Food Policy 55 (2015) 22–32

Contents lists available at ScienceDirect

Food Policy

journal homepage: www.elsevier.com/locate/foodpol

Benchmarking the sustainability performance of the Brazilian non-GM and GM soybean meal chains: An indicator-based approach

Daniel Gaitán-Cremaschi [a,*], Farahnaz Pashaei Kamali [a], Frits K. van Evert [b], Miranda P.M. Meuwissen [a], Alfons G.J.M. Oude Lansink [a]

[a] Business Economics Group, Wageningen University and Research Centre, P.O. Box 47, 6700 AA Wageningen, The Netherlands
[b] Plant Research International, Wageningen University and Research Centre, P.O. Box 16, 6700 AA Wageningen, The Netherlands

ARTICLE INFO

Article history:
Received 7 October 2014
Received in revised form 4 February 2015
Accepted 19 May 2015
Available online 10 June 2015

Keywords:
Sustainability performance
Total Factor Productivity
Total Price Recovery
Soybean meal chain
Externality

ABSTRACT

A commonly accepted approach for measuring the sustainability of agricultural products is the first step toward treating traded products differentially according to their sustainability. If we were able to measure sustainability, business stakeholders could optimize food production chains, consumers could demand products based on reduced environmental and social impacts, and policy makers could intervene to meet the growing demand for food in a context of environmental conservation, population growth, and globalization. We proposed to measure profit adjusted for the negative externalities of production as a promising single metric for benchmarking products in terms of their relative sustainability. The adjusted profit differences between different products are then assessed by means of the Bennet Total Factor Productivity (TFP) indicator and the Total Price Recovery (TPR) indicator to highlight areas for potential sustainability improvement. To illustrate the usefulness of the indicator-based approach, we assessed the relative sustainability of two Brazilian conventional soybean meal chains, non-genetically modified (non-GM) and genetically modified (GM) chains. Based on the results, we indicated potential areas for sustainability improvement. Sustainability issues included in the assessment were profitability, global warming potential, eutrophication potential, environmental toxicity, farmworker toxicity, consumer toxicity, deforestation, and loss of employment. Results showed that the non-GM soybean meal chain is more sustainable than the GM chain (higher adjusted profit due to higher TFP and favorable prices especially for outputs). However, both chains require joint efforts to address their economic, environmental, and social deficiencies. These efforts should focus on providing technical and high quality assistance to reduce biocide use, and improving transportation. The analysis in this study could be extended by undertaking a comparative assessment of the sustainability performance of major soybean meal producers, i.e. United States, Argentina, China, and Brazil.

The approach proved to be a promising benchmarking tool for agricultural trade flows. It allows an integrated assessment of the dimensions of sustainability along food chains that is sufficiently flexible to compare the sustainability level of various biomass stocks that are produced in different locations and in a variety of environmental and socio-economic contexts. Nevertheless, it requires consensus on which components of sustainability are to be assessed.

Introduction

Soybeans are one of the main raw materials in the world (Jaguaribe Pontes et al., 2009). Brazil is the second largest soybean producer, following the United States, with a production of 74.8 million tons from 24 million hectares in 2011 (IBGE, 2013). In Brazil, soybeans are predominantly produced in conventional farming systems, either using non-genetically modified (non-GM) seeds, i.e. the non-GM system, or genetically modified (GM) seeds, i.e. the GM system. The GM system is different from its non-GM equivalent only insofar as the gene that confers degradation of the herbicide glyphosate by the soy plant (MAGP and IICA, 2012). This means that the GM soy plant is resistant to the herbicide glyphosate whereas its non-GM equivalent is not. In the GM system, glyphosate can be applied after the crop has emerged to remove weeds without causing crop damage (MAGP and IICA, 2012;

* Corresponding author at: P/a Hollandseweg 1, Lst gr, Business Economics Group, Wageningen University, 6706 KN Wageningen, The Netherlands. Tel.: +31 7 484065.

E-mail address: daniel.gaitancremaschi@wur.nl (D. Gaitán-Cremaschi).

http://dx.doi.org/10.1016/j.foodpol.2015.05.006
0306-9192/

Meyer and Cederberg, 2010). In contrast, the non-GM system requires the use of a variety of selective herbicides and/or non-chemical methods such as mechanical measures (Meyer and Cederberg, 2010). For both types of farming systems, the harvested soybeans are crushed into two main products, soy oil and soybean meal. The soybean products are then transported, traded, and sold to manufacturers in different industries. Soybeans are used for human consumption, as an input in integrated supply chains for livestock production, and in the production of many by-products, such as paints and greases (Jaguaribe Pontes et al., 2009; The Dutch Soy Coalition, 2008; WWF, 2003). The main trade destinations for soybean products are the European countries and China (Ortega et al., 2004).

