Carbon Pricing and Mind the Hissing

Sustainable Prosperity

RESEARCH PAPER

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The title of this paper refers to a famous quote by Jean Baptiste Colbert: “The art of taxation consists in so plucking the goose as to obtain the largest possible amount of feathers with the smallest possible amount of hissing".

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Executive Summary

We discuss allocation of government revenues generated from carbon taxation, permit auctions and other revenue-generating carbon policies. We suggest three primary objectives that governments consider in the design of a revenue allocation scheme, namely economic efficiency, emission reductions, and social acceptability. We then discuss four alternative channels for the allocation of funds. These are revenue recycling, technology support measures, redistributive measures, and general productivity enhancing measures. We discuss the interplay of these objectives and channels in the Canadian context drawing on examples from four provincial case studies. Our analysis yields the following broad conclusions:

1. Designing the carbon pricing policy and the related revenue allocation scheme in line with economic theory can't assure that economic performance will be good, but it markedly reduces the chance that the pricing instrument will become a negative driver of economic performance. Economic efficiency does not guarantee public support.

2. Public perception is key. The chosen strategy for revenue allocation can significantly shape public opinion about the carbon pricing policy. Support for a pricing instrument may be tied to a clearly established plan for using the generated funds, whether that is through revenue recycling or technology promotion or other allocation channels. Public perceptions of fairness, environmental effectiveness, and economic efficiency of the entire policy package are key. For example, in Alberta, there is acceptance of the fact that the oil sector faces a serious challenge reducing greenhouse gas (GHG) emissions. As a result, allocating the bulk of the revenues to technological development to help the oil and gas sector reduce emissions is viewed as fair. In BC, the perception was that the poor and some rural residents would bear an unfair burden and the government's revenue recycling scheme responded to these concerns.

3. Economic efficiency and environmental effectiveness may need to be compromised somewhat to respond to public concerns. However, an important lesson from the European Union's (EU) carbon trading scheme is that attempts to address the “fairness” issue can go too far. A key contributor to the collapse of the allowance price in the European Emissions Trading Scheme (EU ETS) is the issuance of too many allowances, some motivated by argued "fairness" issues. This collapse constituted a major threat to the ETS' credibility. Particularly in BC and in Québec, the initially established strategy for revenue allocation may be at risk over the long term of being hijacked by popular interests, shifting prioritization of objectives increasingly towards social acceptance and away from economic efficiency and environmental effectiveness.

4. Diversity is key. Trade-offs exist between the three objectives of revenue allocation. It makes sense for governments to prioritize the objective that is particularly relevant in the specific situation, but in general one can argue that no one objective should be completely neglected. It is important to monitor and evaluate the policy's performance according to all three objectives. The diversity in objectives is likely to require a portfolio of allocation options rather than putting all eggs in one basket. Combining different allocation options will become even more important in the future when carbon related revenues can be expected to increase and the marginal returns to each one allocation option will decline.

5. Responsiveness is key. Ultimately, revenue allocation strategies must respond to each jurisdiction's specific circumstances. There is no one-size-fits-all recipe. Individual factors for consideration include public attitude, fiscal budget, existing economic inefficiencies and tax distortions, concrete opportunities for technological innovation etc. For example, Québec uses parts of the carbon revenues to fund infrastructure enhancements and climate change adaptation measures that take into account the province's specific challenges and vulnerabilities. If funds are allocated to general productivity-enhancing measures like infrastructure or education, this should be done in a way that addresses existing productivity challenges or takes advantage of existing opportunities.

6. If clean technology investment is chosen as the preferred channel for revenue allocation a number of subsequent questions emerge about how to best foster invention and innovation. For example, choices must be made regarding the types and development stages of the technologies to be promoted, the design of support programs and their governance. While this paper outlines some of the current debates in the existing literature that are relevant to the Canadian context, additional research on clean technology promotion in Canada appears warranted.

Chapter 1: Introduction

A number of provinces have either adopted or are considering climate policy options involving `carbon pricing.' Carbon pricing, i.e. internalizing the social cost of emitting carbon into the atmosphere, is the economically most efficient solution to fixing the environmental externality problem underlying climate change (Jae, Newell, and Stavins 2005). Depending on the stringency of targets and parameters of the policy regime adopted, such programs can generate a sizeable amount of revenue. As will be detailed below, revenues from BC's carbon tax and Alberta's Specified Gas Emitter Regulation (SGER) each generate revenues in the hundreds of millions. If the stringency of these measures is increased, the amount of revenue is likely to rise. The purpose of this paper is to evaluate alternative uses of government revenues from carbon pricing and to provide preliminary criteria for their assessment in the Canadian context.

Multiple options for channelling such carbon-policy related revenues back into the economy exist and a growing body of literature debates their relative advantages.

1. Carbon revenues can be treated just like public funds from other sources and recycled through the general tax system, e.g. they can be used to cut personal income taxes and/or business taxes. This revenue recycling channel is often discussed in the context of an environmental tax reform (ETR) (see for example (Ekins, Pollitt, Summerton, and Chewpreecha 2012)). For instance, the government revenues from BC's carbon tax regime are largely recycled into the economy, mostly through cuts in personal and business taxes and also through targeted transfers to households.

2. The generated funds can be used more specifically to further promote climate change mitigation through investment in low carbon technologies. Technology investment can either focus on the development of new technologies or the diffusion of existing clean technologies. There is broad agreement in the literature that achieving meaningful reductions in greenhouse gas (GHG) emissions involves a large-scale transformation of energy technologies that requires both improvement of existing technologies and creation of new technologies (Marangoni and Tavoni 2013). For example, Alberta's carbon revenues have been allocated via the CCEMF (option 2) and as such mainly support projects using technologies in the later stages of the development process, such as demonstration and commercialization.

3. Revenues from carbon policies can be spent on redistributive measures such as lump-sum payments, tax cuts, the increase of existing transfer programs or the introduction of new transfer programs with a view to compensating the population groups that are perceived as being unfairly burdened by the carbon policy. Hence, redistributive measures differ from revenue recycling through tax cuts described above in the explicit focus on equity. This motivation can be detected in the two main transfer programs funded through the carbon tax in BC, the Low Income Action Tax Credit and the Northern Rural Homeowner Benefit.

4. Government revenues from carbon policies can be used for targeted spending on general productivity enhancing measures. This channel includes investments in infrastructure, health care, and education. For example, the government of Québec allocates the majority of carbon funds to public transit investments.

Generated funds may of course be allocated through a combination of the four channels.

We consider allocating the carbon revenue based on the following broad objectives:

1. improving economic efficiency
2. reducing future and current emissions
3. assuring/enhancing the social acceptance and political viability of the carbon pricing scheme.

1.1 Economic Efficiency

Improving economic efficiency is often achieved by using the carbon revenue to mitigate the effects of existing market failures or distortions. We distinguish three sources of inefficiencies: existing tax distortions, market failures in technology markets, and under-provision of public goods such as education, infrastructure, and climate-change adaptation.

When carbon policy revenues are used to reduce distortionary taxes, for instance capital and labour taxes, the context is often a broader environmental tax reform (see for example Ekins, Pollitt, Summerton, and Chewpreecha (2012)).

