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Positive and normative analysis of the output opportunity costs of GHG emissions reductions: A comparison of the six largest EU economies

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ABSTRACT

Any policy that aims at reducing GHG emissions by way of modulating the structure of an economy will entail resource reallocation and therefore an implicit economic cost. In this paper, we present a novel answer to this question using positive and normative analyses in such a way that they complement one another. From a positive perspective, we first propose a new look at the analysis of sectors' distributed GHG forward emissions on the basis of absolute rather than marginal effects. Using this information, we then move to a normative viewpoint using an environmental extended input-output linear programming system and compute lower bounds for the potential gross and net output losses for each production unit when facing emissions reduction targets, such as those proposed by the European Union in their 20-20-20 Directive. The originality of our approach relies on two aspects, namely, the introduction of an Armington assumption to link domestic and imported output and that, differently to previous works, total final demand drives the optimal adjustments to reach emissions cuts while minimizing output losses. Our empirical exercise compares the results of these normative and positive analyses for the six largest economies in the European Union.

1. Introduction

From the late 70's thereafter, one of the major focuses of most international organizations and supranational institutions has been securing environmental quality to protect human health, natural resources, and biodiversity. The European Union (EU), among them, stands out for being a worldwide leader in the fight against climate change and has some of the most ambitious environmental targets for 2020. The 20-20-20 package materializes these actions. In addition, the European block has participated actively in the coordination of international efforts to limit greenhouse gas (GHG) emissions; for instance, the EU has been instrumental in establishing the United Nations Framework Convention on Climate Change, starting with the 1997 Kyoto Protocol and following through with the 2015 Paris Agreement.

The fact that the greenhouse effect is a worldwide atmospheric problem justifies the need for enacting international agreements that pursue to combat climate change and global warming. In the context of the EU, even though GHG emissions' targets are set at an aggregate EU level, the implementation of energy and environmental policies has a national dimension. Hence, EU members have to adapt the Environmental and Energy European directives according to its idiosyncratic economic configuration. The goal is to make the achievement of common EU emissions targets more efficient (less costly) and more effective (facilitating the coordination of all EU Members' efforts).

It goes without saying that the design of policies that aim at reducing GHG emissions must take into account their economic costs, in addition of course to their environmental benefits. The reason is that protecting environmental quality and fostering economic growth are usually seen as competing goals, at least in the short run. Indeed, if a particular economy were 'forced' to reduce GHG emissions while keeping unaltered its technological structure, the induced costs in terms of both gross and net income could be remarkable at the national level.

Exploring how these economic costs could be mitigated becomes, therefore, a relevant issue in the economic literature. To this effect, one of the most widely used methodological tools is the class of Environmentally Extended Input-Output (EEIO) models (Leontief, 1970) implemented as a linear programming (LP) problem. These EEIO LP models offer the distinct advantage of controlling simultaneously for both socio-economic magnitudes and environmental indicators. The implementation of the Input-Output (I-O) method as a special case of a LP model is well-known; see Dorfman et al. (1958), Intriligator (1971), and Miller and Blair (2009) for extensive technical explanations and Vogstad (2009) for the specifics of EEIO analysis.

In the present work, we also make use of an EEIO LP model that

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provides the framework for the normative analysis of sectorial GHG emissions' control. Its goal is to provide an estimate of the minimum opportunity costs for each production unit whenever it is subject to GHG emissions' reductions. These minimum opportunity costs are, in fact, lower bounds to the 'minimum' costs evaluated by previous studies. In this regard, in most EEIO LP analyses the objective variables to be maximized, while upholding certain environmental and socio-economic targets, are supply-side variables. This is, for instance, the case of Hsu and Chou (2000), Fan et al. (2010), Hristu-Varsakelis et al. (2010), Fue et al. (2017) and Cortés-Borda et al. (2015) where the objective variable refers to economy-wide net output (value-added) whereas in San Cristóbal (2010), San Cristobal (2012) the optimizing variable of choice is economy-wide gross output. In contrast, in our EEIO LP approach total final demand is the target variable and thus the optimal adjustment mechanisms rely on demand-side flows. Consequently, when evaluating GHG emissions' cuts under our approach that affects one specific sector, the domestic output levels of the remaining production units remain unaltered. As a result, the evaluated cross-sectorial output-to-output elasticities (Miller and Blair, 2009, pp. 283–284) are all equal to zero. Final demand flows of those sectors not directly involved in the GHG emission reductions endogenously adjust in order to leave their domestic output levels at their benchmark equilibrium values. The exceptions are the sectors that incorporate GHG emissions directly induced by households. Apart from controlling for GHG emissions of production activities, as in the approach of Fue et al. (2017), the inclusion of these emissions increase the comprehensiveness of our analyses.

In addition, our methodological proposal offers two significant novelties. In the first place, in both the normative and positive analyses, we use the information on total final demand rather than on domestic final demand. In our view, this scenario is more realistic; indeed, when agents formulate their final demand plans they do not usually distinguish, per se, between domestic and imported goods. For the level of aggregation typical of multisectoral models this is a reasonable empirical assumption. In partial equilibrium demand models where available data allow for the introduction of characteristics of goods and price decisions matter this assumption would be more debatable. With this purpose in mind, we modify the standard I-O model to incorporate the assumption first put forth by Armington (1969). This allows us to evaluate how changes in total final demand translate to variations in domestic gross output and thus on domestic GHG emissions' levels. In fact, the implementation of an Armington I-O model constitutes the main methodological contribution of our analysis. Secondly, the design of our EEIO LP model presents the advantage of computing the opportunity costs of the GHG emissions' reductions that are specific to each production unit in the economy.

