Olive Oil Industry Dynamics: The Case of Turkey

The 35^{th} International Conference of the System Dynamics Society, Cambridge, MA, USA, 2017

Büşra Atamer Balkan and Sedef Meral

Middle East Technical University, Industrial Engineering Department, Ankara, Turkey

busra.atamer@metu.edu.tr, sedef@metu.edu.tr

Abstract

Turkey is one of the top five olive oil producers of the world. In recent years, consumer prices for olive oil have unexpectedly and dramatically increased despite the decreasing producer prices. Additionally, the benchmarking study conducted for Turkish olive oil value chain shows that there is a "share of value" gap among the value chain participants. These symptoms indicate that the economical sustainability of olive oil industry in Turkey is in question.

In this study, taking the case of olive and olive oil, we focus on the complicated structure of the agricultural industry dynamics. Our research objectives are to understand and explain how value emerges as a result of agricultural industry dynamics, to investigate the effect of speculative dynamics and inventories in agricultural industries, and to make policy analysis and recommendations in order to maintain the economical sustainability of Turkish Olive Oil Industry. A System Dynamics model which includes both the supply chain and the value chain structures of the industry is constructed. The initial results are found to be in compliance with the real world observations. The future work is planned to include the completion of model validation, scenario and policy analyses.

Keywords: System dynamics, agricultural industry dynamics, speculative dynamics, value chain analysis, olive oil industry, agricultural policy analysis

1 Introduction

Agriculture is the major source of several industries in the world. The agricultural value chains are fundamental to the survival of human society, the growth or maintenance of regional and national economies, and the wealth and welfare of individual producer (Higgins et al., 2010). Understanding and explaining how value of agricultural products emerges at the market as a result of agricultural industry dynamics is a complex research problem. In this study, considering the complexity of agricultural industries and focusing on Turkish olive oil industry, we aim to understand and explain the agricultural industry dynamics and make policy analysis and recommendations for the Turkish olive oil industry via utilizing System Dynamics Modeling.

Turkey, with its geography and biodiversity, is home to several industrial agricultural products of strategic importance. Hence, policy analysis for Turkish agricultural industries constitutes a critical research area. One strategically important agricultural product of Turkey is olive oil and hence its raw material, olive fruit. Olive oil is strategically important, because Turkey is one of the top five largest olive oil producers of the world, satisfies the domestic demand to its fullest extent and exports olive oil to more than 50 countries. Despite this positive outlook, stakeholders in the sector, from the olive farmers to consumers, are unsatisfied with the condition of the Turkish olive oil market. In recent years, consumer prices for olive oil have unexpectedly and dramatically increased despite the decreasing producer prices. Additionally, it is observed that there is a "share of value" gap among the olive oil value chain participants. These symptoms indicate that the economical sustainability of olive oil industry in Turkey is to be investigated.

Our research objectives are to understand and explain how value emerges as a result of agricultural industry dynamics, to investigate the effect of speculative dynamics and inventories in agricultural industries and to make policy analysis and recommendations in order to maintain the economical sustainability of Turkish Olive Oil Industry. In this study, a System Dynamics model which includes both the supply chain and the value chain structures of the industry is constructed. Although model validation has not been completed yet, initial results are in compliance with the real world observations. After the completion of the model validation, scenario and policy analyses will be conducted.

The paper is organized as follows. In Section 2, problem context is presented with a summary of relevant products, processes, observations and results of data analysis. The results of value chain analysis and benchmarking studies are also presented in this section. In Section 3, problem definition, dynamic hypothesis and research objectives of the study are stated. In Section 4, the methodology and the relationship between the research problem and system dynamics modeling are summarized. In Section 5, the Olive Oil Model is presented with its assumptions, structure and behavior. Based on some selected representative subsystems, the variables and their analytical and mathematical relationships are presented. The paper is concluded and future work is summarized in Section 6.

2 Problem Context

Before presenting the dynamic problem and our research objectives, the problem environment is summarized with the relevant products, processes, definitions and data analysis results.

Figure 1: Olives

Olive and Olive Oil: Olive is a Mediterranean plant cultivated for its fruit which is an important food and source of oil (Figure 1). The olive fruit is a drupe. It has a bitter component (oleuropein), a low sugar content (2.6-6%) compared with other drupes (12% or more), and a high oil content (12-30%) depending on the time of year and its variety. Due to these characteristics, olive is a fruit that cannot be consumed directly from the tree; it has to undergo a series of processes that differ considerably by region and by variety (International Olive Oil Council Website, Online Access: March 2017).

Olive fruit is consumed in two main forms: table olives and olive oil. In this study, we focus on olive oil industry dynamics and consider the behavior of table olives industry only as a given set of parameters in the problem environment.

In order to obtain olive oil from olives, several processes that olives undergo, from olive tree to consumers' tables, can be aggregated under four headings:

1. Olive Growing and Harvesting
2. Olive Oil Extraction
3. Olive Oil Production (Refining (if required), Filtering, Packaging, Labeling)
4. Olive Oil Distribution and Selling.

Processes start with **Olive Growing and Harvesting** the raw material of olive oil. In the northern hemisphere, the olive harvest season is around the last quarter of the year. Depending on the technology used, the olive fruit from the tree is either combed into nets or hand picked into baskets or collected with mechanical pickers.

After harvesting, olives are filled into sacks or plastic boxes, and transported to olive oil extraction mills. In **Olive Oil Extraction**, oil is obtained from the fruit solely by mechanical or other physical means. Extracted olive oil is analyzed for its qualifications and then filled into large tanks as Bulk Olive Oil.

In the **Olive Oil Production** phase of the process, depending on its qualifications, olive oil is either directly filtered, packaged, labeled and turned into Packaged Olive Oil or first sent to olive oil refineries and then joins in the remaining phases.

As Olive Oil Production phase is completed, olive oil is ready for **Distribution and Selling**. Packaged Olive Oil is either exported or distributed to domestic wholesalers, and then reach the retailers' shelves for consumers.

World Olive Oil Market: World olive oil production, consumption and trade are carried out mainly in countries bordering the Mediterranean Sea. More than 95% of olive oil supply and 80% of olive oil consumption are centered in the Mediterranean countries. European Union countries, especially Spain, Italy and Greece are the three most important players in the world market. Spain is by far the biggest supplier, followed by Italy and Greece. Syria, Turkey and Tunisia have close production amounts. The top 9 producer countries, including Morocco, Portugal, Algeria and the countries stated above, produce more than 90% of the world olive oil supply (see Figure 2). On the other hand, the participants of the global olive oil consumption are not limited with the producer countries. Most of the recent increases in olive oil consumption figures are observed in non-producing countries (Lynch et al., USITC, 2013). United States is the top consumer and importer outside of the European Union. United States also invests in olive growing and olive oil production; hence its role as a producer country is expected to expand in the following years. China, Canada, Japan, Brazil and Australia are other examples of growing markets in the world.

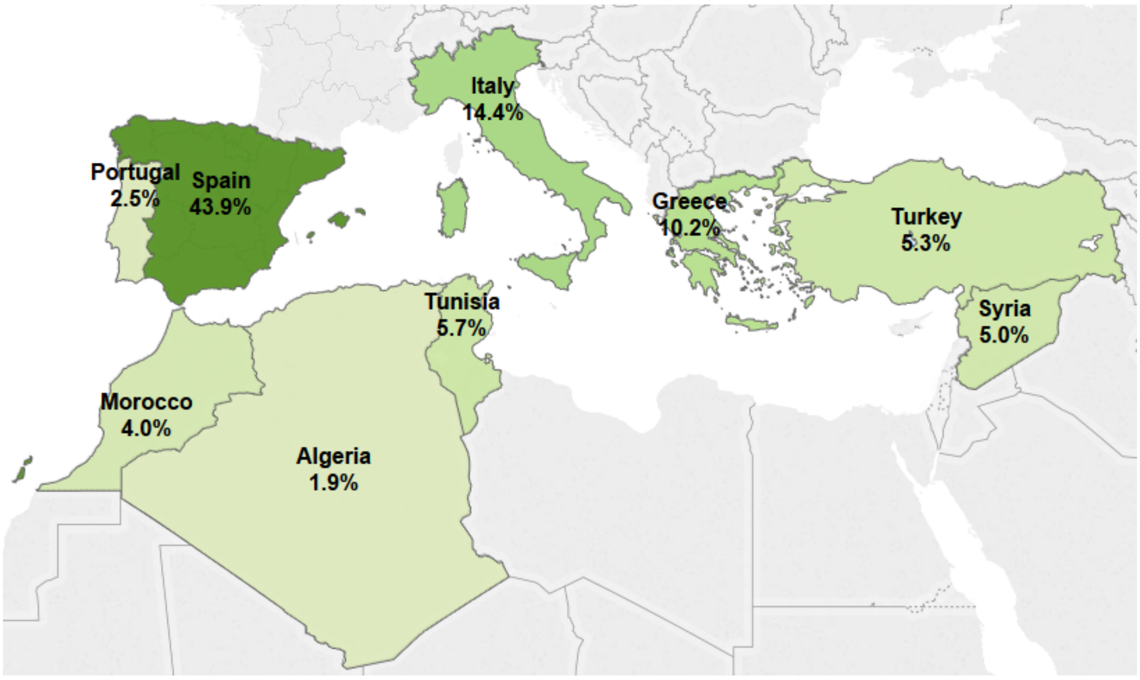

Figure 2: Top 9 Producer Countries and Their Share in World Olive Oil Production (2007 - 2016) (Data Source: International Olive Oil Council.)

