Appendix 2:

Macroeconomic Impacts And Design Considerations for Carbon Markets: A Literature Review

For the Oregon Department of Environmental Quality

January 17, 2017

Energy+Environmental Economics

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1 Introduction

In 2007, Oregon set the goal of reducing greenhouse gas emissions (GHG) to 10% below 1990 levels by 2020 and 75% by 2050 (HB 3543). These goals are commensurate with internationally accepted targets reducing the risks of climate change. A cap-and-trade system for GHG emissions is one potential strategy for achieving these emission reductions.

Oregon has a number of additional laws and regulations that aim to reduce GHG emissions in specific sectors. In particular, SB 1547 increases Oregon's renewable portfolio standard (RPS) to 50% by 2040, eliminates power generation from coal after 2030, and encourages electrification of vehicles (Oregon Legislature 2016). Oregon also passed the Clean Fuels bill in 2015 (SB 324), which sets a target of reducing the GHG emission intensity of transportation fuels by 10% below 2010 levels by 2025 (Oregon Legislature 2015). Also in the transportation sector, Oregon has signed a memorandum of understanding to promote adoption of zero-emission vehicles in partnership with other states (Oregon Legislature 2015). These policies can be considered to be "complementary" to direct regulation of GHG emissions via a cap-and-trade system or carbon tax.

The Oregon legislature has requested a study of an additional policy which would introduce a market mechanism for pricing GHG emissions. A number of states, provinces, and countries have implemented cap-and-trade systems for GHG emissions. Design and implementation experience from these areas can provide valuable insights for policymakers in Oregon. As cap-and-trade systems and complementary policies are often pursued in tandem, this literature review touches on the intersection between cap-and-trade systems and complementary policies.

The review covers policy documents, journal articles, policy reports, and policy commentary. It is intended to summarize theory and experience in other jurisdictions that can estimate the likely economic impacts of an Oregon carbon policy and inform design of a cap-and-trade system.

This review is divided into four sections.

- *Section 2* introduces the role of complementary policies and cap-and-trade systems in comprehensive GHG policy portfolios.
- *Section 3* explores the macroeconomic and distributional impacts of carbon policy portfolios, including cap-and-trade and complementary policies. This includes an evaluation of experiences in other jurisdictions and implications for Oregon.
- *Section 4* discusses design for cap-and-trade systems with a focus on four key considerations: sector scope, permit allocation, offsets, and imports of electricity and natural gas.
- *Section 5* provides a summary of findings and conclusions for Oregon.

Throughout this review, we will highlight the experience in several other areas that have implemented comprehensive carbon policies including cap-and-trade systems. The European Union Emissions Trading System (EU-ETS) was established in 2005 and is currently scoped through 2020. The Regional Greenhouse Gas Initiative (RGGI) in the Northeastern U.S. took effect in 2008. California produced a Scoping Plan in 2008 outlining its compliance with Assembly Bill 32 (AB 32; 2006) which planned emissions reductions through 2020. Quebec legally authorized a cap-and-trade program in 2012-2013, joining as a partner in the Western Climate Initiative (WCI) with California. Recently, Ontario outlined plans to implement its own cap as part of the WCI.

Here, we focus primarily on a cap-and-trade program rather than a carbon tax, based on guidance from the Oregon Department of Environmental Quality (DEQ). A cap-and-trade has some advantages over a carbon tax, such as transparency in the emissions reduction target, the ability to trade with other jurisdictions, and the freedom to allocate allowances freely in some sectors (Stavins 2008).[1] We also note that the Oregon legislature previously commissioned a study on the economic and GHG impacts of a carbon tax in Oregon (Liu et al. 2014).

[1] A carbon tax may be a viable alternative, as it is used in British Columbia (Economist 2014).

2 Greenhouse Gas Policy Portfolios: Inclusion of Complementary Policies

In this section, we describe complementary policies: non-price instruments that regulate emissions reductions. We investigate the reasons policymakers include these policies and how they interact with a cap-and-trade system. These policies are included both to address market failures and political concerns. They likely act to reduce the carbon price and thus the direct macroeconomic impact of a cap-and-trade policy that is pursued in tandem.

2.1 Complementary Policies

Climate policies are generally not limited to pricing instruments — areas that have implemented cap-and-trade systems almost invariably rely on a host of other policies, regulations, and programs to complement those systems. This section examines these policies.

There are a number of theoretical and practical reasons for complementary policies, in addressing either market failures or policy and regulatory challenges. These policies are used to achieve complementary goals to reducing GHG emissions (e.g., energy diversification, enhancing public health by reducing criteria air pollutants), to enhance the efficiency and effectiveness of the cap-and-trade system, or to address political limitations of a pure cap-and-trade system.

Economic theory states that a price on carbon will provide the lowest cost approach to achieving emissions reductions (Carlson 2012; Stavins 2008). However, some economists argue that price signals alone may not be sufficient to induce the long-term behavioral change required to achieve deep GHG reductions (Fay and Hallegatte 2015). A number of market failures may be responsible for the deviation from the theoretical efficiency of a carbon market or tax (e.g., Carlson 2012), including:

+ **Information market failures**: consumers may be unaware of the potential future cost savings in purchasing efficient technologies. Firms may have imperfect foresight about future energy and carbon prices.
+ **Economies of scale and industry learning**: investing in renewable energy technology development may lead to future reductions in their cost. Both of these effects have made photovoltaics markedly cheaper in recent years. Private investors may under-invest because they cannot capture all of the benefits from commercialization; in general, companies may be unwilling to invest in new industries without stable markets or above-market rents.
+ **Environmental externalities**: a price on CO_2 may not be comprehensive of all environmental externalities (e.g., local air pollution).
+ **Split incentives**: for instance, landlords may be purchasing appliances whose electricity usage will be paid for by tenants.

Several of these market failures may lead consumers to under-invest in the purchase of efficient technologies that will lead to future fuel savings. For these reasons, studies often find that vehicle and building energy efficiency standards make consumers better off (Carlson 2012).

For energy-intensive industries such as electricity generation, additional market failures may contribute to arguments for complementary policies such as a renewable portfolio standard (RPS). These include overcoming other non-market barriers such as monopoly infrastructure or political opposition to the siting of new transmission lines (Carlson 2012). In addition, arguments are often made that policies supporting renewables will create jobs in clean energy industries (CARB, 2008). Such arguments are most appropriate for areas which are well-suited to locally capture economic benefits of these new industries (e.g., California, which has a well-developed technology industry).

In addition, politics has driven the desire for complementary policies in areas that have implemented climate policy portfolios. Politicians are uncomfortable with high CO_2 prices, and including complementary policies depresses prices (Section 2.2). This is why California considers cap-and-trade as a backstop for complementary policies (EPRI 2013).

In every area we identified as having implemented a cap-and-trade system – California, the Regional Greenhouse Gas Initiative (RGGI), the European Union-Emissions Trading System (EU-ETS), and Quebec – there has been extensive use of complementary policies (EPRI 2013). In particular, California (part of the Western Climate Initiative, or WCI), is aiming to achieve 78% of its 2020 reductions from BAU with complementary policies (EPRI 2013). Likewise, Oregon has already implemented a number of complementary policies (Section 1), which will interact with a cap-and-trade system and affect its macroeconomic impact, discussed in the next section.

2.2 Interaction of Complementary Policies with a Cap-and-trade system

The primary way in which complementary policies impact the macroeconomic effects of a cap-and-trade system is to reduce the scale of emissions reductions that are achieved merely based on the market signal, reducing the marginal abatement cost and thus the market price of carbon. For instance, assume that a state has 1000 million metric tonnes (MMT) of emissions, half from electricity and half from other sectors, and wants to reduce emissions by the end of the compliance period to 500 MMT, with 250 MMT allocated to electricity and 250 MMT allocated to other sectors. With a pure cap-and-trade, both sectors will bid for the 250 MMT, and the marginal abatement cost and thus carbon price will reflect that. In contrast, with a 100% RPS, 500 MMT of emissions from electricity will be eliminated already, so the electricity sector will sell its 250 MMT of allowances to other sectors. As the other sectors were already only emitting 500 MMT, this will tend to depress the carbon price and reduce abatement costs in other sectors to zero; overall, the abatement costs may be higher or lower in this case, depending on whether the RPS was the most efficient way to eliminate the 500 MMT of emissions.

