

SHORT, NON-REFEREED PAPER

THE DEVELOPMENT OF A PARTIAL EQUILIBRIUM ECONOMIC MODEL OF THE SOUTH AFRICAN SUGAR INDUSTRY IN A BIOREFINERY SCENARIO

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Abstract

The South African Bio-Economy Strategy was launched in 2013 and identifies agriculture as the sector with the highest economic impact. The need to explore the revitalisation of mature industries such as the sugar and wood/forestry product industries in order to achieve “eco-efficiency and innovation in a low-carbon future”, was explicitly mentioned. In the Industrial Sector Strategy, it was stated that “South Africa will need to progressively source second generation biofuels”, in particular, by converting agricultural residues. One of the strategic interventions in the industrial sector is to develop integrated biorefineries from bio-based feedstocks. In order to implement these strategies, specifically for the sugar industry, a step change will have to take place by extending sugar mills to fully fledged biorefineries, and by adding further downstream products (materials, chemicals, fuels) to the existing product portfolios. The objective of this study is to develop a partial equilibrium mathematical programming economic model of the South African sugar industry (encompassing all stakeholders along the value chain) that allows for inclusion of biorefining investments from the cane to the biorefinery product production. The model will be used to project biorefinery investments under a range of division of proceeds scenarios, and to investigate the implications thereof for sugarcane farming. The purpose of this article is to present a conceptual model that includes representative farms (representing the supply of sugarcane to the mills) and representative mills (representing the derived demand for sucrose, molasses and bagasse by the mills), and allows for sale of products on both domestic and export markets. The model will subsequently be developed by incorporating the results of techno-economic analyses (TEAs) of a limited range of biorefinery investment options.

Keywords: biorefinery investment, partial equilibrium model, division of proceeds

Introduction and background

The South African sugar industry was structured as a partnership between growers of sugarcane and millers of sugarcane. This partnership was regulated by the Sugar Act of 1978 and the Sugar Industry Agreement of 2000 (SIA) (NAMC, 2013). The rules that govern division of proceeds (DOP) between millers and growers (clause 166 of SIA) specify which products are included in the division of proceeds (currently only sugar and molasses), how the products are valued for purposes of the DOP, the ratio in which the net divisible proceeds are shared between millers and growers, and the basis on which growers are paid for sugarcane (currently the Recoverable Value system) (Moor and Wynne, 2001; NAMC, 2013). The current DOP assumes an industry that primarily extracts sugar and molasses from sugarcane.

The Bureau for Food and Agricultural Policy (BFAP) argues that there is a need to introduce a DOP method that shares proceeds from all sugarcane products in their totality to the growers as well (BFAP, 2015).

Changes to the division of proceeds to include “biorefinery products” have implications for millers’ incentives to invest in biorefinery developments and growers’ incentives to produce cane suited to those particular biorefinery processes. In the South African context of a partnership between sugarcane growers and millers, an *ex ante* economic analysis of a sugar mill biorefinery investment cannot be undertaken without due consideration of the incentives provided to growers via the cane payments system to supply sugarcane suited for that particular purpose. The suitability of sugarcane supply includes not only its physical characteristics (e.g. biomass vs. sucrose content), but also the quantity of supply and the timing of that supply. This has implications for growers’ selection of sugarcane varieties (traits), how sugarcane is produced, and when and how it is harvested. The objective of this research is therefore to investigate millers’ incentives to undertake various biorefinery investments and the subsequent on-farm impacts for sugarcane production for a set of division of proceeds scenarios.

Conceptual model

Modelling has been recognised as an effective means of understanding and improving sugar supply chains (Lejars *et al.*, 2008; Higgins *et al.*, 2004; Wynne, 2001; Hildebrand, 1998). Partial equilibrium (PE) modelling is a method of economic modelling frequently used to assess the consequences of a policy on a market (Francois and Hall, 1997). PE models are comprehensive market models that describe particular groups of agricultural sub-sectors through analysing the interaction among prices, supply and demand using a set of equilibrium equations (Kotevska *et al.*, 2013; Janda *et al.*, 2012). This type of modelling also looks into the impact of a policy on the producers’ income and supply of products as well as the interdependency of agricultural inputs and outputs between different product lines. Partial equilibrium analysis examines the effects of policy action in creating equilibrium only in that particular sector or market which is directly affected (Janda *et al.*, 2012). Partial equilibrium models have been widely used in the forestry, livestock-feed, meat market, sugar market and biorefinery sectors, amongst many other examples (Latta *et al.*, 2013; Sorda and Madlerina, 2012; Alves *et al.*, 2008; Nolte, 2008; Ignaciuk *et al.*, 2006). As South Africa (SA) is already investing in the establishment of a biorefinery approach for the sugar industry, partial equilibrium modelling is relevant to the South African sugar industry case (Brent, 2014). It will enable the analysis of the various impacts of biorefinery establishment on the supply side of the sugar supply chain (the growers) and the demand side of the supply chain (millers).

