand
	-0.43	Meta-analysis - Carbon tax effect on residential electricity demand
	-0.47	Meta-analysis - Carbon tax effect on commercial electricity demand
	-0.49	Meta-analysis - Carbon tax effect on industrial electricity demand
	-0.38	Meta-analysis - Carbon tax effect on residential natural gas demand
	-0.35	Meta-analysis - Carbon tax effect on commercial natural gas demand

7.3 Appendix 3

The inverse demand function is defined as:

$$price_t = a + b * emissions_t$$

where t corresponds to the compliance period; $price_t$ is the price for the amount of emission $emissions_t$, or equivalently the number of compliance instruments; b represents the inverse price elasticity.

For past compliance periods, the equilibrium prices and quantities are known, as shown in Table 3.

Table 3: Passed number of surrendered instruments and mean settlements prices

Compliance period	Surrendered instruments ($MtCO_2e$)	Mean settlement price (USD)
CP1	327.8	12.72
CP2	1157.6	13.15
CP3	1100.1	16.26

The demand function is thus defined by:

$$price_t = \left[\overline{price_t} - \left(\frac{1}{elasticity}\right) * instruments_t\right] + \left(\frac{1}{elasticity}\right) * emissions_t$$

where $\overline{price_t}$ is the mean settlement price for compliance period t, and $intruments_t$ is the total number of surrendered compliance instruments for compliance period t.