Revenue can also be used to provide subsidies for R&D and deployment of innovative technologies. To achieve greater efficiency in technology markets per se, the funding does not have to be directed toward 'green' technologies or causes, but rather those technologies that are, for whatever reason, supplied at a lower level than is efficient. If green technologies suffer from such market distortions, support for these technologies can be justified on both efficiency and environmental grounds.

Efficiency enhancing revenue use can also mean subsidization of public goods in general, including training and education, health services, and infrastructure, if they are provided at an inefficiently low level.

Finally, carbon revenue allocation can drive economic productivity when used to fix other market failures, for example, associated with education, climate-change adaptation, and infrastructure investments. Private markets are likely to generate inefficiently low levels of supply because investment in both education and infrastructure can generate substantial external benefits that cannot be appropriated by private investors.

In summary, the objective to enhance economic efficiency through carbon revenue allocation ultimately aims at generating a `strong' double-dividend. That is to say to not only balance the economic costs of carbon regulation with offsetting efficiency gains, but to achieve a net positive impact on economic efficiency.

1.2 Emission Reductions

Carbon revenues can be used to reduce future and current emissions in a number of ways. Funds can be invested in further measures for mitigating emissions including subsidies for low carbon technology adoption, supporting clean technology R&D or the diffusion of low-emissions technology. Likewise, information campaigns, reforestation and conservation measures are other possibilities. Most importantly, effort must be made to ensure that chosen allocation channels will not counteract the behavioural responses that the carbon policy was intended to achieve in the first place.

1.3 Social Acceptability

Besides reducing emissions and improving economic efficiency, carbon revenue can also be used for social objectives like income redistribution and other measures that improve the political viability of the carbon pricing scheme.

Achieving this objective requires choosing a revenue allocation strategy that helps with establishing social acceptance of the carbon policy. A considerable body of literature on the public perception of environmental tax reforms mostly in European countries finds that people's comprehension of the logic behind revenue recycling tends to be poor and that as a consequence, the 'textbook' solution may not always be the socially most acceptable choice in practice (Dresner, Dunne, Clinch, and Beuermann 2006). Social acceptance is dependent on people's perception of the policy as fair, equitable, and effective and this perception does not necessarily reflect actual empirical evidence. In the US context Amdur, Rabe, and Borick (2014) finds that the key element favouring approval of carbon taxes is if there is an explicit plan for use of the revenues. While the study found the most support for a revenue-neutral tax with funds being used for tax reductions elsewhere, this was less important than that an explicit plan for the use of funds be established.

Generally, transparency and predictability in policy decisions around environmental tax reforms help to build government credibility and trust.

Achieving long-term viability of the carbon pricing policy also requires choosing a revenue allocation strategy that can be scaled up, especially if carbon revenues are likely to increase in the future.

1.4 Interactions Among Objectives and Cross-cutting Issues

As with many policy decisions, trade-offs are likely to exist among these three objectives. From an economic-efficiency perspective, policies should be designed so as to achieve the set environmental target with least economic costs. Trade-offs with other objectives likely complicate this goal.

Further, it is likely that the marginal benefits, be they in terms of economic efficiency, distributional equity or emissions reductions, of each dollar spent will diminish with additional funds allocated to any given measure. An added complication in the longer term is that it can be very difficult politically to reduce or remove subsidies or benefit schemes once they have been introduced. Revenue allocation decisions therefore need to be made carefully and with a longer time horizon in mind.

The remainder of the paper is structured as follows. Section 2 reviews four provinces, including three with carbon pricing schemes (BC, Québec and Alberta) and one without one (Ontario). Section 3 looks at the economics of allocating climate revenues among the three objectives outlined in this section. Section 4 looks at the governance and transparency issues associated with using climate revenues. Section 5 discusses the relevance of the lessons of Section 3 and 4 to any province considering introducing a new carbon pricing scheme, or restructuring an existing one.

Chapter 2: Selected Cases

2.1 Overview

Table 2.1 summarizes key characteristics of the carbon policies and revenue allocation strategies implemented in the three considered provinces that already have a revenue-generating carbon policy in place. In subsequent sections we will provide more detail about the extent and nature of the carbon pricing elements and chosen allocation channels for the generated carbon funds of each province's climate regime. We will also discuss the current situation in Ontario, where implementation of a revenue generating carbon policy looks increasingly likely.

Table 2.1: Carbon Pricing Case Studies

	British Columbia	Québec	Alberta
Policy Instrument	carbon tax	cap and trade system	cap and trade with compliance fee
Revenue generating?	yes	yes	yes
Size of carbon revenues	$959M in 2011/12	$30M in 2013; cumulative revenue expected at $2B by 2020	$70M expected 2014/2015
Revenue Neutral?	yes	yes	yes
Allocation of Funds	revenue recycling and redistribution	technology promotion, general productivity enhancing measures (adaptation)	technology promotion
Governance	provincial government	provincial government	Non-profit management fund (CCEMF)

2.2 British Columbia

British Columbia, as the first North American jurisdiction to institute a meaningful carbon tax, is a natural place to start discussion of allocating carbon revenues. B.C.'s carbon tax currently stands at $30 a tonne and covers almost all GHG emissions from burning fossil fuels in the province. The tax scheme was designed to be revenue neutral from the outset in 2008. All revenue from the carbon tax (amounting to almost $1 B in 2011/2 and $1.1 B in 2012/13) has been used to finance tax cuts or ramp up lump sum transfers.

In 2012/13, personal income tax reductions and increased transfers accounted for about 40% of the total allocated revenue, and both the transfers and reduced tax rates were heavily focused on lower income households. The remaining 60% of the revenue was used to reduce corporate and business tax rates.

The two main transfers programs funded by the carbon revenue were the BC Low Income Climate Action Tax Credit program (tied to household incomes) and the Northern and Rural Area Homeowner Benefit program. The first measure can be seen as addressing concerns for low-income households, whereas the second responded to expressed concerns about the unfair burden posed on Northern and Rural households.[1]

In a sense, B.C. defines one extreme of the range of revenue allocation strategies available in that all of the carbon revenue was earmarked to either reduce other taxes or increase transfers. Indeed it has been called the first implementation of James Hansen's proposed "Fee and Dividend" approach.[2]

Although the B.C. carbon tax's recycling measures do return all the revenue, not all of it is used for reducing other distorting taxes. In particular, the two major transfer programs funded by carbon tax revenues respond to equity issues: first, the concern that the tax would otherwise be regressive[3] and as such represent a possible political liability issue, and second, the perception that the burden would be unfairly born by Rural and Northern residents.

2.3 Quebec

Although Québec has applied a carbon tax of sorts to motor fuels for some time, the major plank of its climate policy is now its cap and trade system. The system debuted with a trial market[4] in 2013, where the cost per tonne was $10.75 (Sustainable Prosperity 2014). The province's climate plan is intended to reduce emissions by 20% relative to 1990 levels by 2020.

Although the trial auction raised only $30 million, the province expects that the total proceeds

[1] Preliminary findings from (Beck, Rivers, Wigle, and Yonezawa 2014) cast doubt on the basis for this concern. Further, while a key concern with the design of the BC carbon tax's recycling measures was redistributive, the same study concludes that the carbon tax may have been mildly progressive even before the added equity measures.

