Vertical fiscal externalities and the environment

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Abstract

The federal government is generally considered best-suited for providing public goods that cross state boundaries, which is the case for climate change mitigation and other transboundary environmental problems. In practice, however, sub-national governments have been active in implementing climate change policies. State implementation of climate policies raises the possibility of vertical fiscal externalities, which means that since both federal and state governments share a common tax base, a new tax by a sub-national government is partly borne by the federal government. State governments therefore face incentives to set tax rates too high relative to the social optimum. In this paper, we use a computable general equilibrium of the Canadian economy to provide numerical estimates of vertical fiscal externality in a climate policy setting. We find that vertical fiscal externality is a quantitatively important determinant of welfare change in the province implementing carbon regulation.

Keywords: climate, vertical fiscal externality, computable general equilibrium analysis, federalism.

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1 Introduction

Classic models of fiscal federalism offer guidance for dividing government’s responsibilities between federal and state levels. Notably, the federal government is generally considered best-suited for providing pure public goods that cross state boundaries, which is the case for climate change mitigation and other transboundary environmental problems (Oates, 1999, 2001). National implementation helps to avoid a potential ‘race to the bottom’ that could occur with state implementation, since each state faces an incentive to weaken environmental policies to attract mobile factors of production from other states.

In practice, however, sub-national governments have been active in implementing climate change policies, especially during the last decade (Rabe, 2008; Lutsey and Sperling, 2008; Williams, 2011). State implementation of climate policies raises the possibility of vertical fiscal externalities. Vertical fiscal externalities in a non-environmental context have received attention from Keen and Kotsogiannis (2002); Brüllhart and Jametti (2006); Dahlby and Wilson (2003); Esteller-Moré and Solé-Ollé (2001); Devereux et al. (2007) and others, and the early literature is summarized by Keen (1998). However, to date, no papers examine vertical fiscal externalities in an environmental context.

Vertical fiscal externalities may arise due to the shared tax bases of state and federal governments, where a new tax by one level of government has implications for revenue raised by the other. A stylized example helps to illustrate. Consider a federation made up of a large number of states. Each state consists of a single household endowed with a unit of labour, which it supplies inelastically to the representative firm in the region. The firm transforms labour inputs into a homogeneous final good, which is traded between states. The firm also releases emissions as a joint output of production, which are initially untaxed. A federal government imposes a tax at a uniform rate on the income of all households in the country. Consider now the application of a tax on emissions by a single state government, the proceeds of which are returned to the state’s household in lump sum. Because of the assumption that there are a large number of states, it is possible to treat the implementing state as a price taker on the goods market. The incidence of the emissions
tax therefore falls entirely on the wage rate in the implementing state. The lower wage results in a shrinking of the federal tax base, and a reduction in federal tax revenues (holding the rate constant). To maintain balance in the federal budget, the federal tax rate must increase. Again, the assumption of a large number of states is useful in the stylized example, since it allows the increase in the federal tax rate to be treated as infinitesimal, with no effect on disposable income in the implementing state. With these (admittedly very strong) assumptions, the entire burden of the new environmental tax in one state of the federation is shifted to other states. This is referred to as a vertical fiscal externality. The mechanism that generates the vertical fiscal externality is the joint occupation of tax bases by both federal and provincial governments within states. The more nuanced models we present in the paper relax many of the assumptions in this stylized example, but retain the joint federal and state taxation that can lead to vertical fiscal externalities.

As for other taxes and policies, vertical fiscal externalities can have important implications for environmental policy, and these have yet to be identified or explored. This paper focuses on the issues that arise when environmental policy is imposed in a federation. The presence of a vertical tax externality implies that for a state government, taxes should be set higher than otherwise optimal. This has clear implications for the ‘double dividend’ debate, which has until now focused on tax interactions within a jurisdiction to determine optimal tax rates on environmental externalities. The results in this paper show that the vertical fiscal externality is a quantitatively important determinant of welfare change in a state following imposition of a new state-level environmental tax. We aim to explore these issues in the current paper.

Our paper uses a computable general equilibrium (CGE) model to provide numerical estimates of the effect of horizontal and vertical fiscal interactions in a climate policy setting. The CGE approach is a useful complement to standard econometric techniques for exploring issues related to fiscal externalities used by Esteller-Moré and Solé-Ollé (2001); Devereux et al. (2007); Hayashi and Boadway (2001); Brüllhart and Jametti (2006) and others, since it allows us to skirt thorny identification issues and explore a policy domain where previous policy implementation is limited. We show that vertical fiscal externalities can make the unilateral carbon regulation improve the

\footnote{In contrast, horizontal externalities occur as a result of interaction between states in setting taxes, for example is tax base competition.}
Aside from the literature on vertical fiscal externalities described above, the paper is related to a number of other strands of the literature. First, there is an existing literature on environmental federalism. Williams (2011) compares incentive-based to command-and-control regulations in a federation, and finds that under incentive-based regulations, states are able to offload some cost by increasing regulatory stringency. Oates (2001) summarizes the literature on environmental federalism. Second, there is a small literature on interactions between environmental policies set by multiple levels of government. For example, Böhringer and Rosendahl (2010) examine the interaction between the EU emission trading system and renewable electricity obligations, and Roth (2012) examines interactions between federal and state transport regulations. Third, our paper is closely related to the large literature on environmental policy-setting in a second-best setting (Goulder et al., 1999).