Some experience from other jurisdictions is helpful to review here. Further details of the implementation of policies in other jurisdictions (the EU-ETS, California, RGGI, and Ontario) are in Section 4. In the EU-ETS, extensive complementary policies (such as renewable feed-in tariffs) combined with stagnant macroeconomic conditions in 2005-2008 to reduce emissions relative to initial predictions used in setting the cap. This caused the carbon allowance price to be lower than intended (Ellerman and Buchner 2008). [One analysis found that the cap was more binding later in the program (Brown, Hanafi, and Petsonk 2012).] In California, the cap is explicitly intended to be a backstop for the complementary policies, leaving the carbon allowance price at its floor (EPRI 2013).

In general, we expect that the lower price of carbon caused by complementary policies will reduce the magnitude of the macroeconomic impacts of the cap-and-trade system itself and shift more of the net impacts of the climate policy portfolio onto the complementary policies. These may be net benefits (e.g., for energy efficiency, Section 3.1.4) or net costs (e.g., for a Renewable Portfolio Standard, Section 3.1.4). As the complementary policies are more prescriptive, they may also reduce uncertainty about the costs of compliance.

3 Macroeconomic and Distributional Impacts of Climate Policies

This section explores the impacts of climate policies on an economy. We examine comprehensive climate policies rather than cap-and-trade in isolation, following most of the literature and experience in other areas. We first discuss previous macroeconomic modeling of climate policy, including an introduction to the various modeling frameworks and studies in other jurisdictions. We then look at distributional impacts of climate policies across geographies and income levels. Finally, we distill implications for Oregon from the reviewed set of studies and literature.

3.1 Macroeconomic Modeling of Climate Policies

3.1.1 OVERVIEW

To date, it has been difficult to isolate the economic effects of cap-and-trade alone rather than the combined effect with implemented complementary policy. A number of studies have modeled the macroeconomic effects of climate policies (which may include both cap-and-trade and complementary policies), and here we review and place these modeling results into the context of an Oregon policy. Studies of the same region may project positive or negative impacts depending on model type and modeling assumptions. In general, studies find overall effects that are small in magnitude relative to the size of the economy.

3.1.2 EFFECTS OF CLIMATE POLICIES

Climate policies have both positive, negative, and neutral direct economic impacts, not considering the environmental externalities they are intended to address:

- **Positive**: correction of existing market failures (see Section 2). Policies encouraging energy efficiency may lead end users to spend less on energy, freeing up resources for other economic activities. Because energy efficiency may involve a tradeoff between upfront capital costs for appliances and delayed savings in energy spending, consumers may choose less energy efficiency than would be optimal because of high implicit discount rates (i.e., lack of access to credit), information failures, or failures of manufacturers to provide the efficient technology even when it could be profitable.
- **Positive**: stimulus effect. Investments in new energy sources and consumer technologies increase jobs and economic activity in the associated industry and upstream industries; increases in jobs in these industries leads to higher total spending on goods and services and more total employment.
- **Negative**: displacement of other goods and services. The investments in new energy sources and consumer technologies will reduce economic activity in fossil fuel and other industries, causing a negative stimulus effect.
- **Negative**: price effect. A carbon trading system acts to increase the price of carbon-intensive goods and services, acting similarly to a carbon tax of varying value (depending upon the emissions allowance price). This

increases production costs and reduces household income, and, depending on price and substitution elasticities, potentially leads to decreases in total employment and income.

- **Neutral**: distributional effects. As spending shifts from high carbon-intensity to lower-intensity energy sources, goods, and services, some industries and demographic groups will end up better off while others end up worse off. While the overall macroeconomic effect of these "transfers" of wealth is neutral, they have equity and political implications, and policymakers may wish to ameliorate their effects when implementing a cap-and-trade system (Section 4.2).
- **Positive**: shifts in spending between industries. Some authors suggest that spending more on renewable energy rather than fossil energy is a net benefit because it is associated with more jobs per unit of energy and causes more money to be spent in the local economy rather than being sent to external fuel producers (NREL 1997; Kammen, Kapadia, and Fripp 2004; Engel and Kammen 2008). However, this argument has also been criticized (Lesser 2010), so we caution against using it as a core justification for a carbon market.

3.1.3 OVERVIEW OF MACROECONOMIC MODELS

The results of macroeconomic analysis depend significantly on the type of model used. A brief description of different model types is helpful for understanding their results:

1. **Input-output models** measure effects on gross output, income, and employment based on changes in final demand for sectors of the economy. At the core is a matrix describing

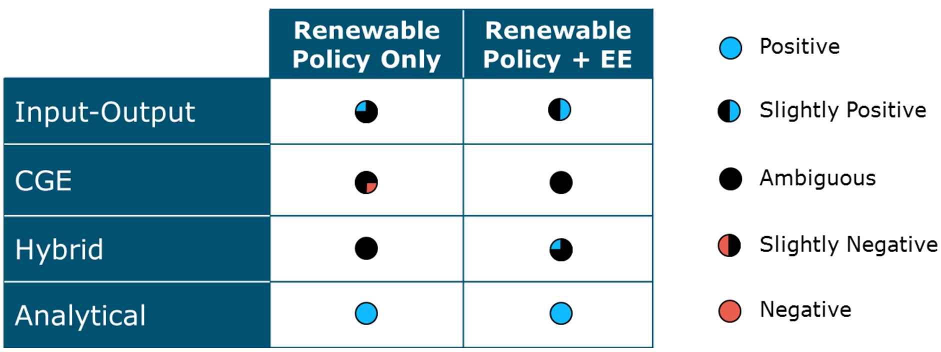
the interrelationships of all the sectors, with data typically populated by the Bureau of Labor Statistics. These models are easy to implement, but they mainly capture stimulus and displacement effects and ignore price effects or structural changes in the economy.

2. **Computable general equilibrium (CGE) models** expand upon I-O models by allowing for prices to adjust so that goods, services, and factors of production (i.e., labor and capital) achieve supply-demand equilibrium. They are comprehensive but expensive and difficult to operate, and they require large amounts of data input.
3. **Econometric models** estimate a statistical relationship between macroeconomic indicators (e.g., employment) and explanatory variables, such as wind energy investment. They require historical data to project future changes. They are simple to use but depend on sufficient data availability to isolate the influences of the explanatory variables and assume that historical relationships hold into the future.
4. **Hybrid models** combine elements of the above. The most commonly used is REMI (Regional Economic Models, Inc.). It captures net economy-wide effects in a bottom-up model that allows for local detail. It is extensively used and well-documented, but also relatively expensive.
5. **Analytical models** use multipliers from surveys and/or input-output tables to approximate impacts. They are simple and intuitive sensitivity analyses, but they neglect indirect and negative effects and assume the economy is static.

3.1.4 REVIEW OF EXISTING MODELING WORK

Energy and Environmental Economics (E3) reviewed the macroeconomic modeling literature for the California Public Utilities Commission (CPUC).[2] E3 included a total of 22 studies spanning the range of model types described above, primarily investigating the effects of complementary policies like RPS and energy efficiency standards.

Figure 1: Summary of Macroeconomic Modeling Impacts



As shown in Figure 1, they found that macroeconomic impacts depended on model type. The Input-Output modeling reviewed here typically was used only to calculate the positive impacts resulting from investment in alternative energy sources, ignoring negative impacts. CGE models find that impacts tend to be small relative to the size of the economy. Hybrid models report similar results to CGE models. Analytical models typically identify positive impacts, but their structure limits their ability to calculate negative impacts.

