Ecological Economics 127 (2016) 156–164

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Casting a long shadow: Demand-based accounting of Canada's greenhouse gas emissions responsibility

Brett Dolter [a,*], Peter A. Victor [b]

[a] Institute of the Environment, University of Ottawa, Ottawa, Ontario
[b] Faculty of Environmental Studies, York University, Toronto, Ontario

ARTICLE INFO

Article history:
Received 13 February 2015
Received in revised form 10 February 2016
Accepted 3 April 2016
Available online 27 April 2016

Keywords:
climate change policy
multi-region input–output analysis
Canada
greenhouse gas emissions
GHG accounting
GHG shadow
carbon footprint

ABSTRACT

Canada is the only country to have ratified the Kyoto protocol and then withdrawn. Part of the justification for Canada's reluctance to commit to greenhouse gas (GHG) emissions reductions is the country's status as fossil fuel exporter. In this paper we use input–output analysis and the World Input–Output Database (WIOD) to ask whether Canada's contribution to global GHG emissions changes when calculated using a demand-based shadow emission approach that excludes GHG emissions created in the production of exports like fossil fuels, but includes emissions released to produce imports to Canada. We find that from 1995 to 2005 Canada's contribution to global emissions was lower using this demand-based GHG accounting approach than a production-based approach. From 2006 to 2009 however, increased imports from GHG-intensive trading partners like China meant that Canada's demand-based shadow emissions were higher than its production-based GHG emissions.

We also introduce a method of calculating sub-national GHG shadows using limited data. Applied to Canada this exercise demonstrates that fossil fuel exporting provinces such as Alberta and Saskatchewan have demand-based shadow emissions significantly lower than their production-based emissions, while populous provinces such as Quebec and Ontario have demand-based emissions that are relatively higher than their production-based emissions.

1. Introduction

Until recently, Canada was an outlier in international climate policy negotiations. In December of 2011, the Government of Canada withdrew from the Kyoto protocol, becoming the only country to have signed and ratified the agreement and then withdrawn.[1] The Government of Canada defended the move by acknowledging that they were not on track to meet their greenhouse gas (GHG) emissions reduction targets and did not want to purchase international carbon credits to achieve their target (Environment Canada, 2013a).

Canada's failure to meet its Kyoto Protocol target was driven by an increase in transportation emissions and expansion of the oil and gas industry. GHG emissions from the Canadian oil and gas sector increased from 101 Megatonnes (Mt) Carbon Dioxide Equivalent (CO2e) in 1990 to 173 Mt. CO2e in 2012 (Environment Canada, 2014). Most of Canada's oil production is exported to the United States; “In 2012, Canada exported 72% of its annual crude oil production, with 99% of exports going to the U.S.” (Government of Canada, 2013: 19). Canada is one of only three Kyoto Protocol Annex 1 countries that is also a net exporter of crude oil (Norway and Denmark were also net crude oil exporters in 2012) (EIA, 2015).

The Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC) assign responsibility for GHG emissions to the country or region in which the GHG emissions are released. This is the “production accounting principle” (Munksgaard and Pedersen, 2001; Turner et al., 2007). Under the production accounting principle Canada is responsible for the GHG emissions released in the production of its exports, including oil and gas.

In this paper, we ask how Canada's contribution to global GHG emissions changes when emissions are calculated using a *demand-based* accounting approach rather than the production-based approach. The demand-based approach assigns responsibility for GHG emissions to the nation or region that purchases the final goods and services in which the GHG emissions are embodied. This means that GHG emissions associated with products exported to other countries are subtracted from national demand-based GHG totals, while GHG

* Corresponding author at: Box 101 Balgonie SK S0G 0E0 Canada.
E-mail address: brett.dolter@gmail.com (B. Dolter).

[1] The Kyoto protocol required the Canadian government to reduce greenhouse gas emissions to 6% below 1990 levels by the Kyoto compliance period 2008–2012. In 1990 Canada released 613 Megatonnes (Mt) of carbon dioxide equivalent (CO2e) (Environment Canada, 2015). The Government of Canada replaced its Kyoto target with an objective of reducing GHGs by 17% below 2005 levels by 2020, which is equivalent to 611 Megatonnes (Mt) of carbon dioxide equivalent (CO2e) by 2020 (Environment Canada, 2014). Without further policy action Canada is on track to exceed this target by 116 Mt. in 2020 (Environment Canada, 2014).

http://dx.doi.org/10.1016/j.ecolecon.2016.04.013
0921-8009/

emissions associated with imports are added to national GHG totals. We calculate national and sub-national GHG emissions for Canada over the period of 1995–2009 using a variety of estimation approaches. We also calculate the national demand-based GHG emissions for some of Canada's important trading partners over the same period.

We refer to the GHG emissions embodied in final goods and services as *shadow emissions*.[2] Taken in total, these demand-based shadow emissions provide an estimate of a country or region's *GHG shadow*. Shadow emissions connect environmental responsibility across national and regional borders. For example, much of the opposition in the United States to the construction of the Keystone XL pipeline, designed to transport bitumen from the Canadian oil sands to refineries in the southern United States, was based on concerns about GHG releases in Canada. GHG shadow calculations capture important aspects of international movements of goods and services by attributing the associated GHG emissions to the consumer rather than the producer.

As a fossil fuel exporter, Canada should be quite interested in measuring its GHG shadow. Emissions associated with producing these exports are excluded from Canada's GHG shadow. However, Canada also imports goods from around the world, some of which required significant releases of GHG emissions in their production, such as imported goods from China. Emissions from these imports do not appear in Canada's reports to the UNFCCC, but are counted in the GHG shadow. We find that emissions embodied in imports to Canada began to exceed emissions embodied in exports in 2006. In this and subsequent years, Canada's GHG shadow exceeded its production-based GHG emissions. This means that, despite Canada's position as a net exporter of emissions-intensive oil and gas, Canada still bears a substantial responsibility for global GHG emissions from the demand perspective.

