Energy Economics 34 (2012) S111–S126

Contents lists available at SciVerse ScienceDirect

Energy Economics

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

Estimating carbon leakage and the efficiency of border adjustments in general equilibrium — Does sectoral aggregation matter?☆

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ARTICLE INFO

Article history:
Received 15 March 2012
Received in revised form 5 August 2012
Accepted 22 August 2012
Available online 8 September 2012

JEL classifications:
D58
F18
Q41
Q56

Keywords:
General equilibrium
CGE
Climate policy
Sectoral aggregation
Disaggregation
Aggregation bias
Carbon leakage
Border carbon adjustments

ABSTRACT

Estimates of the carbon leakage resulting from sub-global climate policies tend to be lower when using economy-wide general equilibrium models than what technology-specific and bottom-up models suggest. In order to test whether this difference is due to excessive sectoral aggregation, I exploit disaggregated data and estimate unobserved values to create a dataset with rich industrial sector detail. The bias caused by sectoral aggregation is estimated by calibrating a computable general equilibrium model to this dataset and comparing results with those generated from more aggregated data.

A stylized unilateral carbon pricing policy is simulated. Results show that aggregated calibrations overestimate industrial output loss and underestimate the increase in the CO_2 embodied in imports. The efficiency of border carbon adjustments at reducing leakage is also underestimated. However, I find that general equilibrium estimates of carbon prices and economy-wide leakage rates are mostly unaffected by the degree of industrial aggregation.

1. Introduction

As some countries put a price on CO_2 emissions, it is feared that production of carbon-intensive goods will be shifted to countries which have not introduced mitigation measures, inducing CO_2 emission leakage. A range of solutions including emission-right rebating schemes or border carbon adjustments (BCAs) — which can include carbon-intensity based tariffs, export rebates, or both — is discussed at the policy-making and academic levels.

The set of countries and regions which have implemented or plan to implement market-based emissions reduction policies is rapidly changing. At the time of writing, the most important emissions trading schemes (ETS) include the European Union Emissions Trading Scheme, the Regional Greenhouse Gas Initiative, the New Zealand Emissions Trading Scheme and California's Global Warming Solutions Act. Some non-annex 1 countries such as China and South Korea are also considering emission reductions. Some policy proposals in the European Union (EU) and the United States (US) make explicit mention of BCAs (Asselt and Brewer, 2010). For example, the now-defunct H.R. 2454 Bill passed in 2009 by the US's house of representatives included provisions for the introduction of carbon tariffs. EU policy also contains provisions to support the sectors deemed to be exposed to carbon leakage and California has included the economically similar policy of including imported electricity within its cap.

A number of studies estimate the extent of carbon leakage, the magnitude of necessary border adjustments and their leakage-reducing potential. Many rely on multi-sectoral, multi-regional general equilibrium models which allow both qualitative and quantitative assessments of economy-wide changes induced by climate policy. These models tend to predict modest leakage rates in the 10% to 30% range. Similar models are also used to estimate the efficiency of Border Carbon Adjustments at reducing this emissions leakage, and find them to be relatively ineffective. However, currently available studies are characterized by a high degree of sectoral aggregation, which might be ignoring significant leakage rates in carbon-intensive sectors. Indeed, another strand of literature relying on sector-specific partial equilibrium models generally predicts higher rates.

☆ Without implication, I thank two anonymous referees, Thomas Rutherford, Jan Imhof, Edward Balistreri, Carolyn Fischer, Dick Eckaus, as well as members of the Border Carbon Adjustment model comparison group, participants of the MIT EPPA seminar and the 14th annual GTAP conference for helpful comments.

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http://dx.doi.org/10.1016/j.eneco.2012.08.015

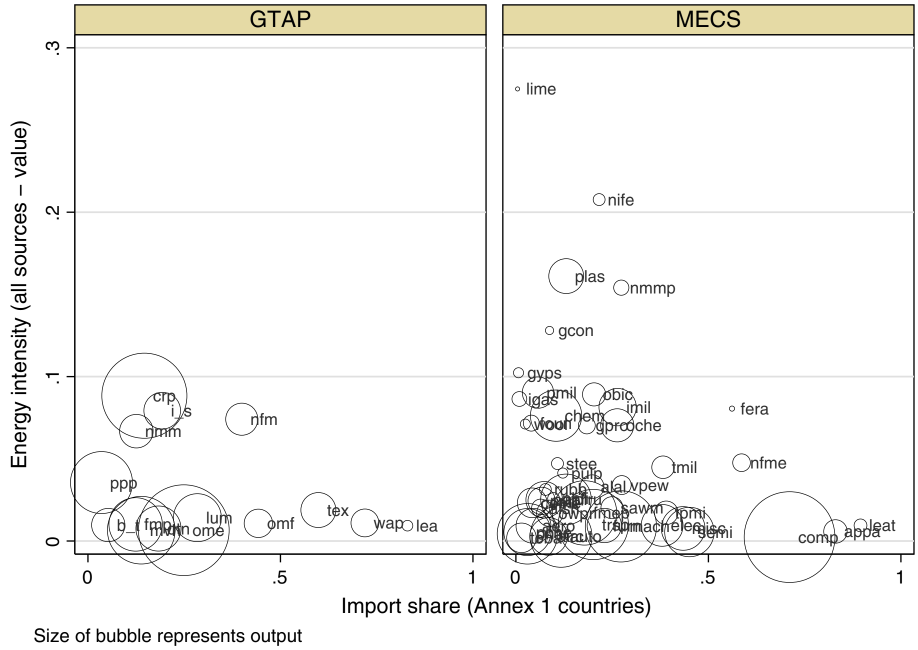

Fig. 1. Comparing GTAP and GTAP-MECS sectors (2004 values).