[2] Price, S., G. Kwok, E. Hart, and F. Kahrl, 2013. *Macroeconomic Impacts of Renewable Energy Policy*. Available from the author upon request.

CGE and hybrid models tend to find slightly positive net costs for renewable-energy-only policies, but negative net costs for energy efficiency. However, the main conclusion of these comprehensive models should be compelling: the effects of climate policies, either positive or negative, are likely to be small relative to the size of the economy.

3.1.5 EXPERIENCE IN OTHER AREAS

3.1.5.1 California

California serves as a key example of the likely experience for Oregon. California's Air Resources Board (CARB) adopted a Scoping Plan for implementing its climate policy in 2008, which includes complementary policies and a cap-and-trade program. The scoping plan included a macroeconomic analysis, which was updated in 2010. The original macroeconomic studies accompanying the Scoping Plan are reviewed in Busch (2009): all found slight increases in gross state product when savings from energy efficiency were included. EPRI (2013) reviewed CARB's economic and environmental analysis of six complementary policies through 2020: the 33% RPS, energy efficiency standards, combined heat and power incentives, passenger vehicle GHG emission standards, the Low Carbon Fuel Standard, and regional vehicle miles traveled (VMT) reduction measures (i.e., "smart growth"). Of these six policies, three were found to have positive net costs and three negative net costs to the economy, resulting in negative net costs of \$106 / metric tonne of CO_2-equivalent (MT CO_2e). The CARB modeling (2010) suggests that there is a possibility for complementary policies to have an overall net positive effect on the economy. In CARB's original economic analysis for the state's climate policy implementation (2008), they summarized the net negative costs as arising principally from investments in energy efficiency "that more than pay back the cost of the investments at expected future energy prices" (CARB, 2008). Moreover, CARB found negative costs accruing to low-income households due to reduced spending on gasoline and electricity (Section 3.2).

The Scoping Plan extended California's energy efficiency policies, which Roland-Holst (2008) reviewed, finding that through 2006 they had created 1.5 million jobs by shifting household spending from out-of-state and job-poor fuel purchases to household spending in-state on more job-rich economic activities.

3.1.5.2 EU-ETS

The EU-ETS is accompanied by a large array of complementary policies in member states that, for instance, incentivize renewable energy. Germany, for example, has large feed-in tariffs for renewables that pre-date the EU-ETS. Estimates for emissions reductions in Germany suggest a 6% reduction in emissions from 2005 to 2008, due to the combination of ETS and the various complementary policies in effect (Brown, Hanafi, and Petsonk 2012). While it is difficult to disentangle the emissions reductions impacts of the ETS from the various complementary policies in place, it is likely that the very low cost of compliance with the EU-ETS in Germany (Brown, Hanafi, and Petsonk 2012) was driven by extensive complementary policies.

3.1.5.3 RGGI

In RGGI states there is a patchwork of complementary policies, including energy efficiency standards in most of the states, electric vehicle incentives in

Massachusetts, and a recent Clean Energy Standard (similar to an RPS) in New York. We did not find a systematic analysis of these policies with RGGI.

3.1.6 IMPLICATIONS FOR OREGON

While research continues on the macroeconomic impacts of carbon policies, it is important to put model disagreements over the sign of the impacts in the appropriate context: whether positive or negative, it is very likely that the total cost of climate policies on the scale considered for Oregon will be small relative to the size of its economy; that is, on the order of 1% of Gross State Product (GSP), or $2 billion per year for Oregon in 2015 (Stern 2006; Hübler, Voigt, and Löschel 2014; Rolland-Holst et al. 2009; Stavins 2008; National Research Council 2010). Negative impacts on Oregon may be further ameliorated by the fact that its economy is not heavily dependent on fossil fuel production: Nextgen America (2015) found that negative regional impacts of deep energy-system decarbonization were most likely to occur in regions "historically dependent on mining and other fossil fuel based sectors," while other regions could see benefits.

It is also important to explicitly consider the time horizon of the impacts. Most of the jurisdiction-specific studies reviewed here model relatively modest emissions reductions associated with near-term targets, which are likely to be cheaper than deep reductions achieved over several decades (Stern 2006; Nextgen America 2015; National Research Council 2010). The National Research Council (2013) addressed the time horizon of climate policies explicitly and highlighted that large-scale energy transitions take decades. Net investment costs needed to overcome transitional barriers may be needed for a decade or two before the benefits dominate.

3.1.7 ISOLATING THE IMPACT OF CAP-AND-TRADE SYSTEMS

Little modeling has isolated the impact of cap-and-trade systems. However, as discussed in Section 2, we hypothesize that the inclusion of a large portfolio of complementary policies likely leaves a small residual macroeconomic impact of a cap-and-trade program. If opportunities for energy efficiency have been largely captured by complementary policy, co-benefits (such as improvements in air quality) are neglected, and revenue recycling is ignored, then this residual is likely to be negative due to the distortionary effects of increased energy prices on the purchasing behavior of consumers, producers, and investors (the price or substitution effect described in Section 3.1.2). This residual is small in magnitude if allowance values are kept relatively low by the complementary policies, as has been observed in other jurisdictions such as the EU (Brown, Hanafi, and Petsonk 2012), California, and Quebec (Purdon, Houle, and Lachapelle 2014).

We did identify two relevant modeling results isolating the effect of a carbon market. One study estimated that a revenue-neutral carbon tax (analogous to a cap-and-trade program where auction revenues were returned to households on a per-capita basis) would have small positive impacts on the U.S. in 2025, with results disaggregated for the nine U.S. census divisions (Nystrom and Luckow 2014); for the Pacific Region (including Washington, Oregon, and California), GSP would increase by 0.6% to 0.8% annually between 2020 and 2035. The second study focused on Ontario's carbon cap, which is intended to cover 82% of the province's emissions, and projected it would cost 0.03% of the province's economy in 2020 (Sawyer, Peters, and Stiebert 2016). In particular, the effects of the cap on energy prices are projected to reduce household consumption by 0.04%, although directing auction proceeds to households is intended to reduce this negative impact. One caveat is that future emissions reductions will be more stringent than those modeled in these studies, which could increase costs. However, they are unlikely to exceed 1% of GSP (Section 3.1.6).

3.2 Distributional Impacts of Climate Policies

Theoretical arguments can frame the likely impacts of climate policies across geographies and income levels. A carbon tax or cap-and-trade alone (without revenue recycling) is likely to be regressive (Stavins 2008) — exerting a larger negative impact as a percentage of income on lower-income households — as low-income households spend a greater proportion of their income on energy-intensive activities. However, energy efficiency standards are likely to be progressive – exerting a larger proportional positive impact on lower-income households – for the same reason. CARB (2008) found that the state's climate policy, which included significant energy efficiency, was likely to benefit low-income households in particular. CARB (2008) investigated the effect of the overall plan on households at or below 200% of the poverty guideline assessed by the U.S. Dept. of Health and Human Services. They found household savings of about $400 per household, as fuel savings associated with vehicle and appliance energy efficiency more than offset increased energy prices. This savings was nearly as large as that faced by higher-income households. Likewise, they found an increase in jobs of about 50,000 available to low-income workers, due to the stimulatory effect of the fuel savings. We note here that these results likely depended on the design of the policy (i.e., which technologies were incentivized, whether financing was included, etc.). CARB (2010) also found that the inclusion of complementary policies would keep carbon allowances low through 2020 and thus mitigate direct negative impacts of the cap-and-trade program.