Building blocks of the partial equilibrium model

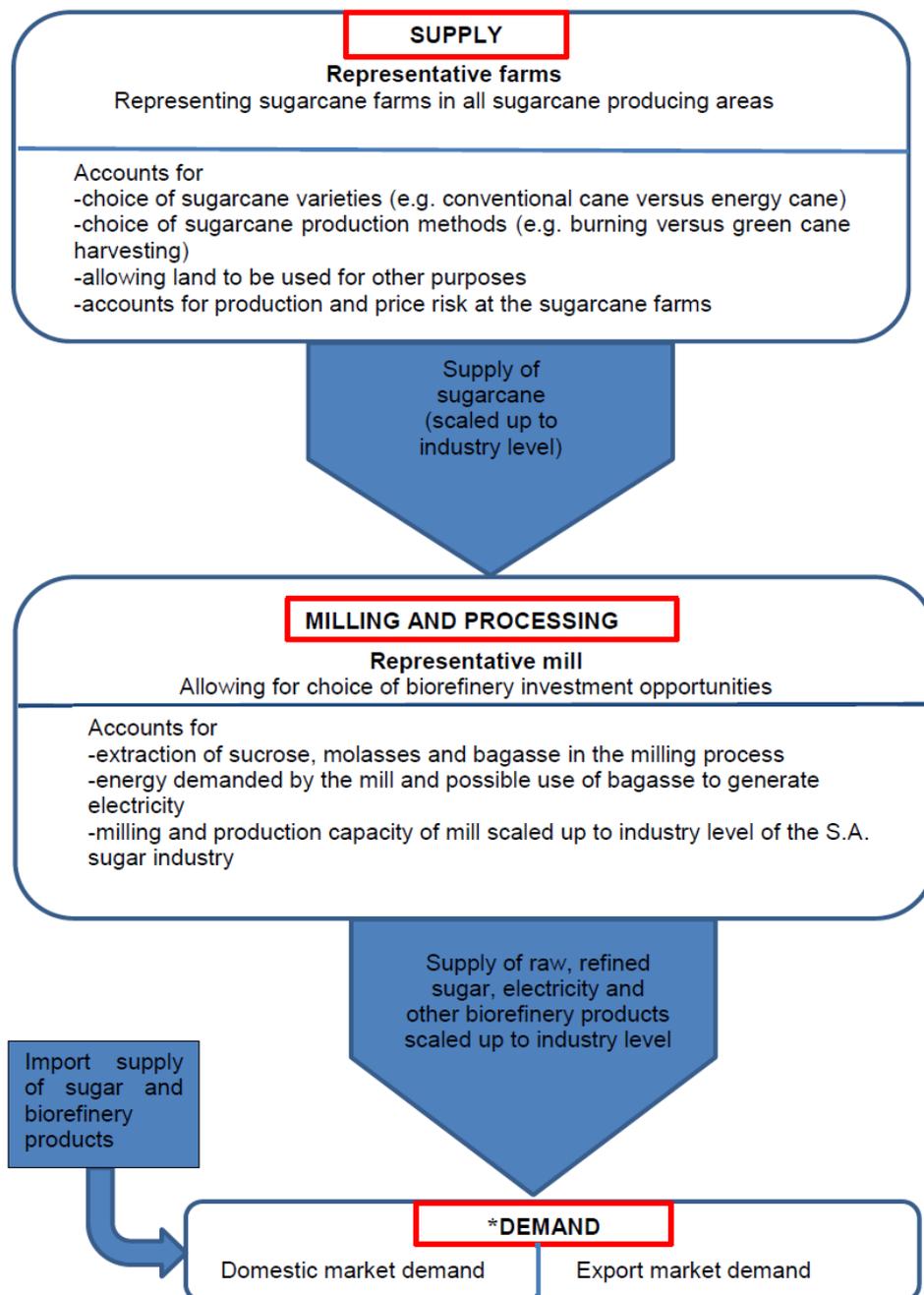
According to Parappurathu (2007), a typical agricultural partial equilibrium model consists of two main central systems; the producer system that represents the supply side of the commodity in question, and a consumer system to represent the demand side of the commodity. In this research the commodity under analysis is sugarcane which is a raw material for the biorefinery products that can potentially be produced from sugarcane processing. The supply side will be represented by linear programming models of representative sugarcane farms. Likewise, a model of a representative mill will be used to represent the processing of sugarcane at a biorefinery. The demand by the mill for molasses, sucrose and bagasse from sugarcane will be derived from the domestic and export market demands for a representative set of products that could be produced by a sugarcane biorefinery (butanol, furfural, bioplastics and electricity generation by the mill and possible sale). Figure 1 below summarises the components of the model.

Model optimisation

The model will be optimised using two scenarios which are:

- a. Maximisation of consumer plus producer surplus which simulates a free market scenario (Norton and Hazel, 1986); and
- b. Maximisation of total revenue by the industry for the purposes of DOP which simulates a heavily regulated industry scenario.