For detailed information on world olive oil market, one can refer to reports published by international organizations such as Country Profiles Reports published by the International Olive Oil Council (IOC, 2012) or Olive Oil Report published by USITC (United States International Trade Commission) (Lynch et al., USITC, 2013). Within the context of this study, we review the relevant literature which utilizes mathematical modeling tools and focus on the relationships among price, supply and demand of olive oil. These studies can be exemplified as follows:

Siskos et al. (2001) focus on French olive oil market and use multicriteria approach in analyzing consumers' preferences for a new agricultural product. Berloni et al. (2002) construct a set of logarithmic regression equations and present a "static" mathematical model for the Italian olive oil market. Migdalas et al. (2004) investigate the economic impact of changes in European policy and industry on the olive oil sector, formulate a mathematical model for the olive oil sector in the island of Crete and simulate the olive oil market equilibrium. Amores and Contreras (2009) propose an allocation system for subsidies via internalizing the positive and negative externalities of agricultural activities in olive-growing farms in Andalusia, Spain. Kavallari et al. (2011) identify the factors determining the olive oil demand in non-producing countries, Germany and UK for their case. Sabbatini (2014) estimates the supply function of Italian olive oil using the double log transformation. Xiong et al. (2014) investigate key determinants of the demand for olive oil in the U.S. olive oil market and conclude that demand for olive oil is inelastic.

Turkish Olive Oil Market: Turkey is one of the top five olive oil producers of the world. The main focus of Turkish olive oil market is domestic consumption. During the last ten years, with the help of increasing government incentives, the number of olive trees has increased by almost 60% and planted acreage has expanded by almost 25% in Turkey. Olive oil production in Turkey continues to increase, providing surplus for increase in export figures. Since olive growing and milling sector has many small producers, participants are not able to benefit from economies of scale, and Turkey is considered to be a relatively high-cost producer in the global market.

The statistics on the number of trees and olive fruit harvest statistics can be found in Figure 3.

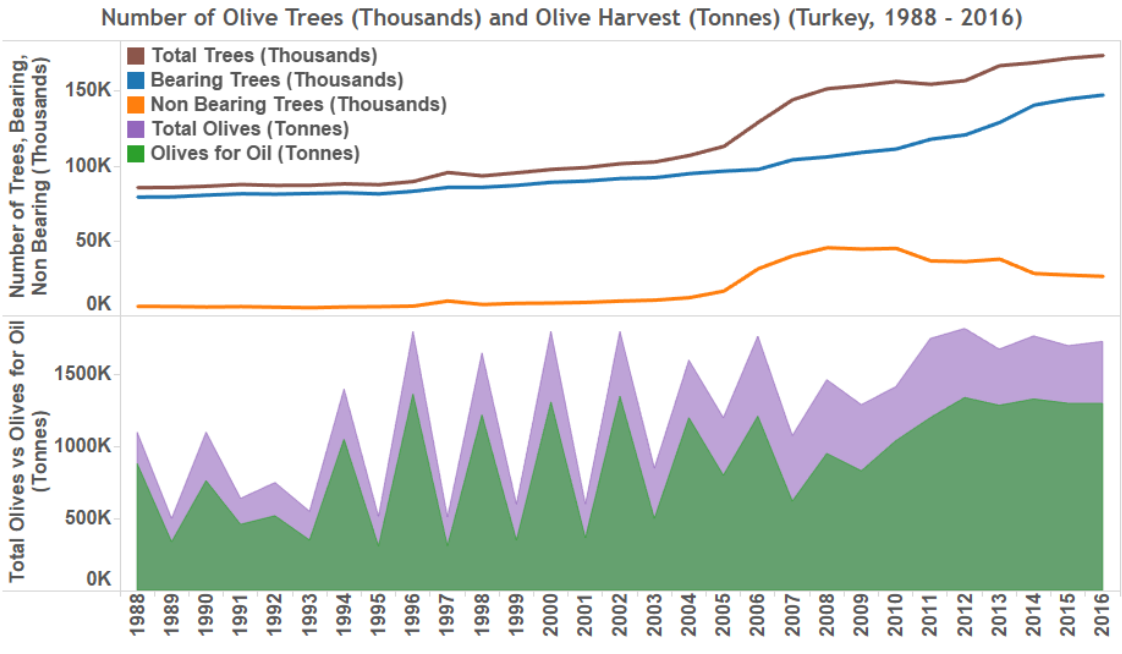

Figure 3: Number of Trees and Olive Harvest in Turkey, 1988-2016 (Data Source: Turkish Statistical Institute)

One prominent observation on the figure is that, in the last ten years, the number of olive trees has increased by almost 60%, but total olive fruit harvest has only increased by approximately 20%. The oscillating behaviour in harvesting among years is called “On/Off Effect” or “Alternation Effect” in olive growing. Before 2007, there is a significant level of alternation effect and the average of two consecutive years shows a steady behavior. Yet, after 2007, the effect of alternation decreases and olive supply shows an increasing trend.

While olive supply increases in the country, consumer prices for olive oil shows an unexpected behavior, especially in the last 2 years. Real and constant values for olive oil consumer prices in Turkey between 2003-2016 can be seen in Figure 4. Starting with the end of 2014, there is a sharp increase in prices which continues through the first half of 2016; and then, after a tipping point, they begin to decrease. Even though olive oil production cost figures almost stay constant for the regarding years, consumer prices for olive oil show a jump despite the increase in olive fruit, and hence olive oil supply. This unexpected behavior contradicts with the classical economy theory and brings about the questions on "the dynamics determining the market value of olive oil".

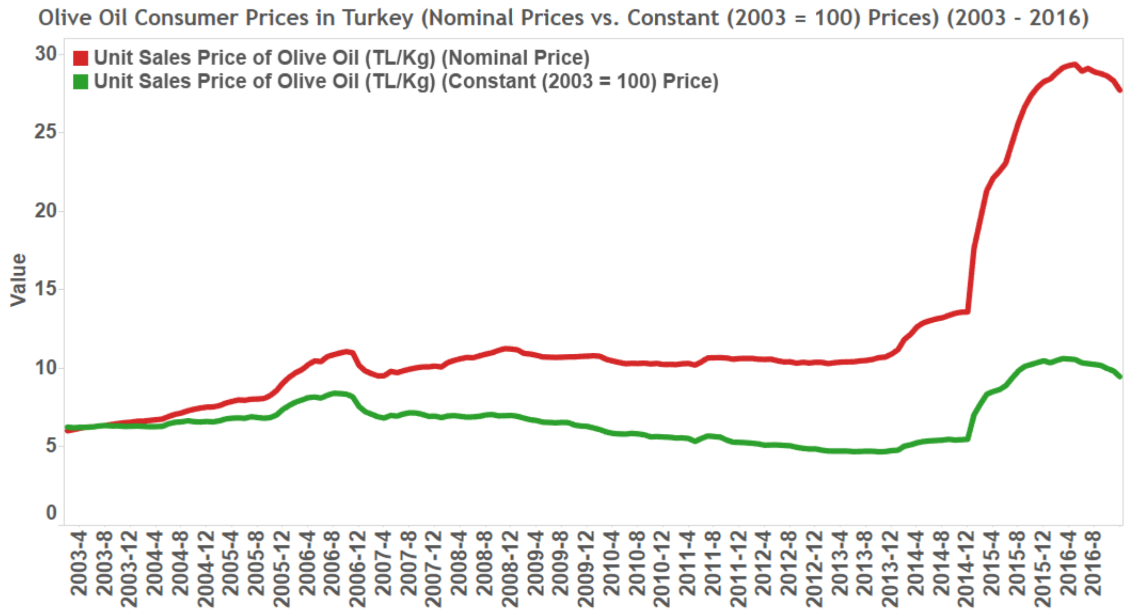

Figure 4: Olive Oil Consumer Prices in Turkey (Nominal Prices vs. Constant (2003 = 100) Prices) (2003 - 2016) (Data Source: Turkish Statistical Ins.)

Olive oil producers point out that, due to high consumer prices, more and more consumers eventually switch their preferences in the favor of "other vegetable oils" and as a result, olive oil demand will decrease. They worry about the fact that, in the near future, there will be a high level of excess olive oil supply, prices will dramatically go down and hence the economical sustainability of the olive oil industry in Turkey will be in question.

The Olive Oil Value Chain: In order to make the best of globalization, and hence entering into the global market powerfully for a sustainable growth, we need to understand the dynamic factors within the whole chain (Kaplinsky and Morris, 2002). As a key framework, The Value Chain perspective guides us in understanding the processes; how inputs and services are brought together and used to grow, transform, and produce a product; how the product moves physically from producer to customer; and how the "value" increases along the chain (Webber and Labaste, 2010).

In order to understand how value of olive oil evolves along the value chain, we consolidate the results of a comprehensive olive oil value chain study conducted in Spain (Lain, 2010) and the results of a similar data analysis we conducted in Turkey. In both studies, starting from agricultural production to consumption of extra virgin olive oil, cost and price added as a result of each process are investigated and compared. In the Turkey case, data from Turkey Olive Farming Sector Report (Ministry of Food, Agriculture and Livestock, 2016) and Olive and Olive Oil Product Report (Ministry of Food, Agriculture and Livestock, 2016) are used. The summary of the results can be seen in Figure 5. Since the two data sets (Spain and Turkey) belong to different harvest years, we compare the percentages instead of the nominal cost and price values.