We identified a small number of modeling studies which have investigated the distributional impacts of cap-and-trade or a carbon tax (Shammin and Bullard 2009; Rausch, Metcalf, and Reilly 2011; Speck 1999). They tend to agree with the theory that a carbon cap would have a marginal regressive effect, but the effect is small (Speck 1999; Rausch, Metcalf, and Reilly 2011) or can be ameliorated with appropriate assignment of allowances or auction revenue to adversely impacted socioeconomic groups (Shammin and Bullard 2009; Section 4). Stavins (2008) argued that the value of allowances would exceed the compliance costs of a U.S. carbon cap by a factor of 2 to 4, leaving plenty of opportunity for compensating adversely impacted groups or firms. Likewise, a carefully designed revenue-neutral carbon tax would have positive overall macroeconomic impacts while disproportionately benefiting low-income households and increasing labor's share of national income (Nystrom and Luckow 2014).

We were able to identify only one study examining the distributional impacts of climate policy on urban vs. rural communities. A national study of a comprehensive climate policy (Rolland-Holst et al. 2009) found that rural states benefitted from the overall policy along with more urban states, as the benefits from increased local household spending outweighed the increased energy costs and effects on resource-intensive industries. Nevertheless, it is possible that rural communities would bear a disproportionate amount of economic impact from a policy that raised energy prices, as they are more likely to drive long distances, have higher building energy loads, and work in resource-intensive industries. Negative cost efficiency standards would disproportionately benefit rural communities (as found in Roland-Holst et al. 2009) as long as households have access to financing for the increased up-front capital costs required to benefit from the long-term fuel savings. Appropriate cap-and-trade system design (Section 4) could allocate allowances or auction revenues to redress any negative impacts of increased energy costs on disadvantaged or rural communities; subsidy of financing for purchasing more expensive and efficient technologies would also allow the full benefits of efficiency policies to accrue to these communities.

Co-benefits of climate policies may represent a disproportionate benefit for low-income households. In California, air-quality benefits of reduced fuel combustion are expected (CARB, 2008). Nystrom and Luckow (2014) also found that a national climate policy would prevent premature deaths due to air pollution. An economic analysis confirmed air quality co-benefits from carbon regulation of U.S. electricity (Holland 2012). We hypothesize that air pollution has a disproportionate health impact on disadvantaged communities, so improvements in air quality would have a positive distributional impact. At the same time, there has been controversy over the use of cap-and-trade in California, based on the argument that cap-and-trade would allow large polluters in disadvantaged communities to avoid making reductions in carbon emissions and thus avoid coincident improvements in air quality (Cushing et al. 2016). When CARB (2011) investigated the likely air-quality effects of the cap-and-trade program, they estimated that disadvantaged communities would see net decreases in criteria pollutant emissions associated with the policy. It is still possible, however, that a direct mandate for reducing GHG emissions from large industrial facilities could result in larger air quality co-benefits than cap-and-trade.

There is concern that climate policies may adversely affect trade-exposed or resource-intensive industries (NextGen America 2015). Nystrom and Luckow (2014) found that even after a cross-border adjustment, resource-intensive industries such as manufacturing and mining were negatively impacted by a national carbon tax. CARB's modeling (2008) found that the design of complementary policies and the cap-and-trade system (Section 4) could be tailored to ameliorate negative effects on resource-intensive industries important to California like cement and agriculture. Moreover, some industries are likely to see positive impacts from climate policies as well, due to fuel savings from energy efficiency or increased spending associated with revenue recycling. Some industries experiencing net benefits from modeled climate policies in Nystrom and Luckow (2014) and CARB (2010) included information services, healthcare, finance, retail, and wholesale trade.

Ontario's Climate Action Plan features a number of policies designed to enhance the distributional impacts of the policy, mitigating any negative impacts or bringing net benefits to "low-income households and vulnerable communities" (Province of Ontario 2016). For instance, they include electric bill assistance, incentives for weatherization and efficient vehicles, and a "green bank" to provide low-interest financing for capital investments in efficient technologies.

3.3 Implications for Oregon

We distill three implications for Oregon: (1) Oregon will likely see similar macroeconomic effects to California from combining cap-and-trade with complementary policies, (2) planned complementary policies in Oregon will decrease the incremental effects of joining a cap-and-trade system, and (3) the introduction of a cap-and-trade program in isolation is likely to have both benefits and costs to low-income areas, though innovative policies and careful program designs may mitigate adverse impacts.

Compared to California, Oregon has lower electricity prices and a greater reliance on hydroelectric power, making it analogous to Quebec, California's partner in the WCI. Sustainable Prosperity concluded that linking Quebec and California together in the WCI will bring benefits to both jurisdictions (Purdon, Houle, and Lachapelle 2014) in terms of cheaper allowances and/or revenue from the other jurisdiction. In this case, emissions reductions are cheaper in California, so Quebec should have a lower carbon allowance price after linkage.

As Oregon is planning a number of complementary policies (Section 1) that will likely be responsible for a substantial fraction of emissions reductions expected under a comprehensive policy, the macroeconomic impacts of the cap-and-trade system alone are likely to be small. As forecasted in other areas, the cap-and-trade system may increase energy prices, but revenue recycling may offset some of that impact.

California's economic analysis provides a basis for estimating the distributional impacts of carbon policies in Oregon. CARB (2008; 2010) estimates that the overall climate policy would have net benefits for low-income households. Air quality co-benefits are also likely to benefit disadvantaged communities. The cap-and-trade system alone may adversely impact low income or rural communities in Oregon, in addition to resource-intensive and trade-exposed industries like timber, pulp and paper, aluminum, and manufacturing. Market design to allocate permits or redistribute auction revenues to these communities and industries could address this concern (Section 4). (Some less resource-intensive industries responsive to household spending could see net benefits from the recycling of auction revenues.) Likewise, the use of complementary policies to mitigate costs and enhance benefits for low-income households could be a viable strategy, based on the plan for Ontario (Province of Ontario 2016). Ontario's green bank is also intending to help resource-intensive industries transition to lower-carbon technologies (Province of Ontario 2016).

4 Cap-and-trade System Design

As Section 3.2 alluded to, a cap-and-trade policy can have varying impacts on the citizens and entities under its umbrella. Two jurisdictions with an identical carbon cap can design their cap-and-trade programs to achieve this cap in a variety of ways, and it is important to think through the design decisions motivating a coherent cap-and-trade system. These will impact the efficacy, efficiency, and fairness of the program. To track this issue further, here we investigate the experiences that various jurisdictions have had in crafting their cap-and-trade policies. We focus on four key design considerations, reviewing the experiences that other areas have had in implementing carbon policies:

1. **Sector scope**: which sectors to track and regulate;

2. **Permit allocation**: how to efficiently and equitably allocate permits;

3. **Offsets**: how to allow emitters to pay off their emissions by buying offsetting emissions from carbon sinks, either within or outside the cap-and-trade jurisdiction; and

4. **Imported electricity and natural gas**: how to track and regulate carbon emissions from energy sources located outside the cap-and-trade jurisdiction's geographic area.

Table 1 below summarizes some of the main program considerations for the jurisdictions we investigate, which include California, Quebec, the European Union-Emissions Trading System (EU-ETS), the Regional Greenhouse Gas Initiative (RGGI), and Ontario.

Table 1. Summary of program design for various cap-and-trade systems

	California/Quebec	**EU-ETS**	**RGGI**	**Ontario**
Scope	Any emitter with annual emissions > 25,000 MT CO_2e; electricity importers; fuel suppliers (~85% of emissions covered).	Electricity, various industrial sectors. Emissions thresholds industry-specific (~41% of GHG emissions covered).	Electricity sector emissions only (~21% of emissions covered).	Any emitter with annual emissions > 25,000 MT CO_2e; electricity importers; fuel suppliers (~82% of emissions covered).
Offsets	Offsets allowed, up to 8% of a facility's annual emissions. Eligible offset categories vary for each jurisdiction.	Unlimited offsets allowed, provided they fall under the eligible offset categories.	Up to 3.3% of a facility's emissions during a control period; offsets must fall under eligible categories.	Offsets allowed, up to 8% of a facility's annual emissions. Eligible offset categories vary for each jurisdiction.
Permit Allocation	Combination of free allowances and	Combination of free allowances and	100% auction-based	Combination of free allowances and

	auction-based distribution	auction-based distribution		auction-based distribution
Imported Electricity and Natural Gas	First jurisdictional deliverer has compliance obligation for electricity; fuel distributor has compliance obligation for natural gas	Imports not covered	Imports not covered	Electricity importer has compliance obligation for electricity; fuel distributor has compliance obligation for natural gas (irrespective of imported or domestic)

4.1 Sector Scope

Having a broad cap-and-trade program to cover many emissions sources has several advantages. A broad cap-and-trade program incentivizes the most cost-effective reductions to occur first; by expanding the sectoral coverage of the economy, these lowest-cost reductions are more likely to be covered and this can reduce the cost of meeting the overall emissions limits (Cope 2006). Furthermore, including the maximum number of sectors reduces the possibility of leakage from capped sectors to uncapped sectors (Stavins 2008).