[2] See https://en.wikipedia.org/wiki/Fee_and_dividend

[3] Or perhaps less progressive than it should be.

[4] There was no compliance requirement to drive allowance purchases for the first auction.

from the auction will have added up to over $2 B by 2020 (Québec 2012) as the coverage of the cap broadens to other sectors and stringency rises. The intent is that all of the revenue "will be fully reinvested in measures focusing on the reduction of emissions and adaptation to climate change in Québec" (Québec 2012, iii).

Two thirds of the carbon revenue will be devoted to the transportation sector including support for public transit. Funds are also anticipated to go to energy-efficiency measures of various types including building retrofits and incentives for improving the energy efficiency of new buildings. Some of the revenue will also be used to support adaptation, as well as reducing emissions related to agriculture and waste management. While the plan includes reference to renewable electricity, the scope for expanding renewable generation in Québec is limited, given that 97% of the province's electricity is already GHG-free.

The cap and trade system in Québec is harmonized and integrated with the system in California in order to allow permit trade between the jurisdictions under the Western Climate Initiative. Québec is likely to be a net buyer of allowances in the Québec-California system, which means that money is flowing out of the province, for two reasons.[5] First, Québec's target is more stringent than California's. Second, Québec has very little scope for abatement via reducing fossil-generated electricity. Both of these facts make it likely that when California and Québec integrate their allowance auctions this year, mutual economic benefits can be gained (Sustainable Prosperity 2014). And while this doesn't necessarily affect the amount of revenue to be generated, it could positively affect the political feasibility of the carbon policy by providing emitters in Québec with an alternative lower-cost compliance option.

2.4 Alberta

Alberta's major climate program is the Specified Gas Emitter Regulation (SGER), introduced in 2002. The SGER intended to reduce emissions by 50 Mt below BAU by 2020. Alberta feels that even more aggressive longer term targets[6] can be achieved with a significant expansion of the unconventional oil and gas sector. Implicit in that assumption is that a large part of the targeted reduction can be obtained by applying Carbon Capture and Storage (CCS) technologies. CCS has become a key element in the province's overall mitigation strategy.

The regulation targets large industrial emitters of more than 100,000 t per year. Emitters are required to reduce emissions from combustion, venting, and flaring by 12% relative to a 2003-2005 baseline. Emitters that outperform this target can earn tradable credits, whereas emitters who fall short can buy the credits. The SGER also includes offsets from Alberta agriculture and transport sectors. A final compliance option is to pay $15/t into Alberta's compliance fund, called the Climate Change and Emissions Management Fund (CCEMF). As of December 2013, the fund had received over $310M and invested $213M in projects with a total value of $1.56B (CCEMC 2013).

[5] Indeed the Quebec climate plan makes explicit reference to this fact (Quebec 2012, ii).
[6] 200 Mt below BAU by 2050

The CCEMF is managed by the Climate Change and Emissions Management Corporation (CCEMC). Since CCS is currently only affordable in some contexts (for example, the processing of natural gas) a major focus of the CCEMF has been on funding R&D or early-stage trials of various CCS processes and their applications. Up to 2013, CCEMF funds have been allocated heavily to CCS innovation (market demonstration or commercialization stage) relative to R&D. There has been some movement in recent years towards allocating more of the funding to earlier stage R&D. In terms of supported technologies, renewable energy projects have received the largest slice of the funding to date ($98M or 45%), followed by projects to green fossil fuels ($55M or 26%), energy efficiency projects ($39M or 18%), and CCS projects ($21M or 10%) (CCEMC 2013).

When and if Alberta decides to tighten their reduction targets and use the SGER to achieve these tightened targets they will also need to increase the compliance price. If they do so, it is very likely that the SGER will generate dramatically more revenue.

Alberta is in a sense at the other extreme of the range of allocation strategies compared to B. C., since none of the revenue has been used to reduce existing distorting taxes.[7] Further, none of the funds have, so far, been returned in terms of household focused transfers. In Alberta's case, the main concern has been with fostering technologies to enable them to meet progressively more stringent reduction targets. As recent developments indicate, there may be some concern that Alberta has sunk too many eggs in the CCS basket.

2.5 Comparing Carbon-Pricing Strategies

Before turning to a look at Ontario, it's instructive to compare the three provincial regimes that already include a role for carbon pricing. For this purpose we consider how the schemes compare in terms of their use of the four identified channels for revenue allocation: 1. revenue recycling, 2. redistribution through the tax system 3. technology supports, and 4. general productivity supports. The different allocation channels can generally contribute to multiple or all of the three objectives (economic efficiency, emission reductions, and social acceptability) at the same time, depending on the specific circumstances.

Table 2.5 illustrates the strategies, i.e. combinations of allocation channels, chosen by the three case studies that have revenue generating carbon policies in effect.

[7] Alberta's taxes are already among the lowest in Canada.

Table 2.5: Comparison of carbon-pricing strategies across provinces

	British Columbia	Québec	Alberta
Revenue Recycling	X		
Technology Support Measures		X	X
Redistributive Measures*	X		
General Productivity Measures**		X	

* via the tax system and transfer programs; ** In Québec's case, we interpreted their support for adaptation as a move to enhance general productivity in the future.

Viewed this way, it is rather striking how differently the three provinces have structured the use of their revenues. While BC stays most closely to the 'textbook' solution for generating a double dividend through environmental taxation (indicating high importance of the efficiency objective), it is obvious that redistributive motivations also play a (possibly growing) role. Alberta's focus on technology support may indicate motivation to foster R&D in order to 'green' the province's fossil fuel industry. Québec's technology support measures seem to have a somewhat different focus, rather aiming to promote adoption of existing energy efficient technologies. Québec's focus on investment in mobility technologies and transport infrastructure can be considered at the intersection of technology support and general productivity measures, while we consider investments in adaptation as productivity enhancing measures.

2.6 Ontario

Ontario's climate policy initiatives so far have generated no revenue. While their move to close all coal-fired generating plants by 2014 was perhaps the most significant climate action in North America, there are no associated revenues. Likewise, the feed-in tariff program under the province's Green Energy Act that was implemented in 2009 aims at encouraging Ontario's renewable energy sector does not generate any revenue.[8] Other elements of Ontario's climate plan include subsidies to ethanol biogas and other technologies (Ontario 2012).

Nevertheless, climate policies with associated revenue may be particularly relevant for Ontario in the future because of Ontario's fiscal context. The province faces a serious budget challenge, with a deficit expected exceed $12 B in fiscal 2014-2015. The recently elected majority Liberal

[8] Indeed, the cost of the feed-in tariff is ultimately born by consumers.

government has announced its intention to eliminate that deficit by 2017-2018. Moreover, while other Canadian provinces may consider carbon pricing, Ontario has recently made more confident and concrete public statements in that regard after years of consultation on the issue. At the Annual Premiers' Conference in August 2014 the introduction of a price on carbon as a possible means to promote the transition to a low-carbon economy was recognized. In November 2014, Ontario reassured its commitment to a carbon price in a memorandum with Quebec and newspaper headlines in January 2015 report that Ontario Environment Minister Glen Murray is working on integrating carbon pricing into a broader strategy that is to be introduced later this year (Morrow 2015). Should Ontario (or any other jurisdiction) decide to move ahead with carbon pricing, a decision on revenue allocation becomes inevitable.