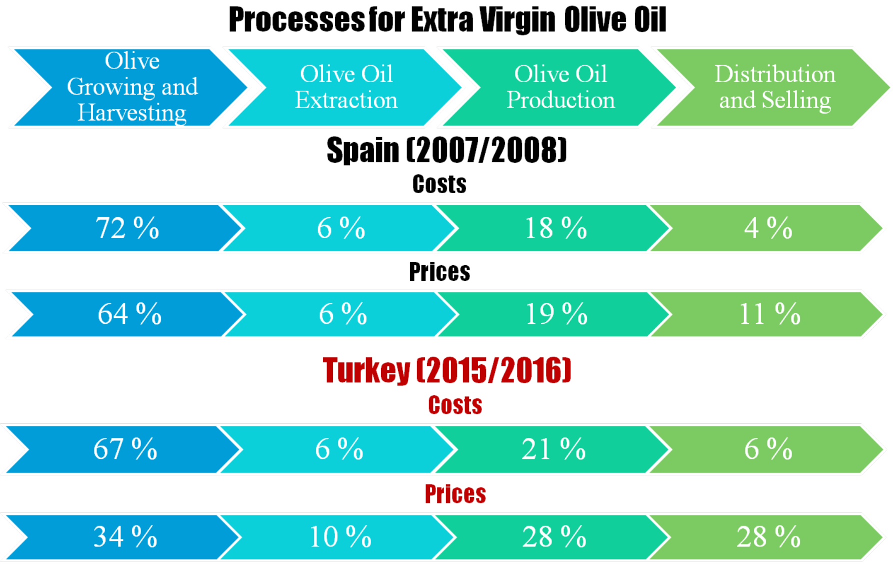

Figure 5: Comparison of Costs and Prices along the Value Chain: Spain vs. Turkey (adapted and updated from Atamer Balkan and Meral (2016))

When we compare cumulative percentages of cost and price values at the end of each stage, we can infer three evident results:

- We can see that percentages of costs are close to each other for Spain and Turkey, that is, the ratio of economical effort made for the final product is more or less the same for similar stakeholder groups of the two countries.
- When we compare percentages of cost and price in Spain, these values are again close to each other, that is, the share of economical effort made for the final product by a stakeholder group is close to the share of their earnings from the product.
- When we compare percentages of cost and price in Turkey, we observe significant gaps among the percentages; especially a negative gap in olive growing and harvesting and a positive gap in distribution and selling. These observations indicate the problem of "share of value" in the Turkish olive oil industry.

3 Problem Definition and Research Objectives

After presenting the definitions, the problem environment and the results of relevant data analysis, the problem in the olive oil industry in Turkey can now be summarized as follows:

With the effect of government supports for olive farming, olive tree inventory of Turkey has increased from 80 millions to 170 millions during the previous two decades. This increase brings about higher expectations for a growing olive and olive oil industry.

When compared to the other olive producer countries, olive farmers in Turkey face with low "yield by tree" values, and hence with higher unit costs of olive farming.

Due to low level of cooperatization, lack of price regulations or powerful commodity exchange markets, and lack of storage possibility for the farmers for olive or olive oil, they keep a portion of their products for self-consumption and/or roadside sales, and then usually sell the rest of their products to the traders/brokers at the best possible price. Traders/brokers store the olive oil as "bulk" and use the power of speculative inventories. As a result, they give rise to oscillations in market prices.

Olive oil producers buy bulk olive oil from traders/brokers at high prices. When prices are too high, they even import olive oil from other countries, although there is available inventory in the country. When the olive oil stands in the retailers' shelves, end consumers face with high sales prices that they naturally compare with the prices of other "vegetable oils", and consequently they may switch their preferences. As for the sales in the international market, Turkey sells at a price similar to that of the European Union countries, hence cannot compete with the countries like Tunisia that sells in higher volumes at a lower price.

Domestic olive oil market tends to shrink due to high selling prices. International olive oil market for Turkish olive oil also does not seem to be promising due to high production volumes and low prices of her competitors. Yet, Turkish olive and olive oil production potential has been growing with an increasing number of olive trees. This contradiction brings about the questions on the economical sustainability of olive oil industry in Turkey.

Our **dynamic hypothesis** can be explained as follows (see Figure 6):

An increase in governmental supports for the raw agricultural product (olive fruit in our case) leads to an increase in agricultural supply and hence a decrease in producer prices. When the raw agricultural product is processed and can be stored in intermediary inventories for longer periods (olive oil in our case, which can be stored in tanks for 1-1.5 years after the extraction process and in bottles for an additional 1.5-2 year period after the packaging process), actors along the value chain can make use of the power of speculative inventories. As speculative actors keep more and more intermediary inventories, available supply to final consumers decreases which leads to an increase in consumer prices. Although total supply in the industry increases, consumer prices keep increasing and the gap in the earnings of the stakeholders along the value chain increases. Increasing consumer prices is expected to lead to a decrease in consumption. In other words, agricultural supply in the long term is expected to increase whereas the demand for the final product is expected to decrease, which leads to a contradiction for the industry. Both the speculative increase in consumer prices and the ever widening gap in the earnings along the value chain threaten the economical sustainability of the agricultural industry (olive oil industry in our case). Redefining the policy parameters (such as government subsidies, plantation or production regulations, price floors / ceilings, etc.) is expected to reduce the gap in the earnings along the value chain and thus to help improve the economical sustainability of the industry.

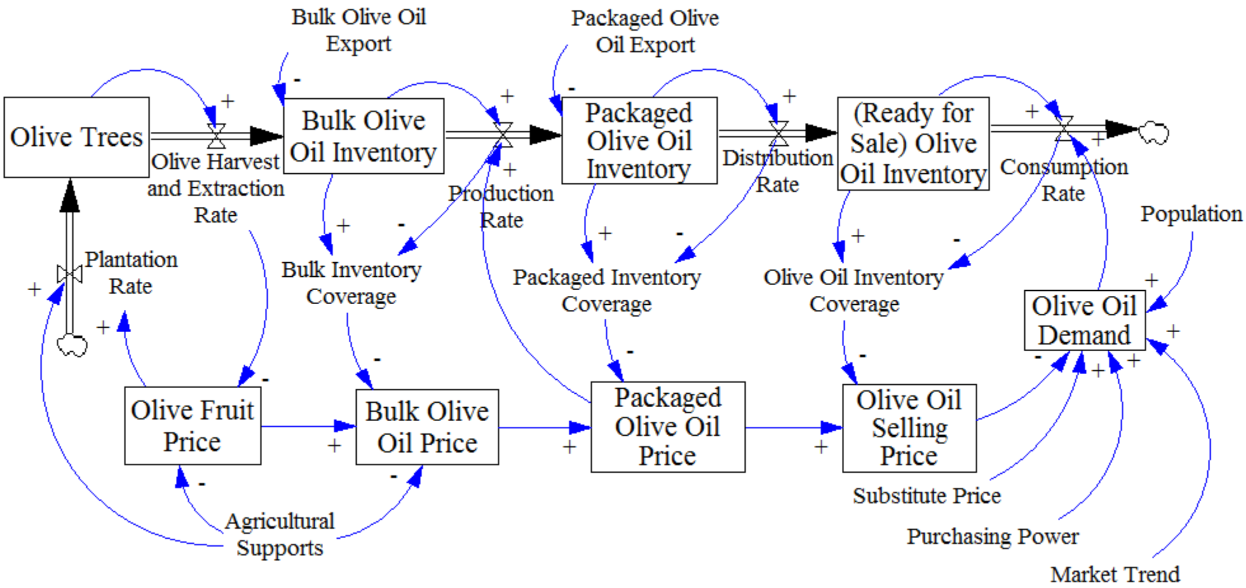

Figure 6: Stock and Flow Representation of Overall Olive Oil Industry Model

The major balancing loop in the model is "Price → (Supply) Rate → Inventory → Inventory Coverage → Price" loop. For Olive Trees, Olive Fruit Price affects Plantation Rate. Stock of Olive Trees behaves as the capacity level of the whole system. This loop corresponds to capacity acquisition loop and it represents the behavior of **the long term supply curve**. For Olive Oil Inventories, Packaged Olive Oil Price affects Production Rate and hence Distribution and Selling Rate. That is, production capacity utilization is determined depending on the Price and hence Expected Profitability of current operations. This loop corresponds to the capacity utilization loop and represents the behavior of **the short term supply curve**.

Another major balancing loop in the model is on the **demand** side: "Demand → Consumption Rate → Inventory Coverage → Selling Price → Demand" loop. Demand function consists of olive oil price, substitute price, market trend, purchasing power, population and other social or technical factors. This structure corresponds to the behavior of the **demand curve**.

In the next phase of the study, "speculative dynamics loop" will be added to the stock and flow structure. Speculative dynamics behavior will be captured by considering supply rates not only depending on the current price and expected profitability of current operations, but also depending on the "rate of change in the price" and hence "expected profitability of future operations".

Within the context of the problem defined, our research objectives are threefold:

- Understanding and explaining the industrial dynamics of agricultural products, namely olive oil in our case, throughout the whole value chain, from tree to fork,
- Investigating the "speculative dynamics" in agricultural industries,
- A first attempt to select the "best" levels of policy parameters in order to ensure the economical sustainability of the olive oil industry.

4 Methodology

The problem as we define in the previous section is a nonlinear dynamic feedback problem. Nonlinear dynamic feedback problems are typically impossible to be represented mathematically and solved by "prescriptive" models, such as optimization models (Barlas, 2002). In such cases, we usually resort to "descriptive" models which do not directly provide a policy recommendation, but the modeler derives the policy recommendations via a set of simulation experiments.

When we consider the case in the olive oil industry, we can see that olive harvest occurs only once in a year as a time-discrete event but olive oil consumption contines along the year. This behavior indicates the requirement of a time continuous-discrete hybrid model. In such a model, we should select the time unit of the model sufficiently small compared to the time horizon of interest.