The approach taken in this paper is to increase sectoral detail within a computable general equilibrium model of the world economy. The objectives are to investigate how available data can be used to provide a more precise sectoral distribution of impacts, re-assess leakage rates and the effectiveness of BCAs and quantify the "aggregation bias" which may be caused by relying on overly aggregated calibrations.

Increasing sectoral detail is relevant from a policy perspective as BCAs are discussed at a fairly fine degree of aggregation. In the US, the Environmental Protection Agency (US-EPA, 2009)[1] has identified 44 sectors as presumptively eligible for allowance rebates, being particularly energy and trade intensive. In the EU, about 105 sectors have been singled out as "exposed to a significant risk of carbon leakage" (European Commission, 2009). These are identified, respectively, at the North American Industrial Classification System (NAICS) 6-digit level, and the NACE-4 classification system — levels of aggregation close to what this paper works with as it includes twenty-three 6-digit and twelve 4-digit NAICS sectors.

None of the general equilibrium studies in the literature use models which are capable of generating such a level of detail. Indeed, a majority of existing models are based on different aggregations of the same global trade and production dataset, Purdue University's Global Trade Analysis Project (GTAP), which has a coarse description of industrial sectors. In this paper, I create a series of GTAP datasets based on different aggregations of the 16 industrial sectors available in cgtap. In addition, I develop GTAP-MECS, a micro-consistent dataset covering the whole world economy which uses GTAP as a starting point and expands its industrial coverage from 16 to 51 sectors. GTAP-MECS exploits detailed industrial energy use data made available in the US by the Energy Information Administration's Manufacturing Energy Consumption Survey (MECS), as well as input–output data from the Bureau of Economic Analysis (BEA) and disaggregated international trade data. Because energy intensity and input/output data outside of the US is not observed, the calibration relies on identifying assumptions for their estimation. The uncertainty due to these assumptions generates variability in results which is carefully accounted for.

Industrial sectors are often both energy intensive and heavily traded: they comprise 69% of total US imports in value and 80% of embodied CO_2 imports. They are thus central to the estimation of carbon leakage rates and the effectiveness of BCAs. GTAP-MECS includes sectors such as cement or aluminum which are the focus of partial equilibrium studies and are missing from GTAP. Fig. 1 compares the GTAP and GTAP-MECS datasets along three dimensions which are important determinants of a sector's relative competitiveness under climate policy: energy intensity (amount of energy inputs per unit of output), import share, and output (all in value terms). As can be seen, there is a wide range of variability in these three dimensions across sectors and across the datasets.

The GTAP and GTAP-MECS datasets are used to calibrate a standard static constant-returns model of international trade based on the Armington differentiated goods assumption. In this class of general equilibrium models, increasing the degree of sectoral detail influences results in different ways: heterogeneity in CO_2 intensities can change substitution possibilities in final and intermediate demand; a more detailed description of technologies and fuel mixes can affect energy input substitution possibilities and overall abatement costs; finally, disaggregation can affect the scope for import substitution if it changes the sector-level correlation of trade and CO_2 intensities. The magnitude of these effects is an empirical matter and its estimation requires calibration.

I implement a simple counterfactual policy in which CO_2 emissions are reduced in a sub-set of countries. Results generated with the detailed GTAP-MECS calibration are compared with those generated by the calibration of the same model to different aggregations of the industrial sectors available in GTAP. I find that, as expected, the range and standard deviations of sectoral impacts increases with disaggregation. The increase in detail can also lead in qualitatively different predictions for some sectors, and changes the relative ranking of impacts across industries. I then estimate aggregation bias at the GTAP-sector detail level: the difference between impacts estimated with a GTAP calibration and the re-aggregated impacts from the disaggregated calibration. The magnitude of this bias is estimated to be large, with considerable differences between sectors both in sign and magnitude. I show how within-sector heterogeneity which is not captured by GTAP is linked to these biases.

Importantly, sector-level biases tend to average out, and the amount of aggregation bias which remains at the overall industrial level is moderate. Relative to estimates generated using GTAP, the decrease in industrial output is predicted to be about 40% smaller. This can be partly explained by the larger variance in industrial energy intensities in GTAP-MECS than in GTAP. Variables related to trade are more affected by

1 In a recommendation report prepared for the US's H.R. 2454 Bill.