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Analysis

Simulating the impact of new industries on the economy: The case of biorefining in Australia

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A B S T R A C T

We investigate the economic and employment consequences of introducing a new sugarcane-based biofuel industry into Australia. We model the new biofuel industry on the production recipe of the existing large-scale gasoalcohol and alcohol sectors in the Brazilian economy. To this end we utilise a hybrid IO-LCA (input–output life cycle assessment) approach, which involves inserting data on new processes and/or sectors into an existing IO table. In particular, we develop and test an analytical and a numerical approach for re-balancing an IO table augmented with rows and columns representing large new biofuel industries. We quantify changes in economic output and employment in the Australian economy. We conclude that a future biofuel industry will be employment-positive for Australia.

1. Introduction

Decision-makers in Australia are increasingly concerned about energy security, and one of the scientific responses considered are domestic biofuels. At present, Australia is in the early days of a biofuel industry. To successfully enhance biofuel opportunities in Australia, a myriad of technological changes are needed. For example, present fleet of cars in Australia cannot run on ethanol fuel. Like Brazil, Australia will need to welcome flex-fuel vehicles that can run on both petrol and ethanol. The technology for the construction of these vehicles is currently not available in Australia. Thus, the introduction of a biofuel industry will require substantial technological change in the economy.

The economic repercussions of technological change have been a topic of research for many years. Researchers often use input–output (IO) techniques to understand the consequences of introducing new products and/or industries into an economy.[1] Rose (1984) provided an overview of the different methods for estimating technological change in IO matrices. One variant of these methods is the augmentation approach, which involves inserting data on new processes and/or sectors into an existing IO table. For example, Lave et al. (1995) used this method to compare electricity use and toxic emissions of paper cup and plastic cup production. Joshi (1999) extended their approach to assess the environmental performance of steel and plastic automobile fuel tank systems.

The augmentation approach is, undoubtedly, useful for modelling the effects of introducing new products and/or industries into an economy. However, this approach disturbs the IO balance of the IO table. If the size of the new sector is small, the disturbance is negligible and the augmentation causes a marginal change for the total output of sectors. For this reason, neither Joshi (1999) nor Acquaye et al. (2011) nor Wiedmann et al. (2011) re-balanced their modified IO table after augmentation. The IO system is significantly disturbed if the insert represents a large portion of the economy. Probably the most explicit treatment in the existing literature is Suh (2004), (Appendix A) who proposed a method for reconciling IO accounts and process data inserts within integrated hybrid life cycle assessment (Heijungs and Suh, 2002). Whilst Suh employed a manual procedure, Li et al. (2012) and Liu et al. (2012) more recently used a RAS approach.

Stone (1961) developed RAS, also known as bi-proportional matrix balancing. It works by scaling the rows and columns of an initial matrix using prescribed row and column sums (marginal totals) to obtain an updated matrix (Bacharach, 1970; Miller and Blair, 2009). Since Stone's initial conception, many RAS variants have been developed and applied

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[1] In addition to IO techniques, econometric and CGE models are available as well. However, we chose the IO model because IO models adopt parameters that are directly measurable and that are able to reflect technologies in great sectoral detail.

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in IO studies, for example, TRAS (Gilchrist and St. Louis, 2004, relaxing the restriction to marginal totals as the only constraints), GRAS (Junius and Oosterhaven, 2003, extending to negative elements), and KRAS (Lenzen et al., 2009, allowing non-unity coefficients and conflicting constraints). Li et al. (2012) utilised RAS to successfully rebalance a 2007 IO table for China, augmented by a large wind energy sector. Liu et al. (2012) added 11 sectors into the 2006 IO table of Taiwan, and used the KRAS approach for balancing. The EXIOPOL project (Tukker et al., 2013) followed a two-step procedure, where first domestic supply–use table blocks were balanced, which in turn were then trade-linked into a complete multi-regional input–output table (MRIO).

RAS has also been used to study technological change in IO systems that were not augmented with new rows or columns, but only perturbed by updating individual cells. Van der Linden and Dietzenbacher (1995, 2000) argued that RAS can be used for measuring technological change, and developed a method for decomposing these changes in the IO matrix into row, column and cell-specific effects. Dietzenbacher and Hoekstra (2002) employed the RAS method for studying the effects of technological change and trade in the Netherlands over the years 1975–1985. Andreosso-O'Callaghan and Yue (2000) used RAS to investigate the industries responsible for causing structural change in the manufacturing sector of the Chinese economy. Dobrescu and Gaftea (2012) estimated the technical coefficients of the Romanian economy to test the applicability of the RAS procedure in an emergent system.

