



## Analysis

## Examining the efforts of a small, open economy to reduce carbon emissions: The case of Denmark

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## ABSTRACT

It is generally understood that greenhouse gasses produced by human activities are having a warming effect on the climate. Discussions concerning efforts to curb carbon dioxide emissions often focus on large countries. However, considerable resources have been spent to reduce carbon dioxide emissions by relatively small, open economies. Although, these economies are small players in international markets, international trade has an important influence on their economies. Investigating the outcome of efforts to curb emissions by these small, open economies provides insights into the situation faced by a large set of the world's economies. This paper has three objectives: (1) investigate the outcome of Denmark's efforts to reduce its carbon emissions by characterizing the relationship between Denmark's macroeconomic activity and carbon emissions; (2) determine the carbon content of Danish trade and document the important effects that growing trade with China has had on Danish consumption emissions; and (3), investigate the robustness of measures of consumption emissions under varying information requirements. Our analysis of the outcomes of Danish efforts to reduce carbon emissions suggest two, related lessons. First, small, open economies, should track both production and consumption emissions when evaluating their progress towards reducing carbon emissions. Second, international trade should be considered in the design of environmental policy. The Danish experience indicates that increasing trade with a much larger and more emission intensive country can have substantial influence on consumption emissions.

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## 1. Introduction

It is generally understood that greenhouse gasses produced by human activities are having a warming effect on the climate (IPCC, 2014). Carbon dioxide (CO<sub>2</sub>), which is emitted by burning various fossil fuels (coal, natural gas, and oil, for example) is the primary greenhouse gas and reducing CO<sub>2</sub> emissions remains a priority on most political agendas around the world. Various policies and international agreements have been implemented to reduce carbon dioxide emissions. Discussions concerning efforts to curb carbon dioxide emissions often focus on large countries, China, United States, and India, for example. However, considerable resources have been spent to reduce carbon dioxide emissions by relatively small, open

economies. Although these economies are small players in international markets, international trade has an important influence on their economies. Expanding trade with a much larger trading partner, China for example, can have a large effect on the smaller economy, but an insignificant effect on the Chinese economy. Investigating the outcome of efforts to curb emissions by these small, open economies provides insights into the situation faced by a large set of the world's economies.

In this paper, we study the outcome of the efforts of a small, open economy to reduce carbon dioxide emissions. In particular, we have three objectives: (1) investigate the outcome of Denmark's efforts to reduce its carbon dioxide emissions by characterizing the relationship between Denmark's macroeconomic activity and carbon dioxide emissions; (2) determine the carbon dioxide content of Danish trade and document the important effects that growing trade with China has had on Danish consumption emissions; and (3), investigate the robustness of measures of consumption emissions under varying information requirements.

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Why study Denmark? Denmark has taken a particularly strong approach to reducing its greenhouse gas emissions.<sup>1</sup> Denmark's existing environmental policies together with its ambitious policy goals make it a good case in which to study the link between domestic and international economic activity and carbon dioxide emissions of a small, open economy. The Danish experience provides an opportunity to study a case in which aggressive national policies were implemented to address a problem that is international in scope. Reducing carbon dioxide emissions is a global problem: first, carbon dioxide emissions and their warming effects are transboundary; second, economic integration complicates both environmental management and the effectiveness of environmental policy. National policies as well as international agreements implemented to curb emissions are incomplete in the sense that a large set of emitters are not covered by national policies or not included in international agreements. The implication is that international trade has important consequences on the environment and environmental policy.<sup>2</sup>

Emissions embodied in international trade are important when agreements are incomplete because they can distort a country's estimate of its carbon dioxide emissions. An issue that arises given Danish carbon dioxide policies is that emissions created via consuming goods and services not produced in Denmark are essentially ignored. A more subtle point is that the carbon dioxide emitted from the production of intermediate goods that are imported and used in Danish production are also ignored: only part of the emissions that were created to produce a product or provide a service are included in a measure of domestically produced emissions. A country's measure of its emissions might be artificially low if it is importing goods with significant carbon dioxide content. Moreover, evaluation of the effectiveness of policies could be misleading if the composition of Danish imports have shifted towards importing more polluting goods.

Evaluating progress towards reducing carbon dioxide emissions requires tracking all emission linked to domestic and international economic activity, including consumption. In this paper, we track carbon dioxide emissions of the Danish economy, using the latest available data, which allows us to account for the international trade of CO<sub>2</sub> emissions through imports and exports of goods and services. A first contribution is to compute both a production-based measure as well as alternative consumption-based measures for the years 1996 to 2009.<sup>3</sup> Using these measures of emissions we characterize the linkages between macroeconomic activity and carbon dioxide emissions. Previous studies of consumption-based emissions computed emissions for only a single year (two important studies are [Davis and Caldeira, 2010](#); [Davis et al., 2011](#)). However, tracking changes in emissions linked to changes in domestic and international economic activity requires computing a consistent time-series measure of emissions.