Nevertheless, putting together an ideal market program which covers all sectors of the economy is difficult to do: (1) not all sectors' emissions are easy to measure; (2) not all sources are politically feasible to regulate; (3) and increasing breadth increases the cost of system administration.

To decide which sectors of the economy to cover under a cap-and-trade program, there is a tradeoff between regulating "upstream" emissions – at the point where fuels and other emitting agents are produced – versus "downstream" emissions – where gases are emitted into the air. While regulating downstream emissions is theoretically more efficient, as it regulates the entity directly responsible for the emitted greenhouse gas, it can be administratively complex. Taking the example of transportation in California, requiring a downstream approach would require regulating over 30 million personal automobiles registered in the state; logistically it would be extraordinarily difficult to measure and track emissions related to each of those 30 million automobiles under a cap-and-trade system. By contrast, regulating the upstream gasoline and liquid fuels providers internalizes the cost of the cap-and-trade program into the cost of the fuel itself (Profeta and Daniels 2006). Most existing cap-and-trade programs focus on upstream carbon emissions, as we describe below.

4.1.1 CALIFORNIA AND QUEBEC

California and Quebec both independently instituted cap-and-trade systems in 2013. The California cap-and-trade system began by covering electricity and industry in 2013, expanding to include transportation and heating fuels in 2015; similarly the Quebec cap-and-trade system began covering electricity and industry in 2013, expanding to include fuels in 2015. In 2014, both jurisdictions linked their cap-and-trade systems together as part of the Western Climate Initiative (WCI). Any emitter with annual emissions greater than 25,000 MT CO_2e is covered under the linked markets; this precludes most households and small businesses from directly participating in the market. These economic units indirectly participate through their electricity and fuels purchases (CARB 2015). As of 2015, the covered sectors contribute to 85% of California's GHG emissions (Reyna and Hsia-Kiung 2014) and 78% of Quebec's GHG emissions (Purdon, Houle, and Lachapelle 2014).

4.1.2 EU-ETS

The EU cap-and-trade system covers electricity; heat and steam production; industrial sectors including coal, iron and steel, cement, glass, pulp and paper; petrochemicals; ammonia; aviation; aluminum; and nitrous oxide from acid production and perfluorocarbons (PFCs) from aluminum. As of 2015, the EU-ETS covered approximately 4.8 GtCO_2e, or 41% of GHG emissions from the EU (World Bank 2014). There is a minimum threshold for any combustion installation over 20 MW of generation capacity, and there are sector-specific thresholds for other sources.

4.1.3 RGGI

The Regional Greenhouse Gas Initiative is focused on reducing emissions related to electricity production alone, and as such it covers only fossil-fired power plants with generation capacity of 25 MW or greater located within the RGGI geographic footprint (Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont). With a focus on power generation, RGGI covers about 21% of GHG emissions from included states (World Bank 2014).

4.1.4 ONTARIO

Ontario is also in the process of forming its own cap-and-trade system, with plans to join the WCI beginning in 2017. The government's analysis concluded that linking to the WCI would make for a lower carbon price and less leakage (Sawyer, Peters, and Stiebert 2016). To enable easier linkage, facilities and natural gas distributors with emissions greater than 25,000 MT CO_2e annually are covered under the cap. This scope has an expected coverage of 82% of Ontario's emissions (Ministry of the Environment and Climate Change 2016; King et al. 2016). Additionally, electricity importers and fuel suppliers selling more than 200 liters of fuel annually are covered.

4.2 Permit Allocation

Permit allocation is a key consideration for crafting distributional impacts and ensuring minimum economic disruption. There are three basic approaches to allowance distribution: free allocation, auction, or some combination thereof. Each of the allocation methodologies can be crafted to mitigate economic impacts. For example, regulators can promote energy efficiency measures by allocating proceeds from the auction towards an efficiency fund, or they can distribute allowances directly to organizations involved in energy efficiency projects (Center for Climate and Energy Solutions 2011).

Conventional microeconomic theory [beginning with Coase (1960)] suggests no difference in efficiency between auctioning and freely allocating permits – both induce the same opportunity cost to emitters and merely transfer wealth within the economy. However, as reviewed in Burtraw and McCormack (2016), some have argued that practical considerations make auctioning more efficient. For instance, "thin allowance markets, poor price discovery, and regulatory or organizational complexities that hinder recognition of opportunity costs and innovation" may make markets less efficient when allowances are given away freely (Burtraw and Mccormack 2016). Moreover, concerns about fairness may also result. Burtraw and McCormack (2016) propose "consignment auctions" as a hybrid approach to address these concerns (as used in California's electricity sector, below). We now briefly review the permit allocation strategies that various jurisdictions have undertaken.

4.2.1 CALIFORNIA

In the first compliance period, 2013 to 2014, California freely allocated most allowances to regulated entities. Between 2015 and 2020, however, the percent of free allowances will decrease as more are auctioned off (Purdon, Houle, and Lachapelle 2014). In the electric sector, free allowances are distributed to both public and private electricity distribution utilities, with the stipulation that the free allocations must be re-auctioned and proceeds used to compensate electricity customers for increased prices (Palmer, Burtraw, and Paul 2009; Purdon, Houle, and Lachapelle 2014). This consignment auction-based system was designed partly to ensure that emissions reductions are balanced against the need to ensure electricity prices do not rise too quickly and to ensure that electricity is accessible to all populations in the state. Free allowances from non-electric sectors are credited according to formulae which take into account historical annual emissions by facility, an emissions benchmark for a facility's industry, and an annual adjustment factor to reflect a steadily tightening emissions cap. Furthermore, the California Air Resources Board (CARB) divides each facility under the industrial sector cap into three leakage classifications (high, medium, and low; based on a combination of trade exposure and emission intensity), and it then ratchets the free allocations downward more quickly for low and medium sectors as compared to high leakage sectors. This is done to represent the greater difficulty that inherently high leakage sectors, such as oil refining, have in reducing emissions relative to sectors with inherently lower emissions intensities. Early monthly auctions saw some available allowances go unpurchased, implying that the cap was set too high or market participants were still figuring out trading strategies. However, since November 2014, CARB has seen 100% of available allowances purchased for vintage 2016 and 2017. This seems to suggest that the market is becoming more mature and the steady migration from free allocations to auctions will not be an economic shock (Purdon, Houle, and Lachapelle 2014).

4.2.2 QUEBEC

Quebec has a similar system to California, in that it uses emissions intensity targets to set efficiency benchmarks for each emitter. These emissions intensity targets are industry-specific, again to allow inherently higher-intensity industries more leeway than inherently cleaner industries. Furthermore, Quebec verifies a facility's emissions by retaining 25% of its allowances until the next year; it then adjusts the allocation amount accordingly. Quebec has a large hydroelectric capacity, and so its electric power is both cleaner and cheaper than California's.