The paper proceeds as follows. In the following section, we describe the numerical model that we use to conduct model simulations. In section 3, we describe the policy scenarios that we implement in the numerical model to generate quantitative insights related to environmental fiscal externalities. Then, we provide results from the numerical model. In section 4, we conclude.

## 2 Numerical model

To provide numerical estimates of the effect of vertical fiscal externalities in an environmental context, we use a static multi-sector, multi-region computable general equilibrium (CGE) model of the Canadian economy. The model is described in detail in Böhringer et al. (2014), and so we focus on a high-level description and the main features relevant to the present paper here. A more detailed and formal model description is provided in the algebraic model summary. In addition, a complete set of model files (written in the GAMS/MPSGE language) is provided as an electronic annex to this article.

The model captures characteristics of provincial (regional) production and consumption patterns through detailed input-output tables and links provinces via bilateral trade flows. Each province
is explicitly represented as a region, except Prince Edward Island and the Territories, which are combined into one region (Table 1). The representation of the rest of the world is reduced to import and export flows to Canadian provinces which are assumed to be price takers in international markets. To accommodate analysis of energy and climate policies the model incorporates rich detail in energy use and greenhouse gas emissions related to the combustion of fossil fuels.

The model features a representative agent in each province that receives income from three primary factors: labour, capital, and fossil-fuel resources. There are three fossil resources specific to respective sectors, namely, coal, crude oil and gas. Fossil-fuel resources are specific to fossil fuel production sectors in each province. The representative agent in each region is endowed with a fixed supply of labour, which can be either consumed directly (as leisure) or supplied to productive sectors. Labour supplied to production is taxed by both federal and provincial governments, whereas leisure is untaxed. This differential taxation of labour generates a distortion in the model. Labour used for production is treated as perfectly mobile between sectors within a region, but not mobile between regions. The representative agent in each region also has an endowment of capital, which it rents to production sectors. We adopt a putty-clay specification for capital, where a portion $\phi$ of capital is fixed in the sector in which it is installed in the benchmark (clay) and the remaining $1 - \phi$ is mobile between sectors and provinces (putty). For malleable capital, we use a constant elasticity of transformation function with elasticity of transformation $\eta$, which allows us to specify how easily it is to shift capital between sectors and regions. This setup allows us to explore scenarios ranging from perfectly fixed capital ($\phi = 1$) to perfectly mobile capital ($\phi = 0$ and $\eta = \infty$). In the reference scenario, we adopt a specification where $\phi = 0.5$ and $\eta = 10$, and we explore alternative values in the sensitivity analysis. Mobility of capital between regions means that the tax on capital is distortionary.

The choice of sectors in the model has been to keep the most carbon-intensive sectors in the available data as separate as possible (Table 2). The energy goods identified in the model include coal, gas, crude oil, refined oil products and electricity. This disaggregation is essential in order

\footnote{Land use associated with agricultural production and forestry is therefore not explicitly accounted for, but instead treated as part of the specific capital stock of the relevant sector.}

\footnote{The consumer’s utility function and overall endowment of labour are calibrated such that the compensated and uncompensated labour supply elasticities match empirical estimates, following the method of Ballard (2000).}
to distinguish energy goods by carbon intensity and the degree of substitutability. In addition the model features major energy-intensive industries which are potentially those most affected by emission reduction policies.

Two levels of government are explicitly represented in the model. In each province, a provincial government raises revenue from taxes on outputs and inputs to production, sales to final consumers, as well as on labour, capital, and natural resource income. Tax rates are calibrated to match benchmark government revenue from the System of National Accounts (tax rates differ according to the province). The difference between benchmark provincial government revenues and expenditures is the provincial deficit, and we hold this fixed during the simulations described in the paper. In the simulations that follow, we focus on the unilateral introduction of a carbon tax by a provincial government. We hold provincial government provision of public services fixed at the benchmark level. To balance the provincial government budget in the policy simulations that we conduct, we endogenously adjust lump sum transfers received from the representative agent within the province. In addition to the provincial government in each model region, there is one federal government agent in the model that serves all provinces. The federal government raises taxes from the same bases as the provincial government: inputs to and outputs from production sectors, sales to final consumers, and labour, capital, and natural resource income. Federal tax rates, which are identical across provinces, are calculated to match System of National Accounts data, and the federal government budget deficit is calculated and held fixed in the same way as for provincial governments. Real federal government expenditure is also held fixed at the benchmark level in the policy simulations that follow. Importantly, we hold real federal government expenditures fixed not just in total, but also at the provincial level. The introduction of a carbon tax by a province can have an effect on federal government revenues and expenditures. In order to maintain the federal government in balance in the model, we endogenously adjust federal government tax rates.
3 Results