Within the context of our problem, olive fruit and olive oil are treated as agricultural commodities. In commodity markets, the negative feedback loops through which price seeks to equilibrate supply and demand often involve long time delays, leading to oscillation. Yet, the classical economic theory of commodity cycles (also known as cobweb models) are not able to capture the market dynamics, since they do not represent the stock and flow structure of real markets, including inventories, work-in-process and production capacity (Sterman, 2000). Deaton and Laraque (1992, 1995) develop non-dynamic models and study on explaining commodity prices with respect to competitive storage and auto-correlation functions; then again Deaton and Laraque (1996) attempt to define the price of an agricultural commodity correlated with the harvest amount. Yet, they state that "storage seems to play only a small part in generating the autocorrelation in prices" and "the results are disappointing since much of the complexity in the econometrics comes from handling the speculative storage".

Hence, in this study, focusing on the industry of an agricultural product, we build a nonlinear, dynamic, hybrid continuous-discrete industry model in order to make policy analysis and suggest recommendations via utilizing System Dynamics Modeling.

5 Olive Oil Industry Model

Olive and olive oil have their own characteristics in terms of their problem environment. When compared to cereals (wheat, corn etc.), olive fruit is much more sensitive to environmental conditions and perishability of olives after harvesting is a great concern. Different from fresh produce (such as fruits, flowers and vegetables), olive can be extracted to obtain olive oil that can be stored and then marketed. That is, perishability of olive can be avoided when it is converted to olive oil. The relationship between olive and olive oil is highly parallel to the relationship between grape and wine, citrus and juice, and milk and cheese. Hence, while building the olive oil industry model, the relevant System Dynamics literature on similar products is reviewed.

Declerck and Cloutier (2002) develop an economic system dynamics model for both the short term and the long term production dynamics of the Champagne wine industry. Then, Area (2003) presents a conceptual system dynamics model for the wine chain in Argentina. He explains the importance of wine price in the operations of wine chain and presents a causal loop diagram adapted from Declerck and Cloutier (2002). Osorio and Arango (2009) build a simple system dynamics model for the world coffee market. In their model, they consider price dynamics, investments, production capacity, inventory and demand. They complete their study without calibrating their model with respect to real world data and they conclude their study with the results of initial tentative runs. Nicholson and Stephenson (2014) investigate the effects of a "Margin Insurance Program" under which dairy farmers can receive indemnity payments from the U.S. government if a margin falls below the insured level. They study whether this governmental intervention weakens feedback processes that would adjust milk production, prices and margins. They make scenario analysis and stochastic simulations for different market conditions.

In Olive Oil Industry Model, the flow of the physical material from one process to another is shown with the supply chain structure. While constructing the model, the studies in the literature which include system dynamics models for multi-echelon supply chains are reviewed in detail. Ge et al. (2004) investigate the bullwhip effect with system dynamics approach within the context of a supermarket chain system in the UK. They build a system dynamics model representing a multi-echelon supply chain with consumers, store, distribution center, factory and procurement. Georgiadis et. al. (2005) study the strategic supply chain management and build a system dynamics model representing a multi-echelon supply chain of a major Greek fast-food restaurant. Barlas and Gündüz (2011) investigate the effect of information sharing among supply chain players on fluctuations and bullwhip effect, and model a three-stage supply chain system with retailer, wholesaler and producer. Kumar and Nigmatullin (2011) use system dynamics approach and investigate the impact of demand variability and lead-time on non-perishable product supply chain performance under a monopolistic environment. They model the supply chain with four echelons: manufacturing, distribution, retailing and consumers. Teimoury et. al. (2013) investigate a supply chain of perishable fruits and vegetables under the influence of import quota policies. Their goal is to determine the best import quota policy by considering the trade-offs among price mean, price variation and markup. They build the supply, demand and price relationships in the supply chain. Langroodi and Amiri (2016) focus on supply chain design decisions and develop a system dynamics model for a multi-area, multi-echelon and multi-product supply chain with retailer, final product distributor, manufacturer, material distributor and supplier.

5.1 Model Overview

The Olive Oil Industry model consists of ten subsystems. Relationships among them are depicted in Figure 7. The subsystems on the left side particularly belong to Olive Oil Supply Chain, i.e., flow and transformation of the physical material from seed to fork, while the subsystems on the right side belong to Olive Oil Value Chain, i.e., how much value is added to the product, and how much value is gained during the flow and transformation. The intra-relationships within a chain are shown with gray arrows and the interrelationships between the two chains are shown with red arrows.

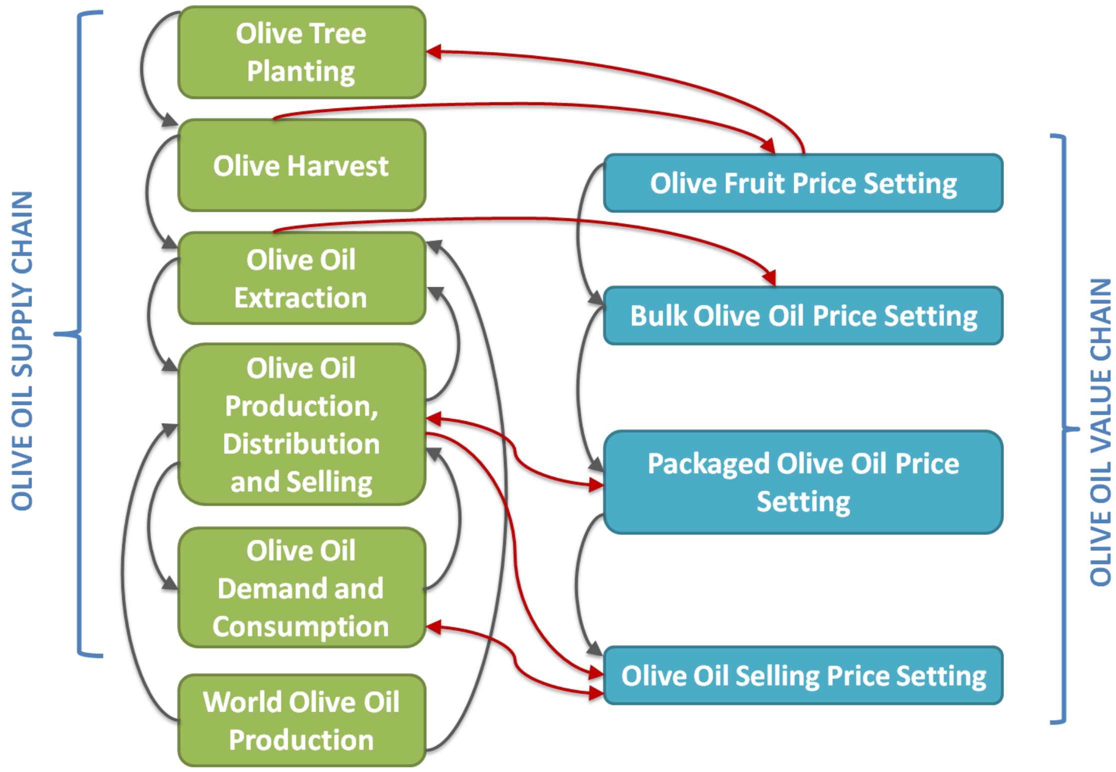

Figure 7: High Level Representation of Olive Oil Industry Model

The structure and the behavior of the model can be summarized as follows: In **Olive (Fruit) Price Setting**, the market price of olive fruit emerges, and it affects the perception on the profitability of olive farming business. Depending on the profitability perception, olive farmers either plant new olive trees (similar to capacity expansion decision of a manufacturer) or do not in **Olive Tree Planting**. Olive tree inventory of the country changes by the plantation tendency of farmers. The number of olive trees affects the number of bearing trees, and hence the olive fruit supply as a result of **Olive Harvest**. Olive fruit supply affects the price of olive fruit in **Olive (Fruit) Price Setting**. Then, a significant portion of olives harvested (approximately 70%) is used to get bulk olive oil as an output of **Olive Oil Extraction**. In **Bulk Olive Oil Price Setting**, price is affected by both bulk olive oil supply and olive fruit price.

Bulk olive oil is either exported as bulk (depending on the **World Supply**) or sent to domestic production facilities for additional production processes such as filtering, packaging and labeling. Packaged olive oil supply is determined in **Olive Oil Production, Distribution and Selling** subsystem. **Olive Oil Production, Distribution and Selling** and **Packaged Olive Oil Price Setting** affect each other as a result of the relationship between packaged olive oil supply and packaged olive oil price. A portion of packaged olive oil is exported (depending on the **World Supply**) and the rest is sent to domestic retailing points and becomes available for consumption in the domestic market. Distribution and selling volume is affected by the available packaged olive oil supply. **Olive Oil Selling Price Setting** represents the consumer price setting dynamics in the domestic market and is affected by packaged olive oil price, olive oil demand in the domestic market and available olive oil supply. For the end consumers in the domestic market, **Olive Oil Demand and Consumption** levels are determined by olive oil selling price and other social or economical factors.

Before getting into details of the model structure, some major points on boundary selection, assumptions and the correspondence of the model with the real world are stated below.

Olive Oil: In the model, Olive Oil can be found in three forms: Bulk Olive Oil, Packaged Olive Oil, and (Ready for Sale) Olive Oil. Olive oil inventories in any form are assumed to be centralized and to have an infinite storage capacity.

Homogeneity: The members of a stakeholder group (groups being farmers, olive oil producers, consumers, etc.) that take role in the processes are assumed to have the same characteristics, i.e. homogenous groups. Hence, at any time t, there is only one price for Bulk Olive Oil, one price for Packaged Olive Oil, and one price for (Ready for Sale) Olive Oil; for a particular form of olive oil, there is no price discrimination among different members of the same stakeholder group. Additionally, it is assummed that there is no technology differentiation in plantation, harvesting, and olive oil production.