Chapter 3: The Economics of Carbon Revenue

This section considers the economics underlying three broad approaches to the use of climate revenues. Section 3.1 considers revenue recycling (using climate revenues to reduce other taxes). Section 3.2 considers alternative approaches to supporting low-carbon technologies. Section 3.3 considers using climate revenues to address distributional issues. Finally Section 3.4 looks at using climate revenues to enhance economic productivity in the economy.

3.1 Revenue Recycling

A growing body of literature assesses the environmental and welfare implications of an environmental tax reform (ETR) where levies on environmental pollution are used to reduce personal and corporate income taxes. Some studies indicate such ETR can yield a double-dividend (Gimenez and Rodriguez 2010), an environmental dividend and an economic efficiency dividend. First, the environmental dividend describes the welfare increase achieved from the tax's effect on environmental quality alone. To isolate the environmental impact, one can assume that tax revenues are paid back to households through lump-sum transfers. Second, the economic efficiency dividend is defined as the additional welfare gain achieved by using carbon tax revenues to reduce distorting labour, consumption, or capital taxes instead of making lump-sum transfers. If environmental dividend and efficiency dividend together are able to balance and even exceed the losses in the factor markets due to higher energy prices caused by a carbon tax, a true double-dividend exists. The theoretical literature shows no consensus regarding the existence and magnitude of a double-dividend from ETR (see for example Bovenberg and de Mooij (1994) and Bento and Jacobsen (2007) for opposing views). The bottom line of a carbon tax with revenue recycling will depend on the initial rates of the taxes as well as the respective elasticities of substitution of labour and capital with the taxed fuels.

More recent studies of environmental tax reform based on computer model simulations have tended to find a significant role for revenue recycling, particularly via reductions in corporate taxes. While the studies do not find a strong enough efficiency dividend to fully offset the impact of a carbon tax, they indicate that revenue recycling can significantly mitigate the costs of climate mitigation policies (see for example Mckibbin, Morris, Wilcoxen, and Cai (2012)). Moreover, our work in progress finds that recycling revenue through reductions in corporate or income taxes normally dominates returning the revenue generated in a lump-sum fashion, sometimes by a significant margin (Beck, Rivers, Wigle, and Yonezawa 2014). Our results are in line with previous studies investigating the relative welfare implications of tax rate cuts versus lump sum transfers implying that the former are preferable (for example Dissou and Sun (2013) and Bovenberg and Goulder (1996)).

Interestingly, revenue recycling through tax reduction can interact with measures for technology promotion. This is because revenue recycling through ETR can implicitly foster low carbon innovation simply by freeing companies' resources for such activities. Both channels for carbon revenue allocation, support for low-carbon technologies and revenue recycling, can have beneficial environmental and economic effects at the same time. Funding policies for the promotion of low-carbon technological change can have secondary economic benefits including reduced production costs, the creation of green jobs, increased competitiveness, and infant industry development (Melitz 2005).

Still, economic and environmental impacts can also be at odds with each other. Importantly, the economic benefits of carbon revenue recycling, e.g. increased production and lower unemployment, may at least theoretically trigger a rebound effect in consumption that outweighs the environmental gains from the initial carbon regulation (Bayindir-Upmann and Raith 2003). Even if the mitigating impact on emissions is not fully offset, the carbon tax necessary to reduce emissions a given percentage will be (if only marginally) higher with revenue recycling than without.

3.2 Investment in Low-Carbon Technologies

Carbon pricing inherently drives investment in low emission technologies as firms are searching for low-cost compliance options. Yet complementary measures may be necessary to incentivize private firms to achieve the socially efficient level of green R&D activities (Gans 2012) and to invest in the early adoption of new, low carbon technologies (Jae, Newell, and Stavins 2005).

Technological change has two distinct phases. Support for technological change therefore can require investment in different activities in the two phases:

- In the invention phase, investment in R&D implies the active search for new ideas to improve technologies or processes. Investment in R&D involves high risks as outcomes and returns are uncertain.

- A newly invented product or process enters the innovation phase when it is first introduced to the market. In this phase of technological change investment, developers are required to fund demonstration projects and commercialization activities, and users are needed to purchase the new product and thus promote its diffusion. The decision to invest in the adoption of a new rather than the established technology is characterized by high uncertainty about the new technology's performance, operation costs, longevity etc.

In the invention phase, development expenditures are commonly very high and returns initially negative. R&D investment is only amortized with commercial technology diffusion. Mass production enables economies of scale and cost-reduction through growing experience or learning-by-doing. Such scale effects reduce the fixed costs per unit, speed up production processes, reduce error rates, reduce maintenance costs, may even lead to incremental new inventions.

With perfect competition, private actors supply both invention and innovation automatically at efficient levels. However, government action is needed if markets fail to deliver socially optimal levels of invention and innovation (Veugelers 2012). Multiple market failures can occur in relation to low carbon technologies (Jae, Newell, and Stavins 2005). For instance, private investors in technological change are unable to fully appropriate the social value of their investment if the created knowledge has public good character (Mowery, Nelson, and Martin 2010). Non-priced benefits from investment in technological change will be more significant if knowledge externalities combine with environmental externalities, i.e. if the improved technology also leads to environmental benefits such as carbon emission reductions. Rennings (2010) calls this phenomenon the "double externality problem". Fischer and Newell (2008) further distinguish between knowledge spillovers from R&D activities (Griliches 1992) and learning spillovers from applying the new technology. Jae, Newell, and Stavins (2005) call the latter “adoption externalities”. Both types of knowledge spillovers as well as environmental spillovers incentivize free riding among technology developers and technology users and justify policy intervention. Two different branches of economic theory deal with the triple externalities associated with investment in low carbon technology development and diffusion: environmental economics is concerned with the pricing of environmental externalities, and innovation economics is concerned with internalizing knowledge spillovers from R&D activities and innovation adoption (Rennings 2010). An economically efficient solution to the triple externality problem requires the integration of environmental and innovation policies (Jae, Newell, and Stavins 2005).

In addition to the market failure justifications some scholars also suggest strategic economic arguments in favour of targeted low carbon technology policies, such as international competitiveness and the creation of 'green' jobs. However, Morris, Nivola, and Schultze (2012) and Borenstein (2011) question whether such objectives alone indeed warrant government intervention. However, using revenues from carbon pricing to invest in low-carbon technological change may enhance both environmental quality and economic efficiency.

Indeed, Fischer and Newell (2008) conclude that a combination of carbon pricing policies, R&D subsidies, and adoption subsidies yields the greatest emissions reductions at the lowest economic cost. Veugelers (2012) and Acemoglu, Aghion, Bursztyn, and Hemous (2009) and Bosetti, Carraro, Duval, and Tavoni (2011) also illustrate the importance of a strong carbon price signal for increasing the effectiveness of technology development and diffusion programs. While Jae, Newell, and Stavins (2005) emphasize that targeted public technology funding is economically costly and should generally complement rather than replace environmental policies, stand-alone technology policies can be the second best option if carbon pricing, the first best policy choice, is impossible to implement for political reasons (Fischer and Newell 2008). Schneider and Goulder (1997) also find that research subsidies alone do not achieve least cost emission reduction but that a carbon tax is the better instrument. Assuming a combination of environmental and technology policy measures, government revenues from carbon pricing instruments such as taxation, auctioning of emission permits, or in the case of Alberta, compliance payments can be used to fund low carbon technology policies.