Figure 2 summarizes the main results from our numerical analysis. It shows the effect of unilateral implementation of a carbon tax in each of the provinces on provincial welfare. In each province, we simulate a carbon tax that achieves a range of emission reductions from 2 to 20 percent, relative to benchmark emissions. There are four simulations in each province, each reflecting a different macroeconomic closure assumption: the blue lines reflect a model closure where imbalances in the federal budget are balanced by increases in federal government tax rates. In this case, federal government tax rates are undifferentiated across provinces, and so imbalances in the federal budget are made up for by increases in tax rates across all provinces. In contrast, the red lines reflect a closure where the federal government differentiates tax rates by region. In this case, when the federal government budget is imbalanced in a particular province, the federal government adjusts tax rates in that province to restore balance. This is a hypothetical closure which we use as a contrast since it eliminates the possibility of a vertical fiscal externality. Dashed lines reflect runs where capital is mobile between provinces, and solid lines reflect runs where capital is immobile between provinces. Eliminating capital mobility eliminates the main avenue by which horizontal fiscal externalities could arise. Thus, the runs in the figure are: (solid red) no vertical or horizontal externality, (solid blue) vertical externality but no horizontal externality, (dashed red) horizontal externality but no vertical externality, (dashed blue) vertical and horizontal externality.

We concentrate first on the solid lines, which correspond to runs where capital is not mobile between provinces. Horizontal fiscal externalities are therefore ruled out by assumption in these runs. For concreteness, the discussion will refer to outcomes in British Columbia (BC), but similar conclusions arise in other provinces. In all runs, carbon abatement is pursued unilaterally in each province (BC in this case). The solid red line illustrates a scenario where any imbalance in the federal budget that arises from implementation of climate policy in British Columbia is offset by a change of federal tax rates in that province only, such that the federal government budget imbalance is exogenous in each province. As a result, in this scenario, we assume away vertical fiscal externalities. Without vertical fiscal externalities, unilateral climate change policy in BC
is unambiguously welfare reducing. Our analysis shows that a 10 percent unilateral reduction in emissions in BC results in a 0.06 percent reduction in welfare in that province. The solid blue line corresponds to the scenario in which the federal government does not differentiate between provinces in setting tax rates. As a result, when implementation of a policy in one region causes a federal budget imbalance, tax rates change in all provinces. As in the theoretical model, this effectively transmits part of the burden of the environmental tax to other provinces. In the case of BC implementation, the result is that over a range of emission abatement targets, unilateral implementation of climate policy results in a welfare gain to the implementing province. Here, the results suggest that unilateral emissions abatement from 0 to 19 percent is welfare-improving for BC.

The dashed lines illustrate runs where capital is mobile between provinces. With capital mobility, horizontal fiscal externalities are possible. In particular, as one province tightens its climate change policies, it reduces the marginal product of capital in that province. This both affects the allocation of capital, as well as the return on capital. We illustrate in Figure B. There are two provinces, A and B, which each have identical demand for capital in the initial equilibrium, illustrated by downward-sloping red lines. The initial equilibrium price of capital is \( r_0 \) and is illustrated by the horizontal black line. The resulting equilibrium allocation of capital is \( \{ k^A_0, k^B_0 \} \). Province A implements a climate policy, which reduces the marginal product of capital in that province, which is illustrated by a downward shift in the demand curve. This results in capital fleeing the province, such that the new allocation of capital, holding the price of capital constant, in province A is \( \tilde{k}^A_1 \). However, this reduction in demand for capital also puts downward pressure on the price of capital, which falls to \( r_1 \). The new equilibrium allocation of capital is \( \{ k^A_1, k^B_1 \} \). Climate policy implementation in province A has caused a relocation of capital from A to B. This causes the decrease in the wage rate in province A and increased wage rate in province B and is the essence of horizontal fiscal externalities. However, it is also important to consider the impact of unilateral implementation on household income in addition to the effect on the wage rate. Because capital is mobile, households in all provinces experience an income reduction from capital when the return on capital falls. To the extent that province A is ‘small’ relative to other provinces, this income
reduction will be borne mostly by other provinces. On the other side, all of the income from en-
vironmental taxation is gained by the implementing province. Effectively, the environmental tax is
collected from residents of other provinces.\textsuperscript{4} Therefore, it is possible that introducing mobile capi-
tal into the model will either reduce welfare in the implementing province relative to the immobile
capital run or increase it. Note that Oates and Schwab (1988) ignore the income effects of reduced
capital rental rates in their analysis of horizontal fiscal externalities by treating capital income as
exogenous. Additionally, they consider a regulation instead of a tax, and so do not capture the
effect we describe here.