Capacity: Since the industry operates at very low average production capacity utilization levels and capacity does not constitute a constraint, production capacity levels and production capacity acquisition decisions are left out of the problem boundary.

Table Olives: In Turkey, table olive has a much more stable behavior than Olive Oil Market in terms of supply, price and demand. Although the Table Olives Industry conditions would affect the decisions of the relevant stakeholders in the Olive Oil Industry, Table Olives Industry has not been yet included within the problem boundary.

Quality: Even though the quality of both the olive fruit and the olive oil is a critical concern in the real-world problem, it is not yet included in our system dynamics model, hence it is assumed that only one type of olive oil is offered in the market.

Self-Consumption and Roadside Sales: Although self-consumption and roadside sales of olive farmers and olive oil producers are mentioned in the problem definition, they are not considered as separate variables in the model. Since there are no official records or statistics related to this informal economy, self-consumption and roadside sales are not totally ignored, but assumed to be included in country-wide statistics.

Import: As it is stated in the problem definition, when domestic bulk olive oil prices are too high, rare cases of olive oil import are recorded in Turkish olive oil market. Yet, the ratio of import levels to production and export levels is so small that olive oil import of Turkey is ignored for the time horizon considered.

Export: In the problem definition, we mention about the high production volumes and low prices of Turkey's international competitors in export. In the model, export is defined as being only dependent on supply of other countries (that is, the availability of olive oil), not the prices. Accordingly, Turkey is assumed to be not a price maker, but a price taker in the world market.

5.2 Model Structure Details

As it is stated earlier, the model consists of ten subsystems. The main state variables in the model are **Olive Trees**, **Olive Oil Inventories** and **Expected Olive Oil Prices** for different forms of olive oil and **Olive Oil Demand** for the domestic market.

Rates related with supply volumes, **Plantation or Removal Rate, Extraction Rate, Production Rate, Distribution and Selling Rate** are one major group of endogenous flow variables.

One group of endogenous converter variables are **Minimum Price**, (actual) **Price** and **Indicated Price** for olive oil of different forms. In the model, multiplicative effect functions are used, which includes **Effect of Costs on Price** and **Effect of Inventory Coverage on Price** as another group of endogenous converter variables.

As for the exogenous converter variables, **Expected Fixed Costs, Expected Variable Costs, Agricultural Subsidies and Premiums, Reference Inventory Coverage** values, **Sensitivity** parameters, and social and economical factors affecting demand level such as **Population, Income** and **Substitute Price** can be stated.

In the following parts, some selected subsystems of the model are explained and detailed with the analytical and mathematical relationships of the variables. Exogenous converter variables are represented as green circles and endogenous converter variables are represented as blue circles.

5.2.1 Olive Tree Planting

Stock and flow structure for Olive Tree Planting can be seen in Figure 8.

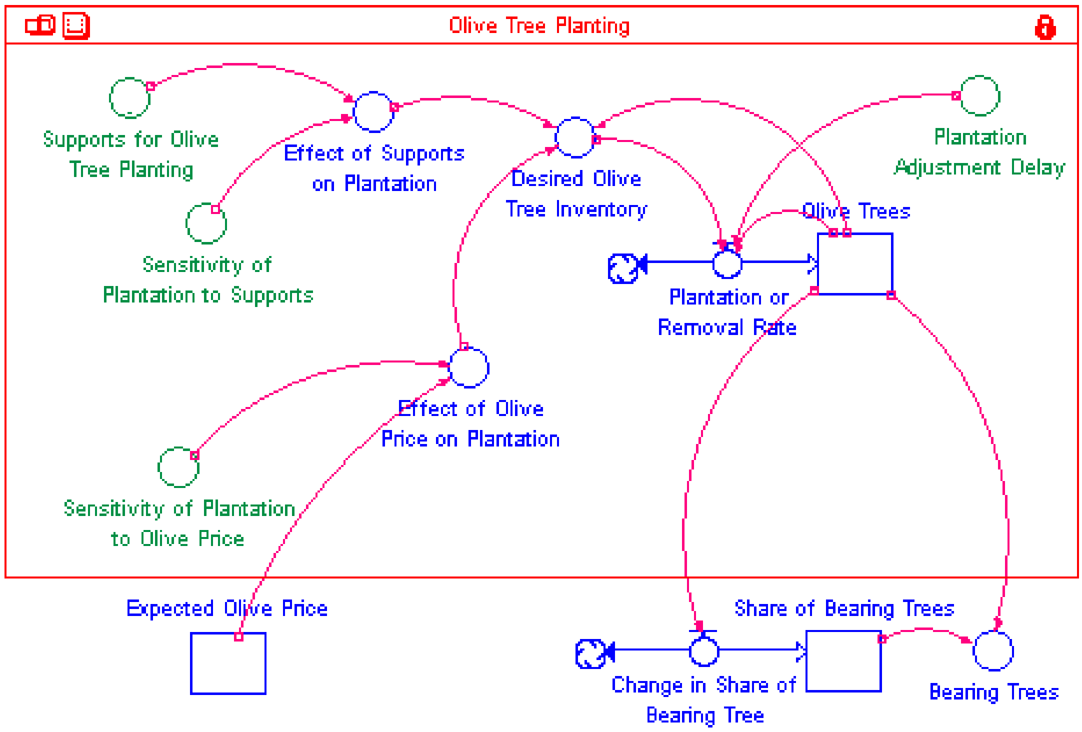

Figure 8: Olive Tree Planting

Olive tree population is the driving force of the industry. **Olive Trees** is defined as a state variable and can be seen as the raw material production capacity of the industry. Hence, **Desired Olive Tree Inventory** level is characterized as similar to a long term supply function. Desired Olive Tree Inventory is defined as a function of expected olive price and financial supports for planting, which are the indicators of profitability of olive farming business. **Plantation or Removal Rate** adjusts the Olive Trees level with respect to Desired Olive Tree Inventory. Depending on the perceived profitability of olive farming business and hence Desired Olive Tree

Inventory, Plantation and Removal Rate may take positive or negative values. Level of Olive Trees directly affect **Share of Bearing Trees** and **Bearing Trees** for olive harvest.

5.2.2 Olive Harvest

Stock and flow structure for Olive Harvest can be seen in Figure 9. Every **Harvest Period**, which corresponds approximately to the last quarter of the year, olive fruits on the **Bearing Trees** are collected. The number of bearing trees depends on the maturity of the olive tree population, hence, **Share of Bearing Trees** and **Change in Share of Bearing Trees** are calculated depending on the historical rate of change in the olive tree population. In this way, the distinction between young and mature trees is implicitly considered. In olive harvesting, there is an effect on olive yield per tree called "On / Off Years **(Alternation)**". **Olives per Tree** shows an alternating behavior with consecutive ups and downs in consecutive years. **Olives Harvested** is calculated as the product of Bearing Trees and Olives per Tree. A larger share of Olives Harvested (approximately 70% of them) is used for olive oil, while the rest is used in table olives production. **Olive Fruit for Oil** is calculated as the product of Olives Harvested and **Share of Olives for Oil**, and it then moves forward to extraction process and accumulates in **Bulk Olive Oil Inventory**. For a particular harvest season, **Effect of Olive Harvest on Olive Price** is determined by the relative magnitude of the realized Olive Fruit for Oil with respect to **Expected Olive Fruit for Oil**.

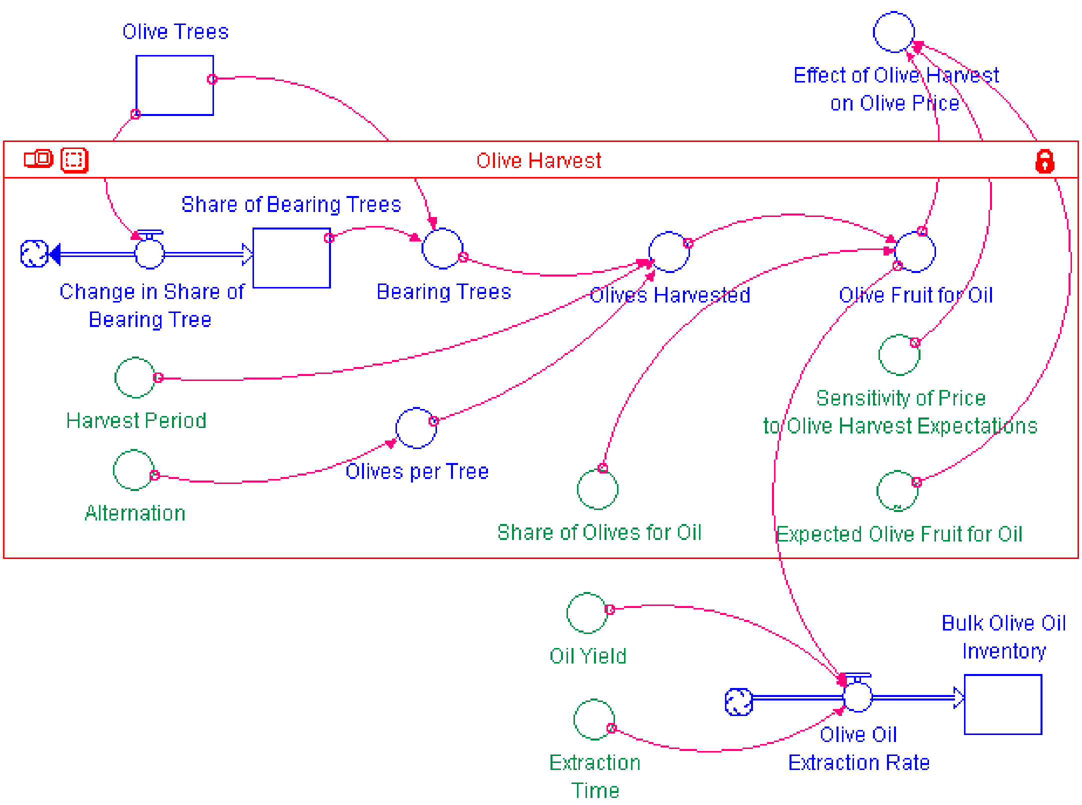

Figure 9: Olive Harvest

5.2.3 Olive Oil Production, Distribution and Selling

Olive Oil Extraction consists of extraction of olive fruit for oil and accumulation of olive oil in **Bulk Olive Oil Inventory**. Olive Oil Extraction subsystem has a similar structure to **Olive Oil Production (Refining (if necessary), Filtering, Packaging, Labeling), Distribution and Selling** subsystem. Hence, the core structure of these two subsystems is illustrated with only one of them, that is, Olive Oil Production, Distribution and Selling. Stock and flow structure for Olive Oil Production, Distribution and Selling can be seen in Figure 10.