Technology support policies typically follow different strategies at each stage of technological change, invention and innovation. Programmes can either support technology suppliers in pushing new technologies to the market or they can work to incentivize demand for the new technologies from users, i.e. create a market pull.

- Technology-push programmes include R&D grants, tax cuts and similar policies to lower the costs and risks for private technology suppliers. R&D activities that are unlikely to yield any return for private firms can also be performed by fully funded public research institutions (Jae, Newell, and Stavins 2005).

- Demand-pull programmes include direct subsidies (e.g. feed-in tariffs) and tax credits for purchasers of new technologies, public procurement programmes, and import quotas. These measures address inefficiently low levels of adoption of existing low carbon technologies by creating demand.

A clear distinction between demand-pull policies promoting invention and technology-push policies promoting innovation is often impossible. Demand-pull policies in the long run are likely to also trigger investment in technical improvement as the pay-off for successful inventions increases. Similarly, technology-push policies may foster adoption of one technology by providing a complementary technology (Nemet 2009).

Alberta's CCEMF's current funding policy focuses largely on technology-push activities. Over 90% of allocated funds so far was directed to technologies already in the demonstration and commercialization phases as opposed to earlier R&D stages (CCEMC 2013). The SGER itself, however, can be considered a demand-pull initiative as it increases firms' willingness to purchase low carbon technologies.

In the following, we discuss one technology-push program (R&D subsidies) and one technology-pull program (adoption subsidies) in greater detail.

3.2.1 Adoption Subsidies

Early adopters of novel technologies face high risks in terms of technology performance, reliability, and operating costs. Even assuming environmental externalities are fully priced, additional subsidies may be needed to compensate early adopters for not choosing the incumbent established technology but taking the risk of innovation and thereby creating new learning and experience effects that benefit society as a whole (Mowery, Nelson, and Martin 2010). Adoption subsidies aim at market building and demand creation.

The effectiveness of demand-pull policy programmes has been subject to much conceptual and empirical research. Three broad research streams can be distinguished:

- One set of studies examines the source and scope of learning externalities in alternative energy industries. Considered technologies include offshore wind power (van der Zwaan, Rivera-Tinoco, Lensink, and van der Oosterkamp 2012), photovoltaics (Wand and Leuthold 2011), clean coal (Nakata, Sato, Wang, Kusunoki, and Furubayashi 2011), and CCS (Li, Zhang, Gao, and Jin 2012). These studies commonly explain the occurrence of cost reductions and quality improvements with increasing output by reference to learning or experience curve models, economies of scale, spillover effects from research and development or declining input factor prices. Learning effects in production and use of the new technology can create positive feedback dynamics. Once a critical level of technology diffusion has been reached, prices have diminished to a competitive level and the technology is able to sustain its growth without requiring further public funding (Melitz 2005). This phenomenon is sometimes called dynamic cost efficiency (Sanden 2005).

- Another body of literature investigates the effectiveness of a specific type of adoption policy, namely demand-side management (DSM) programs that aim to change energy consumption behaviour of end-users such as households, small businesses, and municipalities.[9] Promotion of energy efficiency represents the third pillar of Alberta's Climate Change strategy and CCEMC funded projects to enhance energy efficiency are estimated to achieve close to 0.5 MtCO2e per year (as of May 2012) (CCEMC 2012). Energy efficiency projects in the fund's current portfolio are largely concerned with technical solutions for industrial energy savings as opposed to demand-side management projects. Gillingham, Newell, and Palmer (2004) review studies on the effectiveness of energy conservation tax credits to households and find overall mixed results and a lack of data. Using a panel data set of 38,500 tax returns over the years 1979-1981, Hassett and Metcalf (1992) investigate the impact of energy conservation tax credits on investment and identify a significant positive relation. Similarly, a recent policy brief (Brownlee 2013) investigates the success of retrofit programs financed by municipalities or utilities. The results show that emerging best practices in Canada may have made residential energy-retrofit subsidies more attractive than were previously believed to be. Importantly, any energy efficiency policies carry the risk of triggering rebound effects that may partly or fully offset the positive impact of greater efficiency on carbon emissions (Greening, Greene, and Diglio 2000).

  Alberta's CCEMC has so far invested around 18% of total funds in energy efficiency related projects. Row and Mohareb (2014) very recently estimated the annual mitigation potential in Alberta by 2020 if all currently economic energy efficiency measures were implemented at 27Mt (that is more than twice the SGER compliance burden in 2012). Although Row and Mohareb (2014) find that net annual savings from reduced energy consumption associated with these measures would amount to $1.5 B by 2020, non-financial barriers prevent investment. Row and Mohareb (2014) recommend using the CCEMF to promote energy efficiency investments in the residential, commercial and small industrial sectors by

[9] The literature distinguishes between three components of demand side management: energy efficiency (mainly achieved through technical solutions), conservation (achieved through behavioural changes), and load management (change of consumption patterns through information on peak/non-peak times and price signals) (Carley 2012).

addressing key barriers such as the lack of information and access to capital financing, high transaction costs and high perceived risks. Notwithstanding the potential for energy savings, econometric studies tend to find dramatically lower cost-effectiveness of demand side management programs.

The Québec government has also announced some investment of permit auction revenues in energy efficiency related projects. For example, support is granted to Québec businesses investing in fuel switching or the implementation of energy efficiency measures. These measures may include installation of energy conservation technologies, enhancing the firm's energy management capacities and establishment of a culture of energy conservation and efficiency (Québec 2012). Another focus in the allocation of funds is on increasing energy efficiency of buildings.

- A third body of research investigates how such economies of scale, learning effects, and the good fit of new technologies with existing lifecycles, and infrastructures may lead to path dependencies in technology trajectories. Lock-in of dominant technological solutions can entail a discontinuation of the search process for alternative, possibly superior solutions and non-incremental technical improvements because once a "technological paradigm" has been established it dictates the definition of the problem, the definition of progress towards its solution and as such the long-term "technological trajectory" (Dosi 1982). Public funding for the adoption of prescribed technologies can enhance increasing returns on investment in the promoted technologies, enhance path-dependence and thus inadvertently help the inefficient narrowing of the technological search process (Kverndokk, Rosendahl, and Rutherford 2004).

3.2.2 R&D Subsidies

In the long term, the mitigation of climate change will require radical, non-incremental technological change and therefore investment in R&D (Veugelers 2012). Much of the existing literature implies that technology-push programs are the key driver of non-incremental technological change, with demand-pull forces in a complementary yet less dominant role (di Stefano, Gambardella, and Verona 2012). Watanabe, Wakabayashi, and Miyazawa (2000) describe a virtuous cycle that public R&D support can induce in the presence of knowledge and learning spillovers: technology development funding enhances the economy's knowledge stock, which leads to greater production of new technologies, which in turn reduces production costs through growing experience and scale effects. The declining cost not only motivates ever larger production volumes but also free resources for investment in new R&D projects, thus closing the virtuous cycle. Watanabe, Wakabayashi, and Miyazawa (2000) observe these dynamics in Japan's solar photovoltaic power generation industry. Nevertheless, the empirical literature examining the acceleration of clean technology development (often measured by number of registered patents) achieved through environmental policies in general, and research subsidies in particular, is surprisingly limited (Veugelers 2012). Nevertheless, three conclusions can be drawn from the reviewed studies:

- Public R&D expenditures are more likely to effectively promote invention if targeted on projects that yield significant social value but relatively small returns for private investors, i.e.

where the market failure causing under-investment is particularly pronounced (Clausen 2007). The gap between private and social return is particularly large for many basic research projects and technologies that are promising yet still in early development stages and far from marketization (Mowery, Nelson, and Martin 2010).