A second contribution is that we track the emissions in Danish exports and imports. In particular, we ask the question: Has the composition of Denmark's imports shifted towards more polluting goods? This question is important because it is a necessary first step in determining

whether Danish industry is offshoring pollution in response to relatively stringent domestic environmental policy (see [Levinson, 2010](#)). If Danish industry is offshoring pollution, then the costly domestic policies aimed at curbing production emissions may actually be counterproductive since the warming effects of carbon dioxide is transboundary (see [Levinson and Taylor, 2008](#)).

A third contribution concerns the robustness of measures of consumption-based emissions. Consumption-based measures allocate CO<sub>2</sub> emissions associated with the consumption of goods and services back to the producing country and sector, even if the goods arrived at the consuming country via other countries, or were intermediate goods in a multi-country supply chain. The main difficulty with computing these measures is tracking the flow of intermediate goods and services between countries and sectors. Our approach is feasible because we have access to a new set of longitudinal world input–output tables as well as environmental data that covers the period between 1996 and 2009. However, computing consumption-based emissions using these extensive data is not assumption free. Computing measures of consumption-based emissions under different information requirements and assumptions provides an opportunity to see how these requirements affect measures. In practical terms, if measures are robust in the sense that they do not significantly deviate from the measure constructed from the country-specific input–output tables, then researchers as well as policy makers should be confident in using these data for studying issues related to emissions. In particular, the World Input–output Database (WIOD), provides detailed information on production and consumption as well as on the flow of trade between countries. These data make it possible to compute consumption emissions for a large number of countries, over a relatively long period of time, using a consistent set of data and methodology.

## 2. Data

Before moving on to our analyses of the various measures of Denmark's carbon dioxide emissions, we first provide a description of the sources of the data we used to calculate the measures. One way to think about the differences between our measures of carbon dioxide emissions is by their data requirements. The measures can essentially be divided into those that depend only on the data provided in the WIOD and those measures that also rely on access to detailed Danish data on firms and their products. We proceed with the discussion of the data along these lines by first introducing the World Input–output database and then discuss the data we use from Statistics Denmark.

### 2.1. World Input–Output Database

Constructing measures of Denmark's consumption-based carbon dioxide emissions requires tracking the flow of goods and services across different sectors and between countries. The main source of data is the World Input–output Database (WIOD).<sup>4</sup> The database consists of world input–output tables for each of the years between 1996 and 2001, for 40 countries, including the EU-27 countries as well as 13 other major countries: Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey and the United States. Consequently, our measures can account for the carbon dioxide content in at least 85% Danish imports.<sup>5</sup>

For each country, the WIOD contains data for 35 industries based on the NACE rev 1 (ISIC rev 2) nomenclature (see [Fig. 1](#) for definitions of acronyms). These industries include agriculture, mining, construction, utilities, 14 manufacturing industries and 17 service industries. The WIOD also reports the total output produced by each of these industries

<sup>1</sup> As part of the 1997 Kyoto protocol, Denmark has adopted one of the most ambitious emission reduction targets (21% between 2008–2012, relative to 1990 emission levels) compared to other Annex I countries of the UN Framework Convention on Climate Change (UNFCCC). Likewise, Denmark's target of reducing emissions by a further 20% between 2013 and 2020, independent of the Emissions Trading Scheme (ETS), is among the highest in the EU Burden-Sharing Mechanism. As outlined in the Danish government's *Energy Strategy 2050* launched in 2011, the long-term goal of Danish energy policy is to phase-out the use of fossil fuels by 2050 ([Ministry of Climate, Energy and Building, 2011](#)). In the shorter-term, the goal is to reduce the use of fossil fuels in the energy sector by 33% relative to 2009 levels. In addition, the share of renewable energy in Danish total energy supply is to increase to 33% by 2020 and primary energy consumption is to decrease by 6% by 2020, all relative to 2006 levels.

<sup>2</sup> The converse is also true: Environmental policy can have an effect on international trade. The potential for environmental policy to create incentives for offshoring pollution (leakage) or the creation of pollution havens is two examples. There are a number of interesting studies on trade and the environment. For an excellent overview of the issues see [Copeland and Taylor \(2003\)](#).

<sup>3</sup> The latest year for which comprehensive data are available is 2009.

<sup>4</sup> The WIOD is publicly available at: [www.wiod.org/database/index.htm](http://www.wiod.org/database/index.htm).

<sup>5</sup> The only important omission in the WIOD is Norway. However, there is another country called rest-of-the-world in the WIOD which aggregates trade with those countries not included in the WIOD.

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