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Methodological and Ideological Options

On market-mediated emissions and regulations on life cycle emissions

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ABSTRACT

We analyze the use of life cycle assessment (LCA) as a regulatory tool using biofuel regulations as an illustrative example. A regulatory context calls for a consequential LCA (CLCA) of a policy as opposed to an attributional LCA (ALCA) of a product. In performing CLCA, issues of scale, price effects, technology and policy in the counterfactual state of the world, strategic behavior, policy horizon etc. need consideration. This appears to increase both uncertainty in estimates and the cost of performing LCA. We suggest heuristics for determining vulnerability to harmful indirect effects at an early stage in the policy process and discuss alternative policies to limit harmful indirect effects without engaging in the full effort of computation and selection of a central estimate for uncertain outcomes.

1. Introduction

Economic theory says that the cost-effective approach to addressing global climate change is through a globally consistent greenhouse gas (GHG) policy (Stern et al., 2006). Political consensus for such a policy appears elusive (Bodansky, 2010). Governments worldwide are, however, adopting policies to reduce GHG emissions. In a globalized world, partial measures that target emissions from a subset of polluting activities or regions could prove ineffective or even counterproductive. For instance, reducing automobile GHG emissions by replacing oil with biofuels increases emissions from land use. This provides a rationale for policies that target reduction in emissions associated with the life cycle of a product. The US Renewable FuelStandard (RFS), United Kingdom's Renewable Transport Fuel Obligation (RTFO) and the California Low Carbon Fuel Standard (LCFS) are examples of regulations that seek to reduce the life cycle GHG emission intensity of transportation fuels (Brander et al., 2009; CARB, 2009).

Life cycle assessment (LCA) is a technique for computing the total environmental burden associated with the production, use, and end-of-life of a product or service (Hendrickson et al., 1998; Joshi, 2000; Lave et al., 1995). A life cycle based regulation is implemented by holding one entity in the supply chain, typically the supplier of the final consumer good, accountable for total emissions attributable to the product's life cycle. It is expected that the regulated firm would adjust its inputs in a manner that maximizes its profits while ensuring compliance with the regulation. The suppliers of inputs would, in turn, choose their inputs and their suppliers so as to respond to changing demand under the regulation. This will then induce adjustments by the next higher up entity in the supply chain and so on. A benefit of this approach, when direct and economy-wide policies are infeasible, is that it reduces monitoring and enforcement costs while offering regulated firms the flexibility to choose the least-cost approach to achieve compliance. Although this approach is generally being discussed in the context of renewable fuel mandates and fuel emission intensity standards, it could, in theory, also be implemented under regulations using fees or quotas.

Targeting supply chain emissions may still prove inadequate when the goal is global emission reduction. Biofuels are a case in point. Whereas process-LCA of the supply chain, also known as attributional LCA (ALCA), suggests that biofuels such as corn ethanol and cane ethanol are less GHG intensive than fossil fuels (de Carvalho, 1998; Farrell et al., 2006), economic models predict that biofuel policies will lead to greater GHG emissions for several decades in to the future (Dumortier et al., 2009; Havlik et al., 2011; Hertel et al., 2010; Melillo et al., 2009; Searchinger et al., 2008). An LCA that analyzes the consequences of a decision, say a policy decision to mandate a new technology, is referred to as consequential LCA (CLCA) (Brander et al., 2009; Earles and Halog, 2011; Ekvall and Andrae, 2006).

CLCA differs from ALCA in that it accounts also emissions that are not directly traceable to the supply chain of a product. Such emissions are referred to as market-mediated or "indirect" emissions. The system boundary of CLCA therefore extends beyond the supply chain and may potentially encompass the global economy. Another distinction is that whereas the ISO 14040 and 14044 standards provide guidelines for ALCA, such guidelines do not exist for CLCA. Different

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studies employing different system boundaries, different sources of data, and different modeling approaches seem to provide widely varying estimates of the benefits of a technology. Furthermore, supply chain emissions and indirect emissions present different challenges from a regulatory standpoint, with the latter proving particularly controversial (NFA, 2008; UCS, 2008).[1]

This paper has two main objectives, namely, to outline various economic phenomena that require consideration in a policy-focused CLCA and to discuss alternative strategies for mitigating harmful unintended consequences of life cycle based policies. Although LCA aims to quantify all types of environmental burdens, here, we focus on LCA as a technique for computing a given environmental burden, specifically GHG emissions. This, however, does not restrict the generality of our conclusions which relate broadly to indirect emissions. For illustrative purposes we mainly cite evidence from the biofuel literature although the conceptual insights apply to CLCA in general. The rest of the paper is organized as follows. Section 2 outlines the various considerations relevant to a policy-focused CLCA. Section 3 discusses different modeling techniques for computing indirect effects. Section 4 describes different strategies for addressing indirect effects. Section 5 concludes the paper.