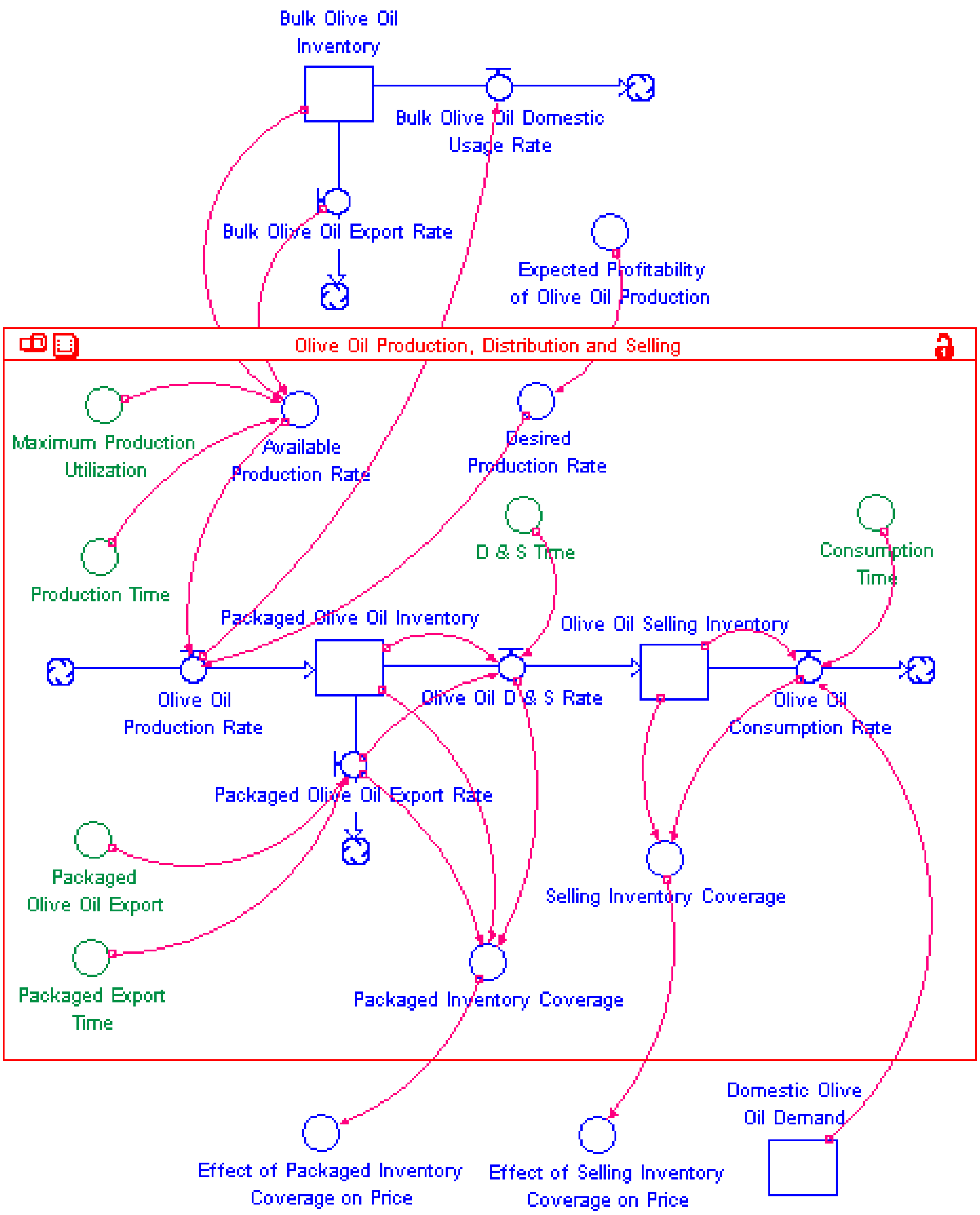

Figure 10: Olive Oil Production, Distribution and Selling

Depending on the olive oil producers' **Olive Oil Production Rate** decision on "How much of **Bulk Olive Oil Inventory** would be processed (i.e. refined (if necessary), filtered, packaged, labeled) for sale?", bulk olive oil is processed and accumulated in **Packaged Olive Oil Inventory** and then moves forward to **Olive Oil Selling Inventory**. While Bulk Olive Oil Inventory is the WIP (Work-in-Process) Inventory, further processed Packaged Olive Oil Inventory can be seen as the finished goods inventory which is available for distribution to wholesalers and retailers. In a similar way, Olive Oil Selling Inventory can be seen as the retailing inventory which is available for selling to end consumers.

Bulk Olive Oil Inventory diminishes with Bulk Olive Oil Export Rate and Olive Oil Production Rate (which is equal to the **Bulk Olive Oil Domestic Usage Rate**) as olive oil is processed and moved to Packaged Olive Oil Inventory. Olive Oil Production Rate is the minimum of **Available Production Rate** and **Desired Production Rate**. Packaged Olive Oil Inventory level is increased with the inflow of Olive Oil Production Rate and decreased with the outflow of **Olive Oil Distribution and Sales Rate** and **Packaged Olive Oil Export Rate**. Olive Oil Selling Inventory level is increased with the inflow of Olive Oil Distribution and Sales Rate and decreased with the **Olive Oil Consumption Rate**. **Inventory Coverage** values for Packaged Inventory and Selling Inventory are defined as the number of periods obtained with the ratio of inventory available to their corresponding outflow rates. Inventory Coverage values are used to calculate **Effect of Inventory Coverage on Price** variables.

5.2.4 Packaged Olive Oil Price Setting

Olive Price Setting, Bulk Olive Oil Price Setting, Packaged Olive Oil Price Setting and **(Ready for Sale) Olive Oil Price Setting** subsystems are built with similar structures. Hence, the core structure of pricing subsystems is illustrated with one of them, Packaged Olive Oil Price Setting.

In order to build the core engine of the price setting subsystems, Generic Structure of Commodity Markets Model (Sterman, 2000) is used as the main framework. In this framework, the model is built on "the process of price discovery - the process by which market participants form expectations about the level of price that would balance demand and supply and clear the market." (Sterman, 2000). Since no one knows the true equilibrium price, market makers can only estimate the equilibrium price depending on the price realizations in the past, in some form of adaptive expectations:

$$P^* = EXP.SMOOTH(Price, Expectation\ Adjustment\ Time)$$

Given market makers' expected price as P^*, actual price P is set by anchoring and adjustment process, where anchor is the Expected Price and several cues such as demand/supply balance, unit costs, competitors' prices and other factors adjust the price and move it away from the anchor:

$$P = P^* * f_1(Cue_1) * f_2(Cue_2) * ... * f_n(Cue_n)$$

Then the price setting process is formulated as below:

Price = Traders' Expected Price * Effect of Inventory Coverage on Price * Effect of Costs on Price

Traders' Expected Price = INTEGRAL (Change in Traders' Expected Price, Traders' Expected Price$_{t_0}$)

Change in Traders' Expected Price = (Indicated Price - Traders' Expected Price) / Time to Adjust Traders' Expected Price

Indicated Price = MAX (Price, Minimum Price)

Stock and flow structure for Packaged Olive Oil Price Setting can be seen in Figure 11. Packaged olive oil price emerges depending on the bulk olive oil price, olive oil production costs and packaged olive oil demand/supply ratio. The price setting formulations are detailed below.

