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Review

Integrated planning model for citrus agribusiness system using systems dynamics

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ABSTRACT

Integrated planning of agricultural and industrial productions in an agrichain may increase the competitiveness of the entire chain and bring benefits to all of its agents. In turn, systems dynamics models could be used to explore and assess quantitatively these benefits. The main objective of this paper was to build a system dynamics model to assess whether integrated mechanisms of agricultural and industrial production planning can improve the competitive performance of the citrus agrisystem in Brazil. The scenarios tested by the model used the gradual introduction of new orange varieties and technological changes in the citrus production. Our paper considers that changes in these parameters have the potential to provide gains to the system by using the expanded capacity implemented by the industries throughout the year, by reducing inventories and blending operations, reducing costs by eliminating seasonal workers, among other factors. The results achieved from the model indicate that integrated production planning mechanisms can effectively improve the coordination of agro-industrial production systems. Moreover, it was demonstrated that models based on Systems Dynamics are suitable to assess these improvements. The model application and assessment results showed that integrated planning can increase the income per hectare of agricultural producers by 70% and the agribusinesses EBITDA margin by 43%. Thus, this study has shown that the use of integrated planning mechanisms is an important strategy for the Brazilian citrus agribusiness system to exploit its growth potential and to remain competitive.

Contents

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1. Introduction

Systems Dynamics-based analysis can be very useful when planning the production of agrifood systems. This method quantifies the gains obtained in the chain as a whole and its agents from the implementation of an integrated planning of agricultural and industrial production. The model was implemented from actual data that is previously unpublished in national and international literature. This quantification enables demonstrate empirically the benefits that the coordination in theory provides for an agrifood system.

In this paper integrated planning refers to processes that involve agricultural and industrial production in a single agrisystem (Scramim, 2004). In fact, the production and marketing processes that take food from the field to the final consumer (from farm to table) require a set of decisions by the players of the agribusiness production chains, including the agricultural production and the industry that processes this production (Batalha and Silva, 1999). Proper coordination of these decisions can improve the overall efficiency of the system by limiting unwanted fluctuations in the production levels and inventories of finished products, intermediate goods and raw materials.

The supply chain management area can contribute, while making use of knowledge in systems dynamics applied to the study of agroindustrial production systems. The premises of supply chain management reinforce the importance of organizations in a specific agribusiness system to continuously exchange information so it can be used in coordinated planning methods. In this context, cooperative practices that allow the integrated planning of productive activities by the players in the agrisystems should be included in the goals to be achieved (Batalha and Silva, 1999).

In situations of uncertainty related to production processes and marketing, in order to leverage resources and expertise with the suppliers and customers, companies usually strive for greater cooperation within their supply chains. Collaborative behaviors can increase competitive advantage and business performance, mitigating the risks related to their participation strategies in their supply chains. Cooperation, maintaining independence and competition between companies are crucial aspects to provide synergies and create higher performance levels in the system (Cao and Zhangb, 2011).

Integrated planning mechanisms that strive for greater competitiveness in a production system cannot disregard production coordination tools of its players (Van der Vorst et al., 2007). It should be noted that only adaptations in the contractual mechanisms may not be sufficient to ensure this coordination. Without going into the question of whether the contractual arrangements are both cause and consequence of new productive arrangements, they should go hand in hand with any changes in the production logic of the socio-economic players involved in the process. Either way, it seems indisputable that the common planning of production operations, marketing and distribution improves the coordination of the chains and thus increases their competitiveness.

In Brazil, the orange agribusiness system has faced coordination problems in the past between the agricultural production players and industrial processing. The trust relationship between these two links in the chain is quite fragile, and there are many extremely conflicting business relationships. This situation has resulted in losses for the entire system. We should keep in mind that Brazil, followed by the US, is the leading producer and exporter of orange juice and its by-products (Neves and Jank, 2006).

The Orange agribusiness system in Brazil creates roughly 200,000 direct and indirect jobs, generating earnings of more than 6.0 billion US$/year (Citrusbr, 2015).

Thus, the objective of this study is to assess whether better coordination, in terms of overall production planning of Orange Agroindustrial System, can improve its competitiveness. Practices and computational tools of Systems Dynamics will be used to use to create a planning model that involves the agricultural production and orange juice production chains of the citrus complex.

The results can be used to propose to the orange Agroindustrial System players the concept of dynamics systems as a support tool for short, medium and long term decision making.

2. Literature review

2.1. Using systems dynamics in the planning of agribusiness production systems

The most widespread disseminated study of the productive systems dynamics can be attributed to Jay Forrester (Pidd, 1992). It was this researcher who laid the foundations of this discipline in his book Industrial Dynamics, published in 1961. In the 1980s and more intensely in the 1990s (the release of the book The Fifth Discipline can be used as a point of reference), there was a considerable increase in the number of publications on the subject (Senge, 1994). Over time systems dynamics analysis has been used in the modeling of production systems and more specifically in production chains, as a decision making support tool (Fisher et al., 2000; Lowe and Preckel, 2004; Schepers and Van Kooten, 2006; Fritz and Schiefer, 2008; Stephens et al., 2012; Miller and Newell, 2013).

Systems dynamics models are considered to have an interpretive epistemological standpoint. The systems dynamics divides the modeling and simulation process into a qualitative and quantitative phase. The qualitative phase consists of preparing the conceptual problem. This phase includes collecting information about the supply chain to be analyzed and the objective of the analysis, followed by the preparation of influence diagrams and stock-flow diagrams. The next phase, quantitative, refers to the technical problem, which means that the mathematical formulation of the problem, its validation and scenario and sensitivity analysis are conducted in this phase. The whole modeling process is consolidated by the constant feedbacks of this methodology (Towill, 1996).

Simulation can help understand the causality of events and decisions in a supply chain and agribusiness supply chains are no exception.

Using simulation in a supply chain serves to generate knowledge about its operation dynamics, propose and simulate scenarios to support its players' decision-making and the possibility to quantify the advantages resulting from implementing the various supply strategies (Sterman, 2000).

Bititci et al. (2004) highlight the advantages that cooperation and coordination can bring to the players of a supply chain. Increased market share, higher asset utilization, better customer service, share and reduce research and development costs, reduce the time and risk of failure to develop new products, share knowledge management, better quality products, gains from economies of scale, reduced inventory levels and faster market access are some of these advantages.

The use of Systems Dynamics models can support the coordination improvements of agroindustrial supply chains, which begins as a positive cooperation between its players (Matopoulos et al., 2007). However, the specifics of the agrifood systems impose restrictions to the potential cooperation strategies (Tsolakis et al., 2014).