Traditionally, both the augmentation approach and the cell-updating approach change the production recipe, which is the structure of a use matrix column, of at least some sectors. Whilst this effect cannot be avoided in the cell-updating approach, the augmentation approach can be modified to keep the production recipe of all existing sectors intact. The rationale for retaining production recipes is that, generally speaking, there is no reason why the introduction of a new sector into an economy should cause changes in the inputs of already existing sectors. In our case, introducing a new biofuel industry into the Australian economy does not require any industry to change the way they produce, except for purchasing biofuels instead of the previously used petrol. This is intuitively clear: Even after biofuels have entered the market, any power plant will use the same proportion of coal, any farmer the same proportion of fencing, and any school the same proportion of paper, in their inputs. This is necessarily a simplified (ceteris paribus) view of how an economy would adjust in real-life, for example because we have assumed that biofuels would be a perfect substitute for petrol, and would fetch the same price, i.e. would not require any subsidy.[2] In reality, introducing a new sector would likely cause relative prices to change, and as a result sectors would adjust their production structures (see for example the work by Duchin and Lange, 1992, and Duchin and Levine, 2011). If such effects would be expected to be large, one would have to adopt a different type of model, such as a Computable General Equilibrium (CGE) model, or a linear-programming type model such as the WTM/RCOT model by Dilekli and Duchin (accepted for publication) in which the choice between several technologies is kept endogenous, and is solved via minimising total factor inputs.

Our work has two main goals: Our first aim is to develop and test an analytical and a numerical approach that allow the re-balancing of an IO or supply–use table that was unbalanced by an augmentation with rows and columns representing large new industries and/or technologies. The novel characteristic of these methods is that they act only on columns and thus keep the production recipe of economic sectors constant. The numerical approach is a modified RAS method that serves to analyse the step-by-step repercussions of the initial insertion of new industries and/or technologies. Our second aim is to investigate the consequences for total output and employment of introducing a new sugarcane-based biofuel industry into Australia. The utilisation of both an analytical and a numerical, iterative approach is useful because they inform, respectively, about the final outcome of the introduction of a new biofuel industry, and about the economy's adjustment trajectory following the initial introduction. We model the new biofuel industry by taking the production recipe of the existing large-scale gasoalcohol and alcohol sectors in the Brazilian economy.

In the following section we will first explain our approach in detail. In Section 3 we will apply our procedures to a case study of introducing a new sugarcane-based biofuel industry into the Australian economy. We discuss our findings in Section 4 and conclude in Section 5.

2. Methodology

Our approach encompasses four steps:

1) we augment an existing supply–use matrix by a number of empty rows and columns; into these rows and columns we insert data for new industries and products, which will unbalance the table (Section 2.1);
2) we re-balance the table using an analytical adjustment approach; and analyse the difference between the state of the economy pre- and post-adjustment (Section 2.2);
3) we use a RAS-type numerical approach to obtain details on the trajectory of the economy between the pre- and post-adjustment stages (Section 2.3); and
4) we quantify the impacts of the new industries on the economy in terms of monetary output as well as employment (Section 2.4).

We will now describe these four steps in detail. We will use the example of our case study described in Section 3. All calculations were carried out in the Industrial Ecology Virtual Laboratory (IELab) on the NeCTAR research cloud (Lenzen et al., 2014). The IELab is a unique research platform that offers high level of automation for analysing input–output data.

2.1. Augmentation of the Transactions Matrix

In our case study (for further details see Sections 3.1 and 3.2) we appraise two new industries and products: a) alcohol made from sugarcane, and b) gasoalcohol made from a mix of sugarcane-based alcohol and conventional petrol. The gasoalcohol replaces part of the demand for conventional petrol.

In a first step, we set the percentage π to which conventional petrol sales shall be reduced, and adjust

$$\begin{matrix} U^1_{\text{petrol},i} = (1-\pi)U^0_{\text{petrol},i}, \ \forall i \neq \text{alcohol, gasoalcohol} \\ y^1_{\text{petrol}} = (1-\pi)y^0_{\text{petrol}} \end{matrix}, \quad (1)$$

where U denotes elements of the use matrix, y denotes elements of the final demand matrix, and the superscripts 0 and 1 denote matrices pre- and post-augmentation. This step is represented by the light grey fields in the use ($\mathbf{U}$) and final demand ($\mathbf{y}$) matrices shown in Fig. 1. Similarly, we adjust the production of the conventional petrol sector:

$$V^1_{\text{petrol,petrol}} = (1-\pi)V^0_{\text{petrol,petrol}}, \quad (2)$$

where V denotes elements of the supply matrix. This step is represented by the light grey field in the supply ($\mathbf{V}$) matrix in Fig. 1.

[2] Using a linear programming type of IO model, Dilekli and Duchin (accepted for publication) study the introduction of a new biofuel sector in the US. Using the biofuel's column as given (instead of rebalancing) they obtain the subsidy endogenously.