Because of this, Quebec chose not to use the consignment auction system. Nevertheless, Quebec has a large aluminum sector, representing up to 4% of GSP. While the Quebec aluminum sector has one of the lowest carbon intensities worldwide, aluminum smelting itself is inherently a carbon intensive procedure[3]; consequently, the Quebec government has tailored emissions allowances to accommodate this sector. Similarly to California, Quebec saw early auctions with the majority of allowances go unpurchased, but it has seen a more mature market recently as most purchase-eligible allowances have been bought (Purdon, Houle, and Lachapelle 2014).

4.2.3 EU-ETS

The EU ETS has relied on historical emissions data in setting firm-level allowances. In its first phase, all permits were allocated free of charge. Many companies were over-allocated permits, and proceeded to short-sell these credits with the belief they could buy cheaper permits in the future. This reliance on historical emissions, combined with the economic slowdown of 2008 and the banking of previous years' allocation, resulted in a large amount of surplus, with over 77% of EU ETS installations holding surplus allowances in 2011 (Laing et al. 2013). Nevertheless, Brown, Hafani, and Petsonk (2012) concluded that the EU-ETS reduced emissions by 480 million MT CO_2e in the first five years of the program.

[3] Process emissions are released from the aluminum ore itself that are not avoidable without capture and sequestration.

4.2.4 RGGI

RGGI allocates its allowances purely on an auction basis. Each state in RGGI is assigned a state-level share of the regional greenhouse gas emission target. This state-level share is then allocated to electric power sources within the state by an auction mechanism, subject to the stipulation that any entity is prohibited from bidding on more than 25% of the total allowances offered at any auction. These auctions are conducted quarterly, with each state submitting its auction clearing price and total amount of allowances for sale, and with the revenues flowing back to the state selling its allowances. To ensure fairness and independence, RGGI has retained an independent market monitor to oversee the auctions (RGGI 2016). Before developing implementing its auctioning system, RGGI carefully considered details of auction implementation and sponsored experiments investigating different auction bidding structures (Holt et al. 2007; Shobe et al. 2009).

4.3 Offsets

In theory, extra-jurisdictional carbon offsets can reduce emissions as much as a local carbon cap, but there are concerns over whether carbon offsets actually function this way in practice. These include concerns over verification and enforcement of offsets, as described below, in addition to concerns that offsets allow entrenched interests to delay making systemic changes necessary to reduce carbon, making these changes harder to make later. In an effort to address some of these issues, offset schemes attempt to specify strict, clear rules for what categories of activities are eligible to provide offsets and in what quantities. Some of the main challenges which these rules are designed to target are the issues of verification and additionality. Verification is a straightforward concern: how a jurisdiction measures and verifies that the offsets from an extra-jurisdictional project are being reported accurately. Additionality addresses the issue of how much incremental carbon reduction offset purchases are actually generating. This involves theorizing a counterfactual world in which the offset was not purchased, and attempting to calculate the marginal carbon reduction due directly to the offsets' purchase (GAO 2011). Below, we briefly describe the offset rules for some existing cap-and-trade programs.

4.3.1 CALIFORNIA AND QUEBEC

California and Quebec, in an effort to aid in linking their markets, have similar offset rules. In both jurisdictions, a facility can offset no more than 8% of its obligation during a compliance period by using offsets (CARB 2015). The specific allowable categories of offsets are slightly different. California allows offsets limited to within-US projects, allowed within five categories: forestry, urban forestry, dairy digesters, destruction of ozone-depleting substances, and mine methane capture. Offsets must be independently verified, and there are provisions to credit offsets registered with entities outside CARB, with a framework for future inclusion of international offset programs. There are a few differences in how Quebec handles offsets. Canadian climate policy restricts the role of forest carbon, so forest offsets are not included. In addition, California assigns liability to the offsets purchaser, meaning the buyer is responsible if the carbon credits are unverified. Quebec, in contrast, has developed an Environmental Integrity Account that functions as an insurance account into which a small portion of offset credits are deposited to act as a buffer in case any offset credits are unverified. Purdon, Houle, and Lachapelle (2014) suggest that

California has been more cautious in its approach to offsets, focusing on environmental integrity; as carbon prices rise, CARB's stringency on offsets may become more relaxed.

4.3.2 EU-ETS

The European Union has no offset limit, but it is considering adding one in 2020. Its offset categories include: (1) the Clean Development Mechanism (CDM); and (2) Joint Implementation (JI) projects, of which those from land use and forestry activities are not acceptable. Before 2013 the ETS allowed offsets to include hydrofluorocarbons (HFCs), a family of chemicals whose greenhouse gas potency is thousands of times that of CO_2. In 2008 the Government Accountability Office found that over-allocation of allowances and offsets had resulted in uncertain effects of emissions while funding offsets of questionable value. By 2011, the same agency reported that an estimated 60% of The EU's CDM offsets went to Chinese refrigerant factories to incinerate HFC-23: while the installation equipment to capture and destroy HFC-23 was estimated to cost $100 million, the projects were expected to generate $4.7 billion in offsets (GAO 2011). This episode illustrates some of the issues surrounding the additionality of carbon offsets – when the EU was accepting HFC credits, there was a perverse incentive for refrigerant factories to overproduce and destroy additional HFC to capitalize on the offset market. In 2011 the EU announced changes to its offset rules; it has now decided to stop accepting hydrofluorocarbon offset credits (GAO 2011).

4.3.3 RGGI

The Northeastern RGGI market allows offsets up to 3% of a facility's obligation, with eligible offset categories including: (1) Landfill methane capture and destruction; (2) reduction in emissions of sulfur hexafluoride (SF_6) in the electric power sector; (3) sequestration of carbon due to afforestation; (4) reduction or avoidance of CO_2 emissions from natural gas, oil, or propane end-use combustion due to end-use energy efficiency in the building sector; and (5) avoided methane emissions from agricultural manure management operations (RGGI 2013). The large number of categories available for offsets coincides with RGGI having a limited scope (Section 4.1). While these offset categories exist, there currently appear to be no offset projects in development or currently operating in the RGGI market.

4.3.4 ONTARIO

As Ontario has not included forestry and agriculture in the scope of its program, it has chosen to investigate allowing offsets in these areas (Province of Ontario 2016).

4.4 Imported Electricity and Natural Gas

Next to transportation fuels and industrial sources, electricity comprises one of the largest sources of carbon in a modern economy. Unlike the previous two sources, though, the electrical grid often has much less clearly defined jurisdictional boundaries, with regulation conducted by a combination of state regulators, national regulators, and system operators whose system boundaries can cross state lines. This can create issues with carbon leakage, as electricity producers outside of a cap-and-trade geographic footprint are implicitly favored over producers within the cap-and-trade geographic footprint. To tackle this leakage problem, various jurisdictions have formulated different policies for handling the issue of imported electricity. Here we briefly describe some of these strategies and discuss strategies applicable for Oregon.

4.4.1 CALIFORNIA

Unlike RGGI, which combines multiple states coordinating over three different independent system operators – ISO-NE, NYISO, and PJM, California benefits from having a single independent system operator (CAISO) control the majority of generation and load within the state. Nevertheless, California has significant import and export connections, especially along its northern border to Oregon and along its southern border with Arizona. To attribute emissions to imported electricity, California takes a two-pronged approach. Electricity can be "specified," i.e., under contract to a particular importer and traceable to a particular resource or recognized Asset-Controlling Supplier's system: in this case, the generator's facility-specified emissions rate can be used. In other cases, imports are assigned a default emissions rate of 0.428 MT / MWh (Bushnell, Chen, and Zaragoza-Watkins 2014). The corresponding carbon compliance obligation is assessed to the "first jurisdictional deliverer:" whoever first delivers the electricity to the California grid (Welton, Gerrard, and Munster 2013). In practice this compliance obligation usually falls onto either the load serving entity which uses the imported electricity directly, or to a wholesale power marketer which supplies electricity to the spot market (Parlar et al. 2012). This first jurisdictional deliverer approach is contrasted with fuels, in which the compliance obligation is assigned to the fuel distributors.