- The effectiveness of public R&D subsidies to trigger additional investment is compromised if public funds merely crowd out private money. Instead, public support should incentivize private engagement because ultimately, a combination of both funding sources is needed to realize the low-carbon technology transition (Mowery, Nelson, and Martin 2010). Almus and Czarnitzki (2001) investigate the effect of R&D subsidies on private firms' R&D expenditures in Eastern Germany. The results indicate that on average, public funding achieves higher R&D investment. Other studies show significant (Busom 2000) or even full (Wallsten 2000) crowding-out effects.

A recent global study on the need for R&D support yields interesting results regarding the performance of clean technology promotion. Marangoni and Tavoni (2013) employ a global integrated assessment model to investigate the contribution of international cooperation on clean energy R&D to achieving the global 2 degree target.[10] The policy simulations assume relatively large knowledge externalities that are fully integrated due to the global scope of the model. Still, at least in the short run, cooperation in international clean energy R&D slightly underperforms compared to a continuation of fragmented mitigation actions currently observed. While this finding can only be regarded with care in the context of revenue recycling options for Canadian provinces, its message seems clear: R&D funding only shows limited environmental and economic effectiveness even under the somewhat idealized conditions assumed in the model study including large spillover effects and large-scale cross-border integration. Nevertheless, Marangoni and Tavoni (2013) also claim that significant clean energy investment is important for achieving the low carbon necessary to meet ambitious emission reduction targets, but carbon pricing also incentivizes such investment.

3.2.3 Comparison of R&D and Adoption Subsidies

Surprisingly, the literature only provides patchy empirical evidence of effectiveness and efficiency of both invention and innovation subsidies (Veugelers 2012) because programme success is difficult to measure (Jae, Newell, and Stavins 2005). Existing case studies generally indicate differential results: specific financial support measures have varying impacts on different technologies so that general conclusions are difficult to draw (Veugelers 2012). However, there is large agreement in the literature that effective climate change mitigation requires more than a one-off specific technology intervention, but rather a large-scale transition of the socio-economic system (Mowery, Nelson, and Martin 2010). Most scholars conclude that investment in both development of new, and diffusion of existing technologies are necessary to achieve such a transition (see Mowery, Nelson, and Martin (2010) and Rennings (2010)). Nemet

[10] Preventing global mean temperatures from rising above 2 degrees Celsius above pre-industrial average is commonly considered necessary to avoid dangerous climate change, which is a key objective of the United Nation Framework Convention on Climate Change.

(2009) claims that the relative effectiveness of technology-push and demand-pull programmes depends on the type of technology change one wants to achieve, either incremental or non-incremental. Investment in radical, non-incremental inventions means investment in future emission reductions, while investment in enhanced deployment of existing technologies promises to yield more near-term impacts on emissions. Action in both time frames is needed to tackle climate change (Veugelers 2012). If the early adopters' experiences are fed back to the technology providers, technology adoption and technological improvement can actually reinforce each other (Mowery, Nelson, and Martin 2010). In short, processes of technological change are complex and neither strong technology-push nor demand-pull approaches to managing technological change can be effective on their own (Dosi 1982).

One interesting aspect in the context of coordination of Canadian provincial policies is the potential for knowledge and learning induced by R&D and adaptation funding will actually spill across borders (both provincial and national) and hence benefit economies in other jurisdictions. Peters, Schneider, Griesshaber, and Homann (2012) find that domestic technology-push initiatives do not promote technology development abroad, whereas the innovation effects of demand-pull policies do spill across borders. Consequently, Peters, Schneider, Griesshaber, and Homann (2012) recommend cross-border cooperation on market creation for low carbon technologies. For example, in the context of Alberta's technology funding strategies, focus on R&D support may ensure that the generated knowledge externalities can be fully appropriated within the province.

Finally, to the extent that technology incentives are delivered through tax expenditures (accelerated write-offs or tax credits) there are concerns about the (negative) revenue-recycling effects. That is, because they involve expenditures rather than generate tax revenues, they tend to be less economically efficient (Duff and Wiebe 2009).[11]

Our analysis of case studies shows that Canadian provinces have so far tended to neglect funding of early-stage R&D. Alberta does focus its support on pushing technologies to the market, but emphasis has been on technologies in the demonstration and commercialization stages. In contrast, Québec has largely announced demand-pull measures to foster the uptake of low carbon, high efficiency technologies in the transport, industry, and buildings sector.

3.3 Redistribution

Redistributive measures include targeted lump sum payments, transfers, and tax cuts to households and businesses that are adversely affected by the carbon pricing policy (or are perceived as being adversely affected). The distinction from revenue recycling through tax cuts described above is the explicit focus on equity rather than efficiency.

Previous studies have investigated the effects of carbon taxes on the distribution of household income. Using micro-simulation models Callan, Lyons, Scott, Tol, and Verde (2009) and

[11] Duff and Wiebe (2009) also suggests there are other concerns with the tax expenditure approach related to their transparency and evaluation.

Grainger and Kolstad (2010) diagnose strong regressivity of carbon taxes implying that lower-income households carry a relatively larger burden compared to high-income households. In contrast, studies based on general equilibrium (CGE) models indicate that carbon taxation can be proportional or even mildly progressive (Rausch, Metcalf, Reilly, and Paltsev 2010) (Dissou and Siddiqui 2014). In our current work we use a static CGE model to examine the distributional effects of the BC carbon tax scheme on households of different income groups. We find that the BC carbon tax in itself is mildly progressive and that the revenue recycling measures, a combination of tax cuts and targeted transfers put in place further enhance the tax's progressivity.

From the considered case studies, only BC has so far allocated carbon related revenues into redistribution measures. Redistributive measures for revenue recycling are commonly introduced to respond to public concerns about perceived injustice of the carbon tax. It seems, however, that in the case of BC the perceived injustice may not actually exist. For example, Harrison and Peet (2012) illustrate that the public perception of the winners and losers of the BC carbon tax significantly influenced policy decisions but did not actually reflect the evidence. Hence, redistributive measures are particularly important for social acceptance and they may adversely impact economic efficiency.

3.4 Productivity Enhancement

Pursuing a holistic approach to carbon tax revenue recycling will include the consideration of investments in all measures aiming at productivity enhancement, emission reductions, and social acceptance of carbon policies. In particular, some analysts emphasize the interplay between the promotion of technological change and the promotion of social/institutional change (Rennings 2010). Since supply of inventions and demand for innovations are shaped by the existing and interacting economic, institutional and technical infrastructures (Dosi 1982), even a combination of invention and innovation support policies standing alone may be insufficient to trigger technological transformation if the wider policy landscape is not conducive to promoting the development of a low carbon economy. For example, Romer (2000) discusses how support for education and training for scientists and engineers can fruitfully complement public research funding. Herring and Roy (2007) claim that policies promoting lifestyle changes will be necessary to prevent rebound effects from the efficiency improvements.

