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"Technical Note"

Using System Dynamics to Model Rod Bar Supply Chain in Iranian Market

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KEYWORDS

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Steel Market Rod Bar
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ABSTRACT

Steel market and particularly rod bar market play important roles in economy of countries. Economic systems are considered as complex systems which are sophisticated to be modeled mathematically. One way to model these systems is simulation and use of system dynamics. This paper models rod bar supply chain in Iran using system dynamics. Data of this research is gathered from first hand materials published by governmental sector. In order to modeling relationships between variables, interviews were conducted with experts in Iran Ministry of Commerce. Proposed model explains turbulence of rod bar market during 5 years ago and the fluctuations of its price. In addition, it is examined and confirmed by experts of this market in Iran Ministry of Commerce. Although proposed model may not offer an exact prediction of future market, but could be used as an applicable tool for analyzing and adjusting the market in Iran Ministry of Commerce.

1. Introduction

The high competitiveness of today's economical environment, added to effects of globalization, mean that industries must find new ways to interact and satisfy their customers. In supply chains, manufactures, business intermediaries, transport companies, suppliers and official organizations collaborate together in order to deliver products quickly and efficiently so that money flows through the economy. An optimized supply chain involves improvements in efficiency which may cut inventory requirements, save transportation costs and other distribution expenses, and improve the time to market (Campuzano, et al., 2009). According to Hwarng and Zie (2008), a supply chain is a complex system which involves multiple entities encompassing activities of moving goods and adding value from the raw material stage to the final delivery stage. Along the chain, there exist various types of uncertainties, e.g., demand uncertainty, production uncertainty, and delivery uncertainty. In the steel industry, the supply chain, apart from actual production, is an extremely complex task, requiring the consideration of numerous factors and objectives. Sharply fluctuating demand, raw materials supply and uncertain prices produce a negative impact on steel production. At the same time, the supply chain of the steel industry has to consider multiple objectives and multiple stages of steel production and supply chain simultaneously in a global market. It requires an optimized supply chain alternative by extending visibility of demand based on economy and market, raw material supply based on transportation, and suppliers and their price (Ziong and Helo, 2008). It is notable that sagging prices in the backdrop of economic slowdown have spelt turmoil in the industry the world over. As in the case of oil and natural gas, there is a felt need for the steel producing countries to come together and evolve an understanding on production and pricing of steel products. According to Potter et al. (2004) studies of the steel sector have been carried out by many academics often with the aim of implementing improvements in the sector to enhance the performance of the supply chain. While this has enabled a good knowledge of the supply chain structure at particular times, the evolution that has occurred over recent years is less well understood. The aim of this paper is to apply the System Dynamics (SD) methodology in order to model and analyze supply chain of steel market in Iran.

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2. Literature Review

SD is a well known and proven modeling method that allows a system (in this case supply chain of steel) to be represented as a feedback system. It is based on the original work of Forrester, who defined it as the investigation of the information-feedback character of industrial systems and the use of models for the design of improved organizational form and guiding policy (Forrester, 1961). The model is an interlocking set of differential algebraic equations developed from a broad spectrum of relevant measured and experiential data (Homer and Hirsh, 2006). The SD method has met with increased recognition during the last decade both by academicians as well as practitioners and has been used in a wide variety of applications, both in the social sciences and in engineering. It has been used to model topics as diverse as risk assessment of water shortage (Feng et al., 2008), political instability (Elis, 2004), conflict management (Choucri, 2005) hospital waste management (Chaerul et al., 2008), building material resource availability (vuuren et al., 1999), urban planning (Fong et al., 2009), land reclamation in the mining industry (Elshorbagy et al., 2005), supply chain management (Vlachos et al., 2007), cement production (Anand et al., 2006), energy and power systems (Kadoya et al., 2005), coastal ecosystem dynamics (Costanza et al., 1990), aviation systems (Quan and Trani, 1997). This paper shows applicability of SD to model and analyze Steel market in Iran. The rest of this paper is organized as follows: Section 2 briefly reviews steel market supply chain. Section 3 describes research methodology of this paper and Section 4 presents models and results of analysis of this research. Finally, paper ends with some concluding remarks in Section 5.