Before implementing the EEIO LP system, we first provide a positive perspective of GHG emissions. Thanks to this approach, we are able to identify the set of sectors where GHG emissions reductions should preferably be focused and obtain valuable insights regarding the reasons for their relevance. We use the classical I-O methodology here but we present its results in a novel way that enables us to visualize the full set of inter-sectorial GHG emissions. We compute what we term the matrix of total distributed GHG emissions. It is a detailed mapping of how total domestic emissions are distributed by production sector (destiny) and goods (origin). We, therefore, go beyond marginal or average forward and backward impacts[1] and we put the accent in the distribution of the total volume of GHG emissions, which provides a better alignment with environmental policy targets. This perspective allows us to discern the relevance of a sector in determining economy-wide GHG emissions not only by means of its GHG intensity levels and the strength of its interindustry linkages but also by its role in total final demand structure and volume.

The normative and the positive analyses are carried out in the context of the six largest EU economies, namely, Germany, United Kingdom, France, Poland, Italy and Spain. These economies are responsible for around three-quarters of total GHG emissions in the EU. Furthermore, this comparison is interesting on its own because they are quite different in their production structure and thus in their specialization patterns within the EU context.

The rest of this work is organized as follows. In the first part of Section 2 we present the generalized version of the EEIO model once we introduce the Armington assumption. In the second and the third parts of this section, we present the structure of the positive and normative analyses, respectively. In Section 3 we describe the 2014 dataset we use in our empirical analysis. In Section 4 we present the main results of both the positive and normative approaches for the six largest EU economies and compare them. Also in the second part of this section, we include an additional empirical exercise[2] that consists in exploring to what extent the fact that part of total supply is imported from abroad affects our results under the normative approach. Section 5 concludes with a discussion of some policy recommendations that could be followed in these EU economies in line with our findings and the insights on how to improve the effectiveness and efficiency of policies addressed to achieve GHG emissions reductions.

2. Methodology

2.1. The Armington generalization of the EEIO model

The standard single economy (national or regional) I-O model can use either the non-competitive or the competitive imports assumptions. Although the non-competitive imports assumption is usually preferred (Su and Ang, 2013), we have opted here for using the other alternative assumption since, in our empirical approach, we make use of total final demand flows instead of just the domestic ones. When we use this assumption, the standard I-O model is given by:

$$\mathbf{x}^d = \mathbf{A}\cdot\mathbf{x}^d + \mathbf{f} - \mathbf{x}^m \tag{1}$$

In this expression $\mathbf{x}^d$ denotes domestic production, $\mathbf{A}$ is the matrix of technical coefficients obtained from the matrix of total intermediate flows $\mathbf{Z}$ and the matrix diagonalisation $[\hat{\mathbf{X}}^d]$ of vector $\mathbf{x}^d$ as $\mathbf{A} = \mathbf{Z}\cdot[\hat{\mathbf{X}}^d]^{-1}$, $\mathbf{f}$ is the vector of total final demand and $\mathbf{x}^m$ is the vector of total imported production. If the technology $\mathbf{A}$ is productive, we can solve (1) for the reduced form as:

$$\mathbf{x}^d = [\mathbf{I} - \mathbf{A}]^{-1}\cdot(\mathbf{f} - \mathbf{x}^m) \tag{2}$$

We introduce now a row vector $\boldsymbol{\varepsilon}'$ whose elements are the physical GHG emissions intensities for each production activity in the economy $i = 1,\dots, n$. Expression (2) is then transformed into the well-known EEIO model:

$$\boldsymbol{\varepsilon}'\cdot\mathbf{x}^d = \boldsymbol{\varepsilon}'\cdot[\mathbf{I} - \mathbf{A}]^{-1}\cdot(\mathbf{f} - \mathbf{x}^m) \tag{3}$$

The EEIO model outlined in (3) allows for the evaluation of the potential changes in total domestic GHG emissions in response to changes in final demand net of imports, i.e. $\Delta(\mathbf{f} - \mathbf{x}^m)$. The model in (3), however, is still incomplete since imports are unexplained and, up to this point, unrelated to domestic production activities. We propose to solve this exogeneity borrowing the well-known Armington (1969) assumption commonly used in computable general equilibrium models. In these models, total output $\mathbf{x}$ is the result of a production technology whose inputs comprise domestic $\mathbf{x}^d$ and imported output $\mathbf{x}^m$, for a given substitution elasticity.[3] Since in interindustry models we take prices as

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[1] See Alcántara and Padilla (2003) and Tarancón and del Río (2007).

[2] We thank one of the reviewers for suggesting this simulation.

[3] Instead of using the term input, we have seen more appropriate to use the word output because the elements of vector $\mathbf{x}^d$ include the domestic output devoted to fulfill both the intermediate demand and final demand requirements. The same reasoning applies to the vector of total sectors' imports $\mathbf{x}^m$.