Together with investment in R&D, public investment in education to build human capital is considered a key driver of endogenous economic growth. The theoretical and empirical literature on human capital theory and the social return on investment in education is large. Social and private return rates have been estimated since the 1950s and updated regularly. In their latest update from 2004, Psacharopoulos and Patrinos (2004) estimate that the social rate of return in OECD countries for one additional year in higher education equals 8.5%. The private rate of return equals 11.6%. Social and private returns to education differ in that the private returns to workers include `signalling' gains which don't represent a social gain. Social returns may be higher than private returns to the extent that better educated workers make other factors (capital and labour) more productive. Coulombe and Tremblay (2009) specifically consider the parts of the literature on post-secondary education and economic growth that are most relevant for Canadian policy. They find, first of all, large agreement in the literature that the macroeconomic effects of investment in education on productivity and growth are positive and potentially substantial, even in developed countries. Canada, according to Coulombe and Tremblay (2009) is no exception: growth of income per capita is largely driven by human capital and return on human capital accounts for around half of the national income. Interestingly, Coulombe and Tremblay (2009) reference empirical evidence showing that economies which are closer to the technology frontier experience larger benefits from investment in post-secondary education. Canada is close to the technology frontier, hence Coulombe and Tremblay (2009) expect additional investment in post-secondary education to still drive substantial returns. They conclude: "Overall, our reading of the theory and the empirical evidence leaves us with a fairly positive view of the aggregate benefits of post-secondary education, and of the notion that investing additional public funds in post-secondary education would be desirable from a macroeconomic perspective."

In this category of funding options we also consider investment in climate change adaptation measures. Alberta's CCEMF has so far granted support to three projects concerned with enhancing resilience of the province's ecosystems to the impacts of climate change. Québec deems investment in reducing vulnerability to the adverse effects of climate change on public health, businesses, infrastructure and natural resources a key part of its climate strategy. It is to be expected that priority given to adaptation measures will be raised in the future as effects become more and more visible.

Chapter 4: Governance and Transparency

The importance of transparency, credibility, and time consistency in public funding decisions and fiscal policies is emphasized in the literature for being crucial to shape actors' long-term expectations and behaviour (Mowery, Nelson, and Martin 2010). Investment in mitigation and innovation requires maximization of certainty and predictability of environmental policy (Johnstone, Hascic, and Kalamova 2010). In the following, governance and transparency issues are discussed with specific reference to Alberta's CCEMC model. It is the only model among the considered case studies in which decisions on fund allocation is not in the hands of a democratically elected government.[12]

Alberta's CCEMC website provides information on funding application policies and the criteria for project selection. A standardized methodology for project evaluation is used in order to keep the selection process as objective and transparent as possible. Moreover, a third party reviewer and a Fairness Monitor are involved in every decision process to ensure objectivity. The CCEMF's Board of Directors decides on the final funding approval based on the information provided by an Evaluation Committee, the third party reviewer, and the Fairness Monitor's report. The Board of Directors consists of energy and manufacturing industry representatives, one academic, and representatives from other industries representing the public at large.

Yet, even assuming that selection procedures are transparent, stable, and openly communicated, fundamental issues around the concept of 'picking winners' in technology promotion remain (Nelson and Langlois 1983). Two issues stand out in particular:

- First, the greater the degree of centralization in funding for technology development and diffusion, the greater the risk of losing valuable technical diversity. Invention and innovation are search processes that generally benefit from broad portfolios and risk-taking. Premature focus of funding efforts on a limited number of technological options increases the likelihood of creating path dependence (Mowery, Nelson, and Martin 2010). In fact, decentralization of funding sources and allocation is especially desirable in the early stages of technology development to avoid premature technology lock-in. Still a certain degree of centralized administration is also important as to promote coordination among initiatives and to avoid redundant efforts.

- Second, all public funding allocation processes are at risk of capture by lobbying groups and vested interests. Ideally, funding decisions would be guided solely by scientific and user interests. Support should be granted to technologies with the lowest abatement costs and the greatest probability of market penetration (Morris, Nivola, and Schultze 2012). Efficient allocation is facilitated if the funder has access to insider information on the new technology. This is more likely the case for generic research or if the funding agency is at the same time also a user of the technology (Nelson and Langlois 1983). However, most invention and innovation investments are characterised by a large information asymmetry between the technology developer and the funding agency (Jaffe, Newell, and Stavins 2005). Due to

[12] We are currently not aware, but it is possible that Quebec also outsources decisions on specific project funding to non-governmental organizations.

incomplete information, funding agencies' decisions will be based on somewhat subjective expectations about profitability and commercial potential. This process of 'picking winners' can then more easily be captured by interest groups who may steer funding toward sub-optimal technologies or towards projects where public funds merely crowd-out private investment rather than create additional incentives (Nelson and Langlois 1983). Whether or not such capture actually occurs, already the perception of biases in decision-making alone may be sufficient to erode public trust and credibility of the funding policies. Morris, Nivola, and Schultze (2012) therefore claim that "funding decisions ought to be ‘insulated as much as possible’ from rent-seeking by interest groups, purely political distortions, and the parochial preferences of legislators." A broad portfolio approach to funding allocation is generally recommended to both prevent technological lock-in and mitigate the investment risks associated with the large uncertainty around future developments (e.g. of global energy markets) (Jaffe, Newell, and Stavins 2005).

Once targeted technology funding decisions have been made, it is important to maintain open communication channels between the funding agency, the private sector researchers, and technology users (Mowery, Nelson, and Martin 2010). Funding agencies should engage in ongoing monitoring and performance assessment of their technology policies (Morris, Nivola, and Schultze 2012). Mowery and Rosenberg (1979) also emphasize the importance of fostering communication between basic research institutions, the non-commercial sector, private firms and laboratories as well as technology users for the purpose of both more effective invention of new technologies and diffusion of existing technologies.

For comparison, revenue recycling through the general tax system can be a very transparent alternative. With revenue recycling through tax cuts, the overall governance challenge regarding the use of carbon revenues is effectively placed in the hands of a democratically elected provincial government. If the revenue is used to cut corporate taxes, leaving companies more resources for R&D, the task of picking technology winners is effectively conferred to private companies who may have more insider knowledge than any funding agency. Granting firms flexibility in meeting environmental targets unleashes a search for new technologies and induces adoption of the most effective and efficient solutions (Johnstone, Hascic, and Kalamova 2010).

Using carbon funds for redistributive measures or general productivity enhancing measures might be considered less open to capture by interest groups than technology promotion, but somewhat less transparent and democratic than broad tax cuts. The media may play a crucial role in communicating and informing about carbon policies and revenue allocation measures and in shaping public opinion. Policymakers may decide to deviate from ideal allocation approaches in order to respond to public pressures. For example, this is what appears to have happened in BC with the Northern and Rural Homeowner Benefit Program, which is a response to vocal opposition from municipalities in the provincial North, claiming Northern communities experienced particularly adverse effects from the tax. These claims received extensive media coverage although all evidence shows the contrary (Harrison and Peet 2012).