Soybean production and its associated industry have brought widespread economic benefits and wealth to Brazil. The agricultural sector contributes up to 27% of Brazilian GDP (Aprosoja, 2014). Nevertheless, the rapid growth of the soy industry has raised concerns about environmental and social sustainability, due to the negative externalities of production, i.e. the external costs that are borne by society (Ortega et al., 2004; Willaarts et al., 2013). Soybean production is associated with environmental costs, such as deforestation, pollution of water bodies and soil, and costs associated with the transportation of soybeans and their derived products. Potential deforestation of the Brazilian biomes, such as the Amazon, the Cerrado, and the Mata Atlântica, can lead to the loss of ecosystem functions and services (WWF, 2003). Pollution of water bodies and soil is mainly caused by the large quantities of pesticides and fertilizers used in soybean production (Pimentel et al., 2009; Willaarts et al., 2013). Soybeans and their derived products are often transported large distance from farms to the crushing units and then on to the importing countries. Transportation of soybeans requires large quantities of fossil fuel combustion, which contributes to the depletion of non-renewable energy sources and climate change. In addition to environmental costs, social costs are also relevant. Soybean plantations are not labor intensive, with an average of one farmworker per 167 ha of soybeans; for large plantations this is reduced to one per 200 ha (Fearnside, 2001). This has resulted in farmworkers migrating to urban areas and the subsequent depopulation of the countryside (Fearnside, 2001; The Dutch Soy Coalition, 2008; WWF, 2003). For example, in the North of Paraná, labor intensive crops, such as coffee, were replaced by soybean cultivation, which resulted in a reduction in agricultural employment (WWF, 2003).

The soybean products derived from non-GM and GM soybeans differ in terms of the economic, environmental, and social sustainability performance throughout the production chain. It is expected that stakeholders, i.e. business stakeholders, consumers, and policy makers, would want to treat traded non-GM and GM soybean products differently according to how sustainably they were produced. Certification schemes are currently used for such differentiation (Sundkvist et al., 2005). These schemes typically cover life cycle issues of a product and often, although in some cases not explicitly stated, use life cycle assessment (LCA) methods. The labels and standards used in these schemes, however, are not commonly accepted (Gaitán-Cremaschi et al., 2014). The current schemes have two main limitations, which are inherent in the use of LCA methods: (i) social and economic implications of food production are often left aside, and (ii) the outcomes of the environmental impacts are measured using different units and cannot be aggregated into a single metric. Hence, decision makers can only judge the most sustainable product by using their own weighting factors, which explicitly rely on complicated trade-offs between sustainability issues that are not normally in their mind sets, e.g. kg of carbon dioxide (CO_2) versus kg of nitrates, (Gaitán-Cremaschi et al., 2014). Thus, certification schemes and their associated LCA methods have limited usefulness for benchmarking purposes.

Following Gaitán-Cremaschi et al. (2014), this paper proposes an integrated indicator, i.e. Adjusted Profit, that is based on the micro-economic theory of production, for benchmarking products in terms of their sustainability. The Adjusted Profit indicator takes into account the multiple input-output nature of an agricultural supply chain, accounts for the negative externalities of production and, provides a single integrated measure of sustainability performance. The approach integrates the multiple outputs (products), inputs (capital, labor, materials, energy, and services), and externalities (e.g. environmental and social impacts such as pollution and loss of employment) along the supply chain into adjusted profits, using a common denominator, money (Barnett et al., 1995). Observed prices can be used for the marketable inputs and outputs, and shadow prices can be attached to the externalities arising from production. Based on the Adjusted Profit indicator, a product is more sustainable than another if its adjusted profit is higher (Gaitán-Cremaschi et al., 2014). To allow a consistent comparison between the adjusted profits of different products, an index number methodology, the Bennet Total Price Recovery (TPR) indicator and the Bennet Total Factor Productivity (TFP) indicator, can be used. Using the Bennet indicators, the variation of total adjusted profit between production chains can be decomposed into variation caused by price differences (the price component reflects differences in TPR) and variation caused by quantity differences (the quantity component reflects differences in TFP) for each output, input, and externality. The latter, pointed as a key element of sustainability (Barnes, 2002; Barnes and McVittie, 2006; Barnett et al., 1995; Ehui and Spencer, 1992; Glendining et al., 2009; Lynam and Herdt, 1989). Such information is valuable as it highlights areas for potential sustainability improvement. Additionally, it provides information that can be used to rank products in terms of their sustainability. Hence, it gives information that can be used to provide market access preferences to products with the highest adjusted profit or green-tariffs to products with the lowest adjusted profit.

The objective of this study was to assess the relative sustainability performance of the Brazilian non-GM and GM soybean meal production chains using the indicator-based approach, and to determine potential areas for improving sustainability according to the sources of variation along these chains.

Data and methods

Indicator-based approach

The Brazilian soybean meal chain, for both non-GM and GM, is defined in this study as a set of four life cycle stages, z = 1, 2…4, integrated in an input–output system: agricultural ($z = 1$), processing ($z = 2$), transport to port ($z = 3$), and transoceanic transportation ($z = 4$). The chain is modelled up to the destination port (Rotterdam Port). At each stage, multiple inputs, denoted by vector x, are transformed into multiple outputs, denoted by vector y. As side effects of production, multiple environmental and social externalities are produced, expressed by vector b, such as waste, pollution, poor working conditions, and loss of biodiversity (Fig. 1). The soybean meal chain has a positive (negative) adjusted profit (AP) if the difference between the aggregated outputs and the aggregated inputs is positive (negative), as the externalities are output penalties that lower the score:

$$\mathrm{AP} = p'y + r'b - w'x \tag{1}$$

The multiple outputs, inputs, and externalities are aggregated using vectors of (shadow) prices, p, w, and r, respectively.

We assume that there are $k = 1, \ldots, K$ observations for the non-GM soybean meal chain and $m = 1, \ldots, M$ observations for the GM soybean meal chain. To assess the relative sustainability