Simulations conducted to support the implementation of cap-and-trade in California (Palmer, Burtraw, and Paul 2009) concluded that allocating to load-serving entities or distributors would result in lower electricity prices but higher allowance prices overall, and could also result in more leakage. They recommended first jurisdictional deliverer as the most efficient allocation option. Additional considerations include avoiding "resource shuffling" and legal considerations such as compliance with the interstate commerce clause. "Resource shuffling" consists of deliverers assigning higher carbon intensive power plants to serve load outside of the carbon pricing area, and allowing lower carbon sources to serve load inside the carbon pricing area, discussed further in Farnsworth et al. (2013). Parlar et al. (2012) note that regulating load-serving entities or first jurisdictional deliverers whose extent surpasses state borders may run afoul of the interstate commerce clause or be pre-empted by federal statutes, and they discuss ways of designing regulations on imports to be robust to these challenges.

4.4.2 QUEBEC

Quebec has an electricity system with excess hydroelectric power and moderate power prices, so it is usually an electricity exporter (Purdon, Houle, and Lachapelle 2014). Quebec has set up the cap-and-trade program to cover electricity imports in the event that (1) the emissions associated with the acquired electricity put the electricity distributor over the 25,000 MT emissions threshold, and (2) the electricity was not generated in a partner cap-and-trade jurisdiction (i.e. California, but could expand to other linked cap-and-trade jurisdictions). To ease concerns over competitiveness, Quebec feely allocates allowances to entities with electricity imports from jurisdictions that are covered under a separate cap-and-trade program but have not agreed to link to Quebec's cap-and-trade program. The natural gas sector is covered at the fuel distributor level (EDF 2014).

4.4.3 RGGI

As a regional initiative, RGGI carbon reduction requirements only bind states participating in the program. Thus, when dispatching into an inter-state regional grid electricity generators covered under RGGI incur a competitive disadvantage relative to uncovered units geographically outside the RGGI footprint. This is a nontrivial concern, as imports into RGGI comprise anywhere from 10% to 50% of each state's electricity mix (Welton, Gerrard, and Munster 2013). Various studies have investigated approaches for adding a compliance obligation for imported electricity (Welton, Gerrard, and Munster 2013), but currently RGGI has none. This raises concerns about the possibility of leakage. An empirical analysis (Kindle, Shawhan, and Swider 2011) found no evidence for leakage early in the program's implementation but noted this could have been because allowance prices were too low to induce significant leakage. A more recent report (RGGI 2014) found no evidence for leakage from RGGI generators to non-RGGI generators serving RGGI load.

Using first jurisdictional deliverer as the point of regulation would be difficult to implement in RGGI because it encompasses multiple electricity jurisdictions that do not correspond to state lines, so using North American Electric Reliability

Corporation (NERC) e-tags as in California would be infeasible (Farnsworth et al. 2013). Although RGGI initially considered making load-serving entities the point of regulation (Cowart 2004), it ultimately decided to use fossil fuel generators. Additional discussion comparing these two approaches is found in Gillenwater and Breidenich (2009).

4.4.4 ONTARIO

Ontario has passed legislation implementing a cap-and-trade market to start in 2017. Electricity imports from non-WCI jurisdictions have a compliance obligation on all imported electricity. To account for imports, imported electricity has a compliance obligation by using Default Emission Factors calculated for jurisdictions which trade electricity with Ontario; these factors are estimates of the marginal CO_2 emissions associated with the electricity imports into Ontario. The domestic electricity sector (for all non-hydro and non-renewable sources of electricity) is covered at the fuel distributor level; in Ontario this type of generation is almost completely natural-gas fired, so the natural gas supplier has the compliance obligation, and will likely pass on the cost of this obligation by charging a higher fuel rate. Similarly, since natural gas distributors cover compliance for electricity, natural gas used for all non-electric purchases is also covered by the distributors. This means that natural gas, whether produced in Ontario or imported, is covered under the cap-and-trade program by assessing compliance on the natural gas distributor.

4.5 Miscellaneous Considerations

Additional considerations include whether to have an allowance price floor or ceiling, whether to allow banking of allowances, and whether to link with other jurisdictions.

4.5.1 PRICE FLOORS AND CEILINGS

Including a price floor ensures prices stay high enough to provide a meaningful incentive signal for capped industries (Purdon, Houle, and Lachapelle 2014). Including an allowance price ceiling trades off some economic risk for environmental risk, allowing additional allowances to be purchased should the price exceed a predetermined maximum (Purdon, Houle, and Lachapelle 2014).

In California and Quebec, the price floors varied for each auction. In California the price floor was set at $10 / MT in 2012 and set to increase by 5% plus the rate of inflation as measured by the Consumer Price Index annually. To ensure price stability, a safety valve was created; a percentage of allowances from 2013-2020 are set aside in an Allowance Price Containment Reserve (APCR), and if needed these allowances will be auctioned at three price tiers: $40, $45, and $50, also increasing by 5% plus inflation (Hsia-Kiung, Reyna, and O'connor 2014). So far these APCR allowances have not been needed. In Figure 2 below, which graphs the price of allowances trading on the secondary market, we see that allowances were trading at $12.90 / MT in August of 2016 (Climate Policy Initiative 2016).

Figure 2. Price of California Carbon Allowance Futures[4]

In Quebec the price minimum was set at C$10 in 2012, rising by 5% plus inflation annually. Quebec also has a safety valve with the same structure as California's APCR, and similarly has not needed to call upon this safety valve yet. In Quebec the settlement price for the allowances have been the price floors, whereas in California they trade at a roughly 20 cent premium (Purdon, Houle, and Lachapelle 2014). In RGGI the price minimum was $2 / MT CO_2 in 2014, rising at 2.5% annually.

[4] Raw data from ICE End of Day Reports – data aggregated by the California Carbon Dashboard, a project of the Climate Policy Initiative. http://calcarbondash.org/. Graph includes data from trading days through August 31, 2016.

4.5.2 BANKING

Banking of allowances allows for flexibility in temporal allocation and minimizes a collapse in the cap-and-trade system should the allowances be over-allocated in early years of the program (Purdon, Houle, and Lachapelle 2014). Banking may also reduce price volatility, reducing program compliance risk (Holt et al. 2007). While most of the discussed jurisdictions allow banking, they also maintain some rules regarding the amount of offsets that may be banked. In California, banked allowances do not expire, but regulated entities are subject to a maximum allowances holding limit based on the entity's annual allowance budget. The EU-ETS allows unlimited banking, and even allows a limited case of borrowing from the future. Allowance allocation takes place in February each year, but the surrender of the previous year's allowance takes place after this allocation, by the end of April. Thus, entities can use some of their allocated allowances to pay for a previous year's compliance obligation.

4.5.3 LINKAGE

California and Quebec have linked their emissions trading schemes together in the Western Climate Initiative (WCI). Purdon, Houle, and Lachapelle (2014) found that both jurisdictions benefitted economically from this linkage through lower allowance prices or revenue from allowance sales. Likewise, Ontario investigated several alternatives for implementing a cap-and-trade system and determined that linking with the WCI would minimize both leakage and program costs (Province of Ontario 2016). The WCI has published design recommendations for regional cap-and-trade programs to facilitate linking. Details can be found on the WCI website, but here we summarize some of the key issues. The WCI suggests sector scope should be the same as described for California, Quebec, and Ontario above, with sectors covered including: electricity generation; combustion at industrial and commercial facilities; industrial process emission sources; and fuel combustion above the threshold of 25 MT CO_2e per year. The WCI suggests an electricity point of regulation as the first jurisdictional deliverer, as described in the section for California electricity imports above. For large sources (i.e. with emissions greater than 25 MT CO_2e annually) the point of regulation will be at point of emission, whereas for smaller sources the point of regulation should be at the fuel distributor. The precise point may vary by jurisdiction, and distribution of the jurisdiction's allowance budget can be used as the jurisdiction sees fit. The rules regarding recommendations regarding offsets are more broad, with WCI recommending offsets allowable up to 49% of an entity's compliance obligation in each year; this is much more generous than the 8% limit set by California and Quebec. For further details of the WCI design recommendations, see WCI (2009).