Chapter 5: Relevance of the Lessons

Public support for a carbon pricing instrument may be tied to a clearly established plan for using the resulting funds. Whether that is through revenue recycling or technology promotion or other mitigation measures. For example, the fact that the BC carbon tax was introduced as a revenue neutral measure has likely contributed significantly to its successful implementation. In contrast, the recently rescinded Australian `carbon tax' was part of a broader `Clean Energy Plan' and as such featured limited revenue recycling. Also, the fact that it was bundled with many other industrial support and transition programs made it hard to see how the funds raised by the tax would be spent. Although there were several other critiques of the plan[13], including it's limited coverage, the lack of clarity as regards the allocation of the carbon revenues may have added to its demise.

Experience with ETR in Europe have moreover shown that mistrust in the government tends to be great when it comes to innovative fiscal policies. Assuring revenue neutrality and maintaining transparency about how the revenues are used is key to winning public support. In particular, public perceptions of fairness of the proposed scheme are important. Nevertheless, while public perception and social acceptance of carbon pricing and revenue allocation choices are key to the viability of the policy, one must be aware that economic efficiency and environmental effectiveness may be compromised somewhat to respond to public concerns. An important lesson from the EU's carbon trading scheme is that attempts to address the `fairness' issue can go too far. A key contributor to the collapse of the ETS allowance price is the issuance of too many allowances, some motivated by argued "fairness" issues. This collapse constituted a major threat to the ETS' credibility. Particularly in BC and in Québec, the initially established strategy for revenue allocation may be at risk over the long term of being hijacked by popular interests, shifting prioritization of objectives increasingly towards social acceptance and away from economic efficiency and environmental effectiveness.

The discussion shows that trade-offs typically exist between the objectives of carbon revenue allocation. We identified three broad objectives of revenue allocation: economic efficiency, environmental effectiveness, and social acceptance. With the existing trade-offs, it makes sense for governments to prioritize the one objective that is particularly relevant in the specific situation. For example, if Ontario introduces a revenue generating carbon policy in the future, the government may choose to prioritize economic efficiency as an objective in designing the revenue allocation scheme as a means to reduce the government's substantial budget deficits. Taking the local context into account can be expected to increase the scheme's longevity.

Still, it is important to monitor and evaluate the policy's performance according to all three dimensions. Importantly, if the environmental effectiveness of the carbon policy is at risk, the objectives of the revenue allocation scheme require reconsideration. The balancing of objectives may best be accommodated by a combination of allocation measures. In fact, Clinch, Dunne, and Dresner (2006) recommend a portfolio approach to the allocation of environmental tax revenues in the European context; a combination of earmarking of parts of the revenues for environmental

[13] The carbon price did not apply to emissions from transportation or agriculture, thus focusing the burden on a subset of the economy. Significantly, one of the major critiques concerned the tax’s impact on the price of electricity.

projects and using the rest to fund labour tax reductions. The European Commission suggests a similar combination of allocation channels for revenues generated from permit auctions in the European trading scheme. The EU ETS, the world's largest emission trading system has moved to full auctioning of permits in 2013. However, member states did not achieve full agreement on how the potentially very large auctioning revenues (estimates are as high as $20 B per year by 2020) should be used. The ultimate wording in the EU Directive is that each EU Member State should decide "in accordance with their respective constitutional and budgetary requirements". However, a non-binding recommendation was included to earmark at least 50% of auctioning revenues on climate change mitigation measures, either domestic or abroad.

Interestingly, none of the three Canadian provinces with carbon pricing schemes in place have implemented a broadly diverse portfolio of the four allocation channels suggested in this analysis. Instead, each province has focused predominantly on one allocation channel and made small adjustments in order to balance objectives. For example, BC's focus on efficiency in revenue recycling is complemented by some redistributive transfer payments in order to increase social acceptance. Alberta's allocation strategy centers on technology invention and innovation. Within this channel, the allocation of funds among alternative technologies and stages of development needs to be made carefully, lest the funds yield less than their ideal return in terms either of reduced emissions, or increased productivity. In a similar vein, caution must be taken in terms of concentrating too many investments in one basket. The inherent issue with picking winners must be acknowledged and capture of the allocation process by interest groups must be prevented. Québec, so far, can be considered to pursue the most diverse approach to allocation, spreading funds across efficiency enhancements as well as infrastructure investments and climate change adaptation measures. If funds are allocated to general productivity-enhancing measures like infrastructure or education, they should be done in a way that addresses existing productivity challenges or take advantage of existing opportunities.

Chapter 6: Summary and Conclusions

Some climate policy instruments such as a carbon tax or cap and trade generate potentially substantial government revenues. This paper discusses alternatives for using these carbon revenues. Four channels for revenue allocation are distinguished: revenue recycling through the tax system, technology support measures, redistributive measures, and productivity enhancing measures. We also identify three broad objectives that governments need to weigh when deciding on an allocation scheme. These are economic efficiency, emission reductions, and social acceptability. Because these objectives may be at conflict with each other, governments need to (explicitly or implicitly) define their priorities and choose their portfolio of allocation channels accordingly. The different allocation channels can generally contribute to multiple or all of the objectives at the same time, depending on the specific circumstances.

Generally one can consider revenue recycling through the tax system to be aimed largely at increasing economic efficiency. Technology support measures also contribute to raising productivity but at the same time promotion of low-carbon innovation can help emission abatement. Redistributive measures are inherently focused on boosting social acceptability of the carbon policy. Lastly, productivity enhancing measures foster economic efficiency. What revenue allocation scheme is socially acceptable and politically feasible will largely depend on specific circumstances and the individual political context. For example, large government deficits may shift public preferences toward schemes that focus on economic efficiency, whereas strong preferences for environmental protection may require policymakers to channel a larger part of carbon revenues into 'green' projects and further mitigation initiatives.

Across the three Canadian case studies of provinces with carbon pricing schemes in effect that are considered in this paper (BC, Québec, and Alberta), we find variation in their revenue allocation portfolios reflecting the emphasis they place on the pursuit of the three objectives as illustrated in Table 6.

Table 6: Prioritization of objectives across provinces

Objective	British Columbia	Québec	Alberta
Economic Efficiency	X	X	
Emission Reductions		X	X
Social Acceptability	X	X	

This analysis suggests that adapting the pursued allocation strategy to local circumstances is key. Concrete strategies must always be designed to fit the specific context including factors such as public attitude, fiscal budget, existing economic inefficiencies and tax distortions, concrete opportunities for technological innovation etc. Still, all three of the broad objectives identified in this analysis (economic efficiency, emission reductions, and social acceptability) should be recognized and monitored to some extent to make the policy environmentally effective and politically feasible in the longer term. Balancing objectives in accordance with a jurisdiction's specific context may require the implementation of a diverse portfolio of allocation channels, i.e. a combination of revenue recycling, technology support measures, redistributive measures, and general productivity enhancing measures. Such an approach will also prevent drastically diminishing marginal benefits of each individual allocation channel in the future if carbon policies are tightened and revenues increase.

The benefits of diversity and adaptivity also show in relation to the design of technology support measures; a diverse portfolio of promoting technologies at different development stages seems most effective in preventing issues with technological path dependence, picking winners and interest group capture.

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