2. From ALCA to CLCA

ALCA is concerned with emissions traceable to processes linked to the supply chain, the use-phase and end-of-life of a product or service at a given point in time, and on average for an industry or for a specific firm. The concern from a policy standpoint is economy-wide and global (for global pollutants) emissions resulting from a policy-induced substitution of one product with the product in question. We summarize below the various issues to consider when comparing future emissions under alternative scenarios, some among which might be partially addressed using ALCA while the others require a more expansive framework. Although some of these are already recognized in the LCA literature (Brander et al., 2009; Earles and Halog, 2011; Ekvall and Andrae, 2006; Weidema, 2011), our discussion reiterates those in a consistent policy context, namely, a biofuel regulation, and highlights others.

1. Change in supply chain emissions over time: These changes may either be exogenous or be induced by the policy under consideration itself and may manifest in several ways.
    (a) Technical change: Historical experience suggests that productivity improves over time due to scale economies; learning by doing (Nemet, 2006); improvements in the quality of inputs (Hillman and Sanden, 2008), etc. Such phenomena may manifest in the form of more efficient energy-conversion technologies (Newell et al., 1999), better quality seeds (Evenson and Gollin, 2003), etc. For instance, corn yield per acre has been growing at an average rate of about 1.7% per year between 1978 and 2008 and is expected to reach 11.1 tons/ha (t/hec) by 2019–20,[2] which is 27% higher relative to the 8.8 t/hec assumed by tefarrell2006ethanol.
    (b) Input substitution and fuel switching: The relationships between inputs and output, which one observes either for a specific firm, or, on average for an industry, are not merely technical. They reflect behavior such as profit maximization or cost minimization. Under reasonable assumptions of limited substitutability in the short term and full substitutability in the long term between various inputs (say, energy and capital) or between different energy inputs, say coal and natural gas, a change in relative prices of different inputs will cause producers to adjust the optimal combination of inputs, affecting supply chain emissions. For instance, the ALCA of corn ethanol is sensitive to the assumption of whether coal or natural gas is used in corn processing.
    ALCA estimates can be derived for any exogenous level of efficiency, fuel shares or any other technical parameter (or for any given distribution of these parameters across firms). However, simulating price-induced change in such parameters, would require a broader framework.
2. Emissions due to joint production: Industrial production often yields multiple products. For instance, corn ethanol is jointly produced with distillers grains (DG) — a substitute to raw corn grain as feed for livestock operations, the distillation of crude oil yields multiple products, including gasoline, diesel, jet fuel, naptha, coke, etc. It is therefore a common practice in ALCA to allocate a fraction of the supply chain emissions to each co-product. For instance, assuming that DG substitutes corn grain in animal feeding operations, and if each kilogram (kg) of corn processed into ethanol yields approximately x kg of DG, ALCA's of corn ethanol have allocated x% of the total ethanol supply chain emissions to DG (Farrell et al., 2006; Liska et al., 2008; Wang, 1999). However, the substitutability of a co-product may change with scale of production, say due to saturation of demand for co-products because of technical or economic reasons. This suggests that apportioning emissions from joint production to each individual product can be a complex task.
3. Impact on input producing sectors: By breaking down the life cycle into a series of sequential phases such as raw material extraction, processing, use phase and end of life, ALCA accounts for emissions across the vertical supply chain. In doing so it ignores the horizontal linkages arising from competition for intermediate goods. For instance, allocation of farmland to biofuel crops reduces supply of food and increases demand for land for food. Thus, expanding biofuel production increases demand for farmland which results in land use conversion towards farming, a phenomenon referred to as indirect land-use change (ILUC), which amplifies GHG footprint of biofuels (Dumortier et al., 2009; Havlik et al., 2011; Hertel et al., 2010; Melillo et al., 2009; Searchinger et al., 2008).
4. Impact on final-output sector: It is often implicitly assumed that a new technology will simply displace an equal amount of its substitutes and that total consumption of this basket of substitutes remains unchanged. However, increasing the supply of a new and cleaner substitute reduces the demand for the dirtier technology whose price declines. In a globalized market, this will lead to a partial rebound, i.e. an increase in consumption of the dirtier technology such that total global consumption increases (Chen and Khanna, 2012; Thompson et al., 2011). Similarly, Ekvall and Andrae (2006) predict that the benefit of eliminating lead use in soldering applications may be partially offset by the accompanying fall in lead prices and therefore increased use of lead in batteries and other products. Rebound effects may even lead to an unintended increase in total emissions.
5. Strategic behavior: Hochman et al. (2011) model the behavior of the Oil Producing and Exporting Countries (OPEC) cartel in response to biofuel mandates and show that a model of the world oil market, which assumes perfect competition, underestimates the reduction in global oil consumption relative to a model which assumes non-competitive behavior by OPEC. The competitive model also therefore underestimates the impact of biofuels on greenhouse gas emissions from the fuel sector.
6. Time path of emissions: Similar to cash flow under an investment, emissions tend to be higher before net emission reduction begins to accrue, and so entail a carbon payback period. Different technologies may exhibit different time path of emissions. Whereas the carbon payback time of solar panels is estimated to be in the

[1] Hearing To Review Low Carbon Fuel Standard Proposals, U.S. Congressional Record, 111th Congress, Serial No. 111-15, May 21 2009, http://www.gpo.gov/fdsys/pkg/CHRG-111hhrg52330/html/CHRG-111hhrg52330.htm

[2] USDA Maize Outlook 2010 http://usda.mannlib.cornell.edu/usda/ers/94005/2010/Table18.xls