In the model developed here, horizontal fiscal externalities reinforce vertical fiscal externalities
through their effect on household income. The dashed blue line allows capital mobility and balances
the federal budget at a national rather than provincial level, thus allowing both horizontal and
vertical fiscal externalities. This case with both horizontal and vertical fiscal externalities is more
welfare improving than the case with only vertical fiscal externalities (blue solid line). The red
lines eliminates the vertical fiscal externalities, and in this case including horizontal externalities
does not affect significantly, or red dashed line and red solid line are very similar.

Although patterns are different in different provinces, the qualitative results remain identical for
most provinces. In each case, our model suggests that for all provinces vertical fiscal externalities
argue for a higher environmental tax rate than otherwise and that horizontal externalities reinforce
it. In other words, allowing for vertical fiscal externalities with or without horizontal fiscal exter-
ernalities suggests that the optimal level of emission reduction is non-zero, even when zero benefit is
assigned to emission reductions.

4 Conclusion

When we consider transboundary environmental problems such as climate change mitigation, the
regulation of federal government is generally the first best solution. In the absence of the substantial
federal regulation in climate change mitigation in the countries like the USA and Canada, however,

\textsuperscript{4}A similar mechanism is at work in Williams (2011), except that he considers the environment as the only tax
base and considers simultaneous environmental taxation by state and federal governments.
sub-national governments have been active especially during the last decade. Those sub-national regulation can lead to vertical fiscal externalities that we explored in this paper. Our simulation result shows that vertical fiscal externalities can make the unilateral carbon regulation even improve the welfare and that horizontal fiscal externalities reinforce them. Correspondingly, the result indicates that the optimal emission reduction would be higher with vertical and horizontal externalities than otherwise.

References


## A Tables

### Mnemonic Region

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Region</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>Alberta</td>
</tr>
<tr>
<td>BC</td>
<td>British Columbia</td>
</tr>
<tr>
<td>MB</td>
<td>Manitoba</td>
</tr>
<tr>
<td>NB</td>
<td>New Brunswick</td>
</tr>
<tr>
<td>NL</td>
<td>Newfoundland and Labrador</td>
</tr>
<tr>
<td>NS</td>
<td>Nova Scotia</td>
</tr>
<tr>
<td>ON</td>
<td>Ontario</td>
</tr>
<tr>
<td>QC</td>
<td>Quebec</td>
</tr>
<tr>
<td>SK</td>
<td>Saskatchewan</td>
</tr>
<tr>
<td>RC</td>
<td>Rest of Canada (Nunavut-PEI-Yukon-NWT)</td>
</tr>
</tbody>
</table>

Table 1: Regions included in the model

### Mnemonic Sector

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Sector</th>
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</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Natural Gas</td>
</tr>
<tr>
<td>CRU</td>
<td>Crude Oil</td>
</tr>
<tr>
<td>COL</td>
<td>Coal Mining</td>
</tr>
<tr>
<td>OIL</td>
<td>Petroleum and Coal Products Manufacturing</td>
</tr>
<tr>
<td>ELE</td>
<td>Electric Power Generation, Transmission and Distribution</td>
</tr>
<tr>
<td>AGR</td>
<td>Agriculture and Forestry</td>
</tr>
<tr>
<td>MIN</td>
<td>Other mining</td>
</tr>
<tr>
<td>CON</td>
<td>Construction</td>
</tr>
<tr>
<td>PPP</td>
<td>Pulp and paper mills</td>
</tr>
<tr>
<td>PRM</td>
<td>Primary metal manufacturing</td>
</tr>
<tr>
<td>CHM</td>
<td>Chemical manufacturing</td>
</tr>
<tr>
<td>CEM</td>
<td>Cement</td>
</tr>
<tr>
<td>MFR</td>
<td>Other manufacturing</td>
</tr>
<tr>
<td>TRD</td>
<td>Wholesale Trade (WHL) and Retail Trade (RTL)</td>
</tr>
<tr>
<td>TRN</td>
<td>Transportation and Warehousing</td>
</tr>
<tr>
<td>SER</td>
<td>Services</td>
</tr>
<tr>
<td>GOV</td>
<td>Government Sector</td>
</tr>
</tbody>
</table>

Table 2: Sectors included in the model
Figure 1: Horizontal externalities and climate policy
Figure 2: Hicksian equivalent welfare after unilateral climate change policy implementation