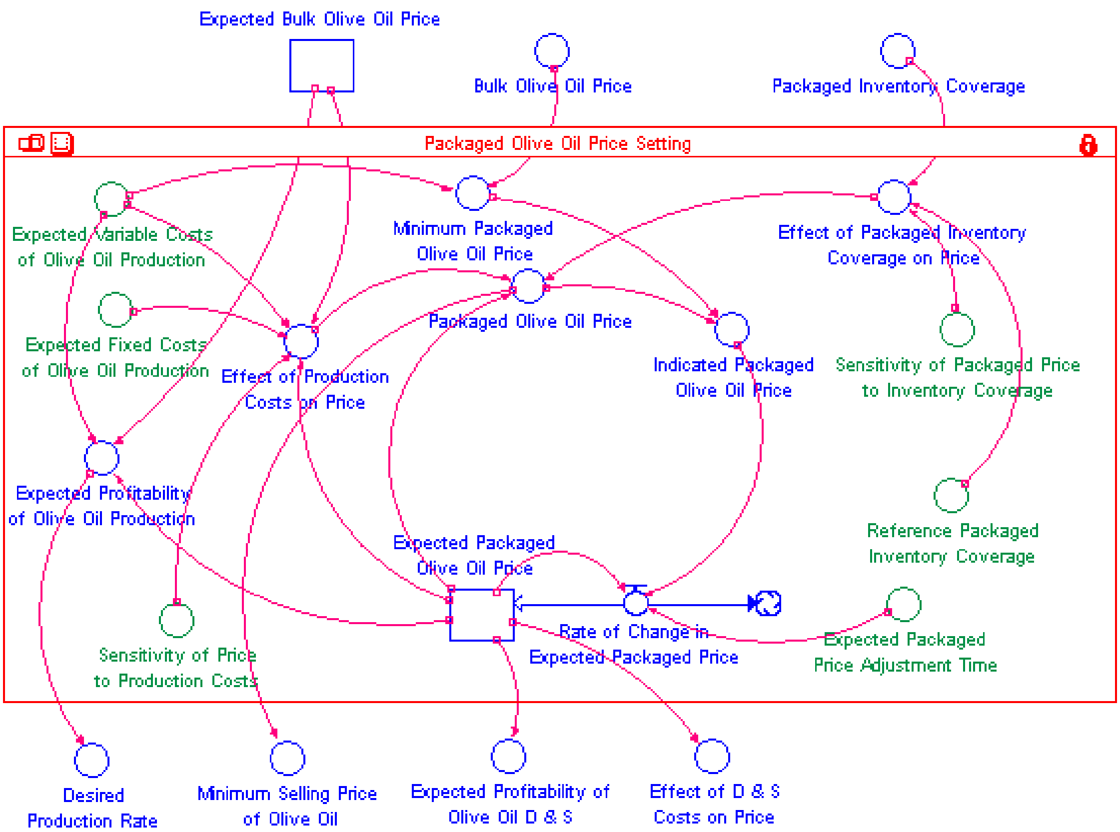

Figure 11: Packaged Olive Oil Price Setting

Minimum Packaged Olive Oil Price = Bulk Olive Oil Price + Expected Variable Costs of Olive Oil Production

Packaged Olive Oil Price may temporarily fall below the total cost of olive oil production. Yet, a producer can not operate if the unit price is lower than the total unit variable cost. Hence, lower bound of the Packaged Olive Oil Price is set to summation of Expected Variable Costs of Olive Oil Production and Bulk Olive Oil Price (which corresponds to variable raw material cost for Olive Oil Production).

Packaged Olive Oil Price = Expected Packaged Olive Oil Price * Effect of Packaged Inventory Coverage on Price * Effect of Production Costs on Price.

As explained earlier, prices are set by anchoring and adjustment process, where Expected Packaged Olive Oil Price is the anchor, and Production Costs and Packaged Olive Oil Inventory Coverage can adjust and move the price away from the anchor.

Indicated Packaged Olive Oil Price = MAX(Minimum Packaged Olive Oil Price, Packaged Olive Oil Price)

Indicated Packaged Olive Oil Price is the maximum of Minimum Packaged Olive Oil Price and Packaged Olive Oil Price.

Rate of Change in Expected Packaged Price = (Indicated Packaged Olive Oil Price - Expected Packaged Olive Oil Price) / Expected Packaged Price Adjustment Time.

Rate of Change in Expected Packaged Price takes on a positive value if Indicated Packaged Olive Oil Price is higher than Expected Packaged Olive Oil Price, and takes on a negative value if Indicated Packaged Olive Oil Price is lower than Expected Packaged Olive Oil Price.

Expected Packaged Olive Oil Price (t) = Expected Packaged Olive Oil Price (t - dt) + (Rate of Change in Expected Packaged Price) * dt.

Expected Packaged Olive Oil Price increases or decreases with Rate of Change in Expected Packaged Price.

Expected Profitability of Olive Oil Production = Expected Packaged Olive Oil Price - (Expected Bulk Olive Oil Price + Expected Variable Costs of Olive Oil Production).

Expected Profitability of Olive Oil Production is calculated with related expected cost and price variables, and it affects Desired Production Rate. This relationship constitutes a short term supply curve for Olive Oil Production process.

5.2.5 Olive Oil Demand and Consumption and World Production

Olive Oil Demand and Consumption subsystem represents the domestic demand and consumption in the country. Olive Oil Demand is modeled to be dependent on the Relative Price of Olive Oil (Olive Oil Selling Price / Substitute Price) and other external factors such as Market Trend, Income (GDP) and Population. Olive Oil Consumption Rate is determined depending on the quantity demanded and availability of the product in the Olive Oil Selling Inventory. **World Olive Oil**

Production is the smallest subsystem of the model where production volumes of selected producer countries are exogenously generated for modeling purposes.

5.3 Initial Results and Discussions

The Olive Oil Industry Model has been completed in terms of its structure, but some variables still require additional data analyses before the model validation step. For the current phase of the study, hypothetical values or functions are assigned for these variables and thus initial results are obtained using STELLA 9.1.

Reference time horizon for the data analysis to capture the behavior of the industry is taken as the period between 2007 and 2015. Since several data sources in Turkey consider the base year as 2003, cost and price values used in the model are adjusted according to inflation rate and price indices, where the base year is taken as year 2003 (2003 = 100).

In the model, time unit t is selected as quarters and time horizon T is selected as 48 quarters (12 years). For the current phase of the study, dt is set to 1/3.

The initial results of Bulk, Packaged and Selling Olive Oil Inventories are seen in Figure 12. Bulk and Packaged Olive Oil inventories show cycling up and down behavior depending on the harvest season. With the harvest season, inventory levels increase and then decrease until the next season. After almost the half of the observed time period (after Quarter 24), Olive Oil Selling Inventory shows a decreasing trend while Bulk Olive Oil Inventory keeps its increasing trend. After that point, olive oil accumulates more and more in the intermediary inventories and diminishes in the final inventory. These initial results are compatible with the dynamic hypothesis defined and the real world behavior observed.

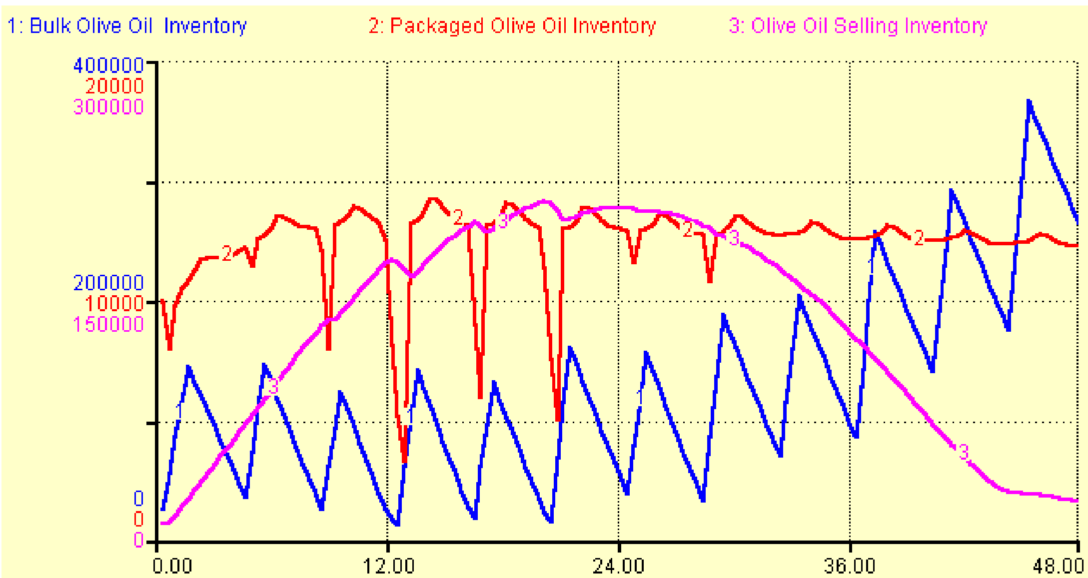

Figure 12: Initial Results for Inventories (Bulk, Packaged and (Ready for Sale) Olive Oil Inventories)

In compliance with the results in Figure 12, the initial results of Expected Prices of Olive Fruit, Bulk Olive Oil, Packaged Olive Oil and Olive Oil Selling can be seen in Figure 13. It is observed that expected prices are also affected by the supply increases in harvest seasons and show cycling up and down behavior similar to inventories. Except for the jump at the first quarters, Expected Prices of Olive, Bulk and Packaged Olive Oil show decreasing trend as a response to increasing overall supply in the country. Yet, the final price, that is, Expected Olive Oil Selling Price first decreases for a certain period and then increases sharply since the final inventory shown in Figure 12 is in a decreasing trend. The initial results in Figure 13 are also compatible with the dynamic hypothesis defined and the real world behavior observed.