Prior efforts to account for Canada's GHG shadow emissions include Gaston (2011) and Norman et al. (2007). Gaston (2011) measured Canada's demand-based GHG emissions for the year 2002 using a four-region input–output model that included Canada, the United States, China, and the ‘Rest of the World’. Gaston (2011) calculated that Canada's GHG shadow was approximately 530 Mt. CO2e in 2002, while direct emissions from production within Canada's borders were 689 Mt. CO2e, “Of this, 401 Mt were emitted in Canada while 58 Mt and 14 Mt were embodied in Canadian imports from the United States and China respectively” (p. 16). Simulating how the situation changed over time, Gaston (2011) reported that Canada's GHG shadow increased between 2002 and 2006, driven especially by increased imports from China. Our results are compatible with Gaston's (2011) findings.

Norman et al. (2007) focused on the GHG implications of trade between Canada and its largest trading partner, the United States. They found that up to 74% of the emissions triggered when Canadians purchase a product such as an automobile are released in the United States. From a production perspective these emissions would be assigned to the United States, but from a demand-based accounting perspective these shadow emissions are attributed to Canada.

Canada is a strongly federated nation where the sub-national provinces enjoy jurisdiction over natural resource policy. Climate policy within Canada is the product of provincial and federal government action and negotiation. Additional information on GHG emissions responsibility can inform these federal-provincial discussions. In this paper we introduce a method of assigning responsibility for demand-based GHG emissions on a sub-national level with limited information. We use this approach to ask the question, are there differences between demand-based GHG accounting and production-based accounting at the sub-national level in Canada? We find that oil-producing provinces such as Alberta and Saskatchewan have GHG shadow emissions that are lower than their production-based emissions, while the contrary is true for more populous provinces such as Ontario and Quebec. This finding has implications for GHG emissions reduction policy within Canada.

Our regional analysis bears similarities to work by McGregor et al. (2008). These authors conducted an intra-national analysis of demand-based CO_2 emissions in the United Kingdom (UK), comparing Scotland with the rest of the UK. They found that Scotland registered a trade surplus in CO_2 emissions, exporting more embodied CO_2 emissions to the rest of the UK than it imports from the rest of the UK.

2. Method

We carry out our analysis using an environmentally extended multi-region input–output (EE-MRIO) model, which uses the approach of Leontief (1936, 1970) to calculate the relationship between final demand for goods and services and the total output required to meet this final demand, and then, based on the work of Victor (1972), adds an environmental extension to calculate the shadow emissions associated with final demand. EE-MRIO analysis has become the standard approach for demand-based GHG accounting (IPCC, 2014; Wiedmann, 2009; Wiedmann et al., 2007) and is also used in ecological footprint analysis (Wackernagel, 2009). Wiedmann et al. (2011) writes that EE-MRIO is “en vogue” due to the realization that global supply chains - and environmental impacts - are increasingly globalized. Applications of EE-MRIO include global efforts such as Moran et al. (2013) who use the technique to assess the relative global environmental impacts of high-, middle-, and low-income nations, as well as regional case studies such as Hermannsson and McIntyre (2014) who use a three-region model to assess the environmental impacts of the City of Glasgow relative to its surrounding region and Scotland as a whole.

EE-MRIO analysis has been made possible with the development of high-quality multi-region input–output (MRIO) databases (Wiedmann et al., 2011). These databases include: GTAP (Andrew and Peters, 2013); Eora (Lenzen et al., 2013); EXIOPOL (Tukker et al., 2013a); and the WIOD (World Input–Output Database) (WIOD, 2012). In our analysis we use the WIOD, which contains input–output tables for Canada based on data from Statistics Canada and is publicly available for free on-line.[3]

The WIOD contains production and trade data for $r = 41$ world regions, including Canada, the United States, China, each of the

[2] Our use of the term “shadow emissions” deserves clarification. We introduce the term to provide a salient metaphor for demand-driven GHG accounting. The term “shadow emissions” is offered as an alternative to the oft-used metaphor of the GHG “footprint” (See for example Druckman and Jackson (2009) who refer to a "carbon footprint" as the measure resulting from taking a "consumption perspective" to GHG accounting). The reason for creating an alternative is that the “footprint” concept, developed by Wackernagel and Rees (1996), focuses on calculating the area of land required to absorb the GHG emissions generated in the production of goods and services. The GHG “shadow” refers to the emissions themselves. The two concepts are different, but complementary in that Canada's GHG shadow contributes to the ecological footprint for the country. Methodologically, our approach to calculating a GHG shadow shares much with recent developments in ecological footprint accounting (Wackernagel, 2009). Ritchie and Dowlatabadi (2014) use the term shadow emissions in a fashion similar to us.
We are conscious of the relationship between the term shadow emissions and the concept of shadow pricing. Shadow pricing in economic theory refers to a marginal cost or benefit incurred by loosening a constraint in an optimization problem by one unit. Shadow emissions are the GHG emissions released globally in order to supply national or regional demand. The shadow emissions of a country like Canada represent the incremental increase in global GHG emissions resulting from Canadian demand. We suggest that the term *shadow emissions* is a useful way to speak about incremental GHG emissions resulting from demand for goods and services. Shadow emissions can be associated with the purchase of a given product, or the final demand of an entire nation like Canada.

[3] While older versions of the GTAP database are available for free, it is necessary to purchase the GTAP database in order to receive the latest version (Andrew and Peters, 2013). Eora and EXIOPOL can be accessed for free and in future work we may compare our results using different databases. Unfortunately, we are unaware of plans to update the WIOD input–output tables or environmental data at this time.