Optimising the model will result in the determination of the prices and quantities of final products in the markets, which biorefining investments are undertaken at the mill, and how the derived demand for molasses, bagasse and sugar impacts on the optimal selection of on-farm production systems and sugarcane varieties.



*Demand component accounts for the relationship between price and quantity demanded in each market for each product

Figure 1. Illustration of the building blocks of the partial equilibrium model

Model verification

Model accuracy will be determined by analysing the ability of the model to accurately simulate prices, input use and historical patterns. Expected values from the results will be replaced with values obtained in the previous year and the correlation between the two noted. A calculation of percentage absolute deviations and a comparison of the value marginal product estimate versus actual prices will aid in the validation process.

Product choices and division of proceeds scenarios

The choice of representative products is set to include other biorefinery products that can be made from sugar, molasses or bagasse. DOP scenarios that will be considered in the model include the current scenario with DOP arising from molasses and sugar sales, and scenario two that includes sales from molasses, sugar and other biorefinery products.

Conclusion

This paper presents the building blocks of a PE model aimed at identifying the likely direction in which the biorefinery economy will evolve in the SA sugar industry. The results that will be obtained can provide crucial information relevant for policy makers and other stakeholders in the sugarcane industry.

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REFERENCES

- Alves E, Gazzola R, and Marra R (2008). The meat market in Brazil: a partial equilibrium model. *Revista de Economia e Sociologia Rural*, 46(4):1189-1208.
- BFAP (2015). Navigating policy and strategies in a turbulent world economy. [Internet] Bureau for Food and Agricultural Policy Baseline Agricultural Outlook 2015- 2024. Available from: http://www.bfap.co.za/documents/baselines/BFAP_Baseline_2015.pdf [Accessed 13 June 2016].
- Brent A (2014). The agricultural sector as a biofuels producer in South Africa. Understanding the Food Energy Water Nexus. WWF-SA, South Africa.
- Francois JF and Hall HK (1997). Partial equilibrium modeling. *Applied methods for trade policy analysis: A handbook*, pp.122-155.
- Hildebrand QL (1998). Maximising profits from sugar through optimising the length of milling season. *Proceedings of the Annual General Meeting of the South African Sugar Agronomists Association*, Mount Edgecombe, Durban, South Africa 26:1-6.
- Ignaciuk A, Vöhringer, F Ruijs, A and van Ierland EC (2006). Competition between biomass and food production in the presence of energy policies: a partial equilibrium analysis. *Energy policy*, 34(10):1127-1138.
- Janda K, Kristoufek L and Zilberman D (2012). Biofuels: Policies and impacts. *Agricultural Economics*, 58(8):372-386.
- Kotevska A, Dimitrievski D and Erjavec E (2013). Partial equilibrium model as a tool for policy analysis in agriculture: an empirical evidence of Macedonia. In *50th Anniversary Seminar, Agriculture and Rural Development: Challenges of Transition and Integration Processes, September 27, 2013* (No. 161772). University of Belgrade, Department of Agricultural Economics, Faculty of Agriculture.

- Latta GS, Sjølie HK and Solberg B (2013). A review of recent developments and applications of partial equilibrium models of the forest sector. *Journal of Forest Economics*, 19(4): 350-360.
- Lejars C, Le Gal P and Auroux S (2008). A decision support approach for cane supply management within a sugar mill area. *Computers and Electronics in Agriculture*, 60:239-249.
- Moor GM and Wynne AT (2001). Economic maximisation of grower and miller sugar cane profits: optimising the length of milling season at South African sugar factories. *International Society of Sugar Cane Technologists' 24:245-249*. Proceedings of the XXIV Congress, Brisbane, Australia, 17-21 September 2001.
- NAMC (2013). *Document 1: Overview of the Sugar Industry in South Africa. Contribution to Social and Economic Development and Contentious Issues*. Growing the Sugar Industry in South Africa Series. Unpublished Report of the National Agricultural Marketing Council Pretoria, RSA, 49p.
- Nolte S (2008). The future of the world sugar market: a spatial price equilibrium analysis. In *107th European Association of Agricultural Economists (EAAE) Seminar: Modelling Agricultural and Rural Development Policies*.
- Norton RD and Hazell PB (1986). *Mathematical programming for economic analysis in agriculture*. Macmillan; London: Collier Macmillan.
- Parappurathu S (2007). Partial Equilibrium Models for Agricultural Policy Analysis. *Rev. Agric. Econ.* 27(2):164–180.
- Sorda G and Madlener R (2012). Cost-Effectiveness of Lignocellulose Biorefineries and their Impact on the Deciduous Wood Markets in Germany.
- Wynne AT (2001). Delivery efficiencies and cane quality in the South African sugar industry: benchmarking and penalty allocations. *Proceedings of the South African Sugar Technologists' Association, Mount Edgecombe, Durban, South Africa 75:38-42*.