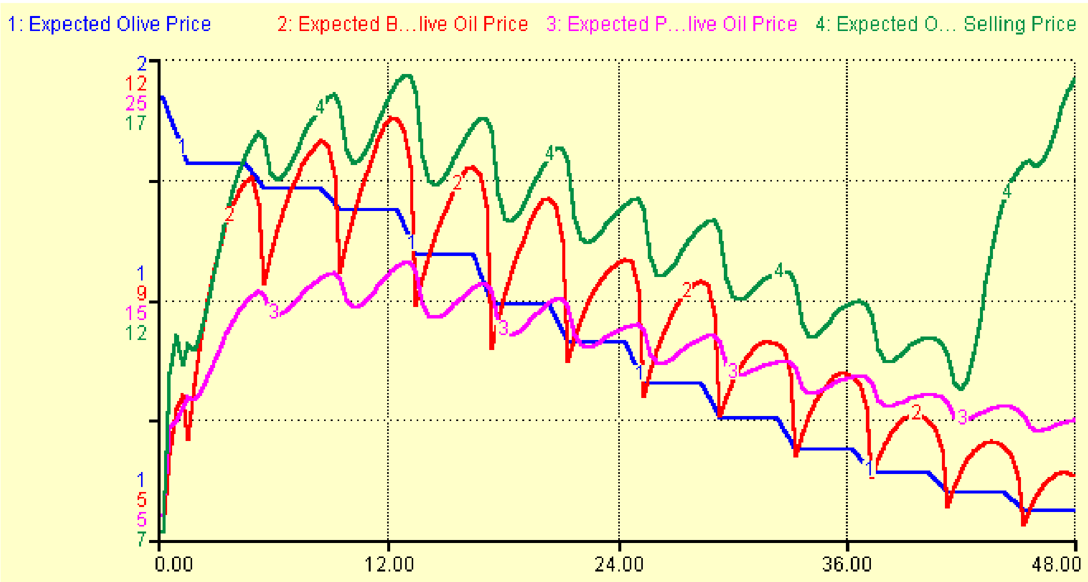

Figure 13: Initial Results for Expected (Olive Fruit, Bulk, Packaged and (Ready for Sale) Olive Oil) Prices

6 Conclusion and Future Work

Understanding the dynamics of an agricultural industry and making policy analysis for improvement constitutes a nonlinear dynamic feedback problem. The aim of this study, focusing on the olive oil industry in Turkey, is to understand and explain how value of products (olive and olive oil) emerges at the market as a result of agricultural industry dynamics, and also to investigate the effect of speculative dynamics and inventories along the supply chain. The Olive Oil Model is built using system dynamics modeling tools, including both the supply chain and the value chain structures. The initial results for the critical stock values are found to be in compliance with real world observations. Yet, in order to understand whether the model we build is "appropriate for the purpose", we should complete all relevant assessments for our model in the following phases.

In Olive Oil Industry Model, data analysis is already completed for several variables. As it is mentioned before, reference time horizon for the data analysis to capture the behavior of the industry is taken as the period between 2007 and 2015. Yet, there are some exogenous and endogenous converter variables which still require additional **data analysis** before the validation of the model. As the first step in the near future, data analysis for these variables will be completed.

In terms of **model validation**, relevant Model Assessment Tests (Sterman, 2000) are still being conducted. Boundary adequacy, availability of decision rules to real decision makers and conservation of elements in the model are already tested. For each subsystem of the model, validation and modification (if needed) of the analytical and mathematical relationships among variables and unit consistency tests are still in progress. In the near future, after the completion of data analysis for all variables, runs at the current industry conditions will be performed. At that step, the model is expected to show the most-typical pattern characteristics of the real industry behavior, such as amplitude of a peak, time between two peaks, minimum value, slope, number of inflection points, time to settle, etc. (Barlas, 1996). In the meantime, extreme condition tests, integration error controls and sensitivity analysis will be conducted.

For the **scenario analysis**, several possible scenarios are listed through discussions and interviews with stakeholders and sector experts. Some examples of these scenarios are: unexpected rise or fall of olive fruit supply or olive oil demand, unexpected world market conditions, disruptive events like droughts, epidemics, economic crises, etc. After the model validation, scenario analysis will be conducted.

Again with the aid of discussions and interviews with stakeholders, especially with governmental and cooperative representatives, some relevant areas in **policy analyses** in the industry are listed:

- Subsidy policies
- Premium policies
- Olive tree plantation or removal regulations
- Production regulations
- Tax policies
- Pricing policies
- Export regulations

In policy analyses, model variables representing these policies will be selected or added to the model if they do not exist. Then, a series of simulation experiments will be performed and the “best” available values of policy variables will be determined in order to improve the selected performance criteria.

The boundary selection and some assumptions of the model are still open for improvement. Some examples of improvements are:

- Addition of **table olives industry** to the model as a subsystem,
- Expansion of the model for **different quality grades** of olive oil,
- Inclusion of more sophisticated **world market relationships** instead of exogenous variables of world supply,
- Addition of **climatic and ecological effects** on olive harvest.

References

[1] Amores, A.F., Contreras I., (2009), New approach for the assignment of new European agricultural subsidies using scores from data envelopment analysis: Application to olive-growing farms in Andalusia (Spain), European Journal of Operational Research, 193, pp. 718–729.

[2] Area, N., (2003), The wine chain in Argentina: influence of the production - consumption dynamics, Proceedings of the 21th International Conference of The System Dynamics Society.

[3] Atamer Balkan, B., Meral, S., (2016), Olive Oil Value Chain Dynamics: Turkish Olive Oil Industry Case, Acta Horticulturae (In press).

[4] Barlas, Y., (1996), Formal aspects of model validity and validation in system dynamics, System Dynamics Review Vol.12, No.3, pp. 183-210.

[5] Barlas, Y., (2002), System Dynamics: Systemic Feedback Modeling for Policy Analysis, Encyclopedia of Life Support Systems, pp. 1131-1175.

[6] Barlas, Y., Gündüz, B., (2011), Demand forecasting and sharing strategies to reduce fluctuations and the bullwhip effect in supply chains, Journal of the Operational Research Society, 62, pp.458-473.

[7] Berloni, D., Esposti, R., Lobianco, A., (2002), An Italian Olive Oil Model - General Framework and Preliminary Estimate Results, Department of Economics, University of Ancona.

[8] Deaton, A., Laroque, G., (1992), On the behavior of commodity prices, Review of Economic Studies, 59, pp. 1 – 24.

[9] Deaton, A., Laroque, G., (1995), Estimating a nonlinear rational expectations commodity price model with unobservable state variables, Journal of Applied Econometrics, 10, pp. 9-40.

[10] Deaton, A., Laroque, G., (1996), Competitive storage and commodity price dynamics, Journal of Political Economy, 104, pp. 896–923.

[11] Declerck, F., Cloutier, M.L., (2002), The Champagne Wine Industry: An Economic Dynamic Model of Production and Consumption, ESSEC, Research Center, Working Paper, No DR 02011, Canada.

[12] Ge, Y., Yang, J.B., Proudlove, N., Spring, M., (2004), System dynamics modelling for supply-chain management: A case study on a supermarket chain in the UK, International Transaction in Operations Research, 11, pp. 495–509.

[13] Georgiadis, P., Vlachos, D., Iakovou, E., (2005), A system dynamics modeling framework for the strategic supply chain management of food chains, Journal of Food Engineering, 70, pp. 351-364.

[14] Higgins, A.J., Miller, C.J., Archer, A.A., Ton, T., Fletcher, C.S., McAllister, R.R.J., (2010), Challenges of operations research practice in agricultural value chains, The Journal of the Operational Research Society, Vol.61, No. 6, pp.964-973.

[15] International Olive Oil Council Website, http://www.internationaloliveoil.org.

[16] International Olive Oil Council Country Profiles Reports, http://www.internationaloliveoil.org/estaticos/view/136-country-profiles.

[17] Kaplinsky, R., Morris, M., (2002), A Handbook for Value Chain Research, prepared for IDRC (International Development Research Centre).

[18] Kavallari, A., Maas, S., Schmitz, P. M., (2011), Examining the Determinants of Olive Oil Demand in Non-producing Countries: Evidence from Germany and the UK, Journal of Food Products Marketing, 17, pp. 355-372.

[19] Kumar, S., Nigmatullin, A., (2011), A system dynamics analysis of food supply chains - Case study with non-perishable products, Simulation Modelling Practice and Theory, 19, pp.2151 - 2168.

[20] Lain, C.S., (2010), The Value Chain and Price Formation in the Spanish Olive Oil Industry, The Olive Oil Agency, Spain.

[21] Langroodi, R.R.P., Amiri, M., (2016), A system dynamics modeling approach for a multi-level, multi-product, multi-region supply chain under demand uncertainty, Expert Systems With Applications, 51, pp.231-244.

[22] Lynch, B. et al., (2013), Olive Oil: Conditions of Competition between U.S. and Major Foreign Supplier Industries, United States International Trade Commission.

[23] Migdalas, A., Baourakis, G., Kalogeras, N., Meriem, H.B. (2004), Sector modeling for the prediction and evaluation of Cretan olive oil, European Journal of Operational Research, 152, pp.454–464.

[24] Ministry of Food, Agriculture and Livestock, Food and Agricultural Products Market Monitoring and Evaluation Committee, (2016), Olive and Olive Oil Product Report.

[25] Ministry of Food, Agriculture and Livestock, (2016), Turkey Olive Farming Sector Report.

[26] Nicholson, C.F., Stephenson, M.W., (2014), Government Intervention in Agricultural Commodity Markets: U.S. Dairy Policy Under the Agricultural Act of 2014, Proceedings of the 2014 International Conference of the System Dynamics Society.

[27] Osorio, F.A., Arango, S.A., (2009), A System Dynamics Model for the World Coffee Market, Proceedings of the 27th International Conference of the System Dynamics Society.

[28] Sabbatini, V., (2014), The Supply Function of Olive Oil: A Case Study of Italy, Procedia Economics and Finance 14, pp.553-558.

[29] Siskos, Y. et al., (2001), Multicriteria analysis in agricultural marketing: The case of French olive oil market, European Journal of Operational Research, 130, pp.315-331.

[30] Sterman, J.D., (2000), Business Dynamics: Systems Thinking and Modeling for a Complex World, New York Irwin, McGraw Hill.

[31] Teimoury, E., Nedaei, H., Ansari, S., Sabbaghi, M., (2013), A multi-objective analysis for import quota policy making in a perishable fruit and vegetable supply chain: A system dynamics approach, Computers and Electronics in Agriculture, 93, pp.37-45.

[32] Webber, C.M., Labaste, P., (2010), Building Competitiveness in Africa's Agriculture: A Guide to Value Chain Concepts and Applications, The World Bank.

[33] Xiong, B., Sumner, D., Matthews, W., (2014), A new market for an old food: the U.S. demand for olive oil, Agricultural Economics 45, supplement pp.107-118.