3. Rod Bar Market System Dynamics Modeling

3.1. Reference Model

Systems dynamic model makers, intend to describe the problem dynamically, this means that the problem as a pattern of behavior over time will be revealed. This pattern shows how the problem has been occurred and how it will appear in the future. Reference model, is a series of charts and descriptive data that indicates the system behavior in the past. Figures 3 and 4 indicate price, import, and export trend of rod bar for three years as were available in formula and governmental references.

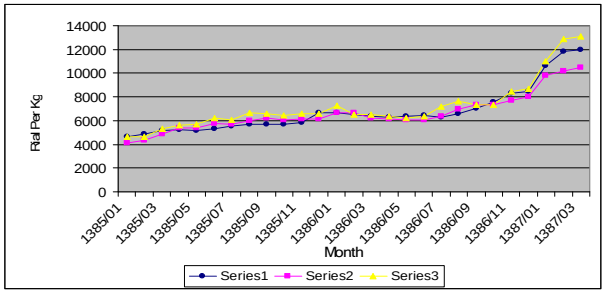

Fig. 3. International and domestic price trend (www.cmrd.ir)

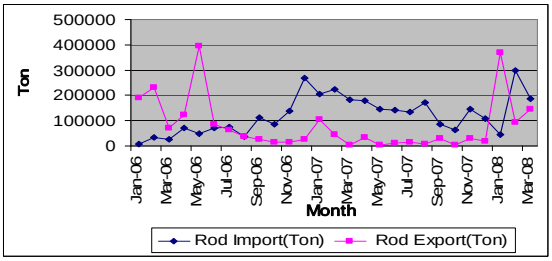

Fig. 4. Rod import and export trend comparison (adopted from: www.cmrd.ir)

3.2. Dynamic Theory

Consumption of steel products has always been considered as one of the determinant factors of economic development and especially industrial development. On the other hand, increasing demand in society and dependence of Iran's economy to steel products requires estimation of its supply in future. Politics, policy and decision makers in different economic areas should know which equipments will influence the demand and supply of steel in case of changes in programs and policies in related sectors.

In this regard, Ministry of Commerce as a most important custodian body of market adjustment has to control the governing approaches in market of these products. By this way it can respond on time to evolutions of global markets and local needs and by managing supply and improving supply conditions it can prevent price fluctuations.

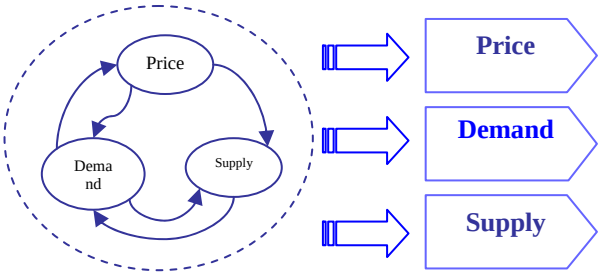

Fig. 5. Relation between supply, demand and price

3.3. Cause and Effect Diagram

Cause and effect diagram based on dynamic theory mentioned is show in Figure 6.

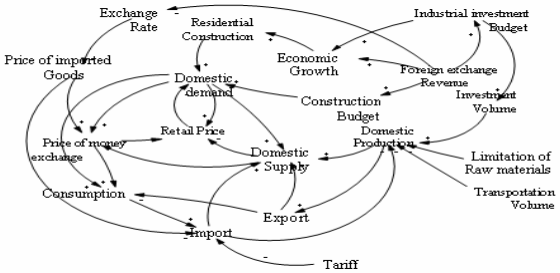

Fig. 6. Cause and effect diagram of rod market

3.4. Flow Diagrams

Figure 7 shows the Flow diagrams which are composed of state, rate and auxiliary variables according to the cause and effect diagram.

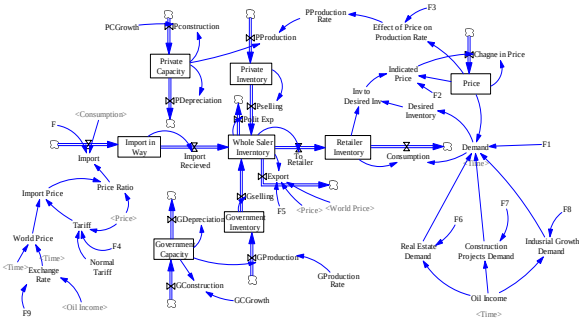

Fig. 7. Flow diagram of rod product market

3.