4.6 Implications for Oregon

Overall, we draw six implications for Oregon from the experience of other jurisdictions and from economic theory:

(1) a broad scope will lead to a more effective market,

(2) free allowances should be allocated carefully,

(3) offset rules should likely mirror those used in the WCI,

(4) including imports of electricity and gas would prevent leakage,

(5) banking of allowances should be considered, and

(6) the program should be considered as a backstop for emissions reductions not achieved by complementary policies.

In order to minimize leakage and maximize effectiveness, fairness, and efficiency of a carbon policy, the scope should include as many sectors of the economy as possible. There are limits to what is politically and practically feasible, so most areas have settled on encompassing a subset of their emissions. California and Quebec cover roughly 80% of GHG emissions under their respective caps, while RGGI and the EU-ETS programs cover fewer GHG emissions under their caps – roughly 21% and 41% of their jurisdictions respectively. The point of regulation is simplest to impose on upstream producers or procurers of fossil fuels. (Electricity and natural gas imports are discussed below.)

Conventional economic theory suggests it is equally efficient to auction and give away allowances freely. However, there are some arguments that allowances should be auctioned as much as possible. Revenues can be used to enhance the efficiency or effectiveness of the policy or to compensate disadvantaged households, communities, or industries. Following the approach used in California, allowances could also be given away to resource-intensive or trade-exposed industries such as timber, pulp and paper, and other manufacturing; California ranks industries according to leakage risk and gives more allowances to high-risk industries. As electricity prices are relatively low in Oregon, allowances for utilities could conceivably be either auctioned, given away freely, or provided using a consignment auction as in California. The key political and economic fairness consideration is that the allocation of allowances addresses the potential distributional impacts of the cap-and-trade system.

Because Oregon has constitutional limits on the permitted use of revenues collected relating to the purchase of transportation fuels (Article 9, Section 3a of the state constitution), that sector will need to be considered carefully. Awarding free allowances to transportation fuels could hypothetically address adverse distributional impacts of the cap-and-trade system. However, giving away allowances to transportation fuel procurers or distributors could potentially result in windfall profits, and it would be difficult to implement, as the fuel demand and supply markets are both dynamic. A better approach would be to use revenues from auctions in other sectors (or general state funds) to mitigate negative distributional impacts of increased transportation fuel prices.

Offsets may be an important part of a cap-and-trade system, but they must be designed carefully. All areas have limited their use. They should be limited in scope to alternative emissions reduction options that are primarily within the jurisdiction, to maintain credibility of the emissions reductions achieved under the program and to prevent moral hazard. Following similar rules to those used under the WCI would be advisable.

Because Oregon imports a substantial amount of electricity and natural gas, covering these imports under the cap would prevent leakage. To address this, Oregon could regulate midstream fuel distributors, consistent with the WCI's recommendations. Handling electricity imports is more complicated; while Portland General Electric operates mostly in Oregon, PacifiCorp operates across six states in the Western United States, including Oregon, Utah, Wyoming, Washington, Idaho, and California. Using first jurisdictional deliverer as the point of regulation for electricity is recommended by WCI (WCI 2009) and Palmer, Burtaw, and Paul (2009). Additional investigation is needed to determine whether this approach is feasible in Oregon, as it lacks a single ISO or vertically integrated utility, complicating the use of e-tags to track imports. Assigning the compliance obligation to load-serving entities is an alternative approach, but legal considerations deserve more analysis (Parlar et al. 2012), particularly because several of Oregon's large electric utilities extend outside state borders. Careful consideration is also needed to navigate overlapping jurisdiction between Oregon state agencies for regulation of electric utilities, and to consider how the emissions of imported electricity will be specified, which received extensive discussion in California. The only firm conclusion from the literature is avoid assigning the compliance obligation to fossil fuel generators as in RGGI, as this would expose the policy to greater risk of leakage.

In the cases of Quebec, California, and Ontario there are no adjustments made for carbon costs associated with exports. This implies that carbon emitting generators within these jurisdictions exporting electricity to non-cap-and-trade jurisdictions may become less competitive. Ontario has significant hydropower resources which are unaffected by this, and California has been a historic net importer of electricity, so it remains to be seen whether this dynamic will have a significant effect on each jurisdiction's electricity markets. As it is a net exporter of hydroelectric power, Oregon is similar to Ontario in that hydroelectric exports are not heavily affected by an internal carbon price, and they should be able to continue exporting as before.

Allowing allowances to be banked would enhance the flexibility of the policy. Inclusion of price floors and ceilings enhances stability and predictability of the policy. Regarding linkage, each relevant analysis reviewed here has concluded that linking with other jurisdictions (specifically the WCI) would reduce the costs or enhance the benefits of their programs (in California, Quebec, and Ontario). Consequently, we recommend linkage to the WCI. Linkage would interact with recommendations above, requiring a broad scope of coverage (Purdon, Houle, and Lachapelle 2014).

5 Conclusions

Oregon has committed to significant reductions in GHG emissions. Cap-and-trade systems may be part of the strategy to reduce emissions. This paper reviews the literature on the macroeconomic impacts of climate policies and cap-and-trade system design. This conclusion section distills a number of key insights from our review:

1. Complementary policies are always included and act to reduce the impact of the cap-and-trade system itself.

2. Macroeconomic models find small effects of climate policies relative to the size of the economy.

3. Distributional impacts of cap-and-trade could be unfavorable, but this can be ameliorated with careful policy design.

4. Macroeconomic theory and experience in other jurisdictions provide ample guidance for designing a cap-and-trade system in Oregon.

Carbon cap-and-trade systems have always been implemented in concert with complementary policies. Arguments for these policies include addressing market failures beyond that of the effects of greenhouse gases on climate, decreasing uncertainty, achieving complementary goals (such as energy diversification), and addressing political concerns about cap-and-trade acting as a large tax on energy-intensive goods and services. Complementary policies likely act to absorb the macroeconomic impacts of the comprehensive climate policy, reducing the direct effects of the cap-and-trade system itself.

Climate policies have generally been subject to macroeconomic models that lump together complementary policies with cap-and-trade systems. These models have often found small net negative costs, primarily due to addressing existing market failures in investments in energy efficiency. Sometimes small net positive costs are found, as increased energy prices displace spending on other goods and services. However, these costs have been found to be less than 1% of GSP / GDP in magnitude, even when modeling aggressive long-term greenhouse gas emission reductions like those contemplated by Oregon.

Theoretically, a cap-and-trade can act as a regressive energy tax, disproportionately impacting low-income and rural households and resource-intensive industries. In practice, there is no evidence that this has occurred in any of the areas implementing climate policies, and it can be ameliorated via policy design: the inclusion of energy efficiency policies with robust incentives / financing support can bring benefits to low-income and rural households; carbon allowance value can be returned to households or allocated to resource-intensive industries to mitigate negative impacts of the policy.

Careful design of a cap-and-trade system enhances the efficacy, efficiency, and fairness of the policy. Using the Western Climate Initiative examples of California, Quebec, and soon Ontario as a template for policy design is recommended. There are five main insights from design experience elsewhere that are relevant for Oregon. We recommend that sector scope be as broad as practically possible. Oregon should auction allowances when feasible, and use auction revenues to address negative distributional impacts of the policy. Giving away allowances freely should be considered as an alternative method of addressing negative distributional impacts of the policy only when dictated by legal or political considerations. Oregon should include offsets but limit their scope. Assessing upstream producers for the implied carbon emissions of their products is simplest, except for imports of electricity and natural gas, which need to be treated separately. Oregon should include price floors, ceilings, and banking, and we recommend linkage to the WCI. As in California, the cap-and-trade can be considered as a backstop to fill emissions gaps left from complementary policies.

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