The CO_2 Content of Consumption Across U.S. Regions: A Multi-Regional Input-Output (MRIO) Approach

Justin Caron

Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology, MA, USA.

Gilbert E. Metcalf

Department of Economics, Tufts University, Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology, and National Bureau of Economic Research (NBER), MA, USA.

John Reilly

Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology, MA, USA.

We use a multi-regional input-output (MRIO) model to uncover the patterns of embodied carbon dioxide (CO_2) consumption within the US. An extensive literature attempts to trace the full effect of consumption patterns on CO_2 emissions through the economy. One common approach relies on an engineering-based life-cycle approach that identifies emissions related to a particular production process, including emissions related to the production of inputs, with the goal of identifying all emissions associated with a product through its full life cycle. These studies can provide product-level estimates but typically stop somewhere along the production chain. A second common approach relies on input-output (I-O) tables, which describe the entire production chain. I-O modeling has been used to track CO_2 emissions through the economy across countries, made possible by international trade data sets providing information on bilateral trade flows.

Our contribution is to improve on empirical estimates for states or regions within the US—a timely issue, as recent Congressional efforts have focused on crafting legislation with mechanisms to "fairly" distribute the cost of a carbon policy among states. Our methodological contribution to the literature is to develop a multi-regional input-output (MRIO) model with over 100 countries and the United States disaggregated to the state level. We do so by combining a large number of input-output tables with available data for the US on interstate and international trade flows to estimate a full matrix of bilateral trade flows—both inter-state and between US states and foreign countries. This allows us to track carbon embodied in imports and exports, as

well as products domestically produced and consumed. We thus advance on previous work (e.g. Hassett *et al.*, 2009) which relied on the key assumption that commodities produced in and exported out of any given state are equally likely to be consumed in any other given state, an assumption that is not supported by the data.

By tracking both the domestic and international sourcing of goods, we are able to improve on the estimation of *indirect* emissions intensities – the emissions embodied in the consumption of non-energy goods and services. While emissions associated with these goods are fairly low, the vast bulk of household spending goes toward their purchase and a large share of household emissions are thus embodied in non-energy goods and services. Assuming that indirect emissions associated with consumption are uniform among different regional sources of the same product leads to very low estimated differences in indirect intensities across states.

To implement the MRIO approach we construct a dataset which includes input-output tables, final demand data and CO_2 emission coefficients for all 50 US states as well as 113 countries and regions outside of the US for 2006. The dataset also includes the full matrix of bilateral trade between all regions, including US intra-national trade and trade between international trading partners and US states. Because the dataset we have constructed covers most of the global economy, we are able to compute the total CO_2 intensity of both internationally and domestically traded goods.

We first find that measures of CO_2 accounting differ substantially when computed on consumption rather than a production basis. Consider California, for example: its consumption-based emissions are about 25% larger than its production-based emissions as California imports 1.85 times more embodied CO_2 than it exports. Considering the carbon embodied in trade matters: almost all states consume more imported CO_2 than domestically emitted CO_2, and most states export a majority of the CO_2 they emit in the production of goods.

Next, focusing on the CO_2 intensity of consumption (the physical amount of carbon embodied in each dollar of consumption), we find that the indirect component (from consumption of non-energy goods) accounts for more than half of the total intensity. On average over all states, each dollar of consumption contains 0.218 kg of direct emissions and 0.265 kg of indirect emissions. While policy makers tend to focus on the impact of carbon pricing on energy goods that cause direct emissions through consumption (e.g., gasoline, home heating fuels and electricity), most consumer spending is on non-energy goods where embodied emissions occurred during production.

Importantly, we find that both the direct *and* indirect emissions vary across regions. The direct emissions intensity of consumption is found to range from 0.12 to 0.29 kg/$ (generally, northern states have greater fossil fuel requirements for heating, and southern states have greater electricity requirements for air conditioning). The literature had already identified this variability and our estimates are consistent with those of Hassett *et al.* (2009) and Mathur and Morris (2012). The picture changes, however, when we focus on indirect emissions. These are found to vary considerably more than suggested by the aforementioned studies, which argued that the variance in geographic distribution of indirect emissions is much lower than that of direct

emissions. We find that indirect carbon intensity varies from 0.18–0.33 kg/$—a ratio of almost two to one.

These large differences in the indirect CO_2 intensity of consumption have important implications regarding the incidence of carbon taxation: the extent to which households will be affected will vary across regions not only because of differences in the consumption of fossil fuels and electricity, but because of differences in non-energy consumption as well. The disparities in the impact of carbon pricing go well beyond direct energy consumption.

We provide a decomposition exercise in which we identify the relative roles of consumption patterns and of the domestic and international sourcing of consumption. We find that most variability in the indirect emissions intensity of consumption comes from differences in the sourcing of domestic goods, although the sourcing of internationally produced goods also matters. Differences in consumption patterns are small and do not play a large role in determining differences in the emissions intensity of consumption.

Our results are important for understanding regional patterns of CO_2 intensity in consumption and contribute to explaining regional variation in support for climate policy. Our findings are also relevant for the analysis of state-level carbon policy which, given the failure to enact carbon pricing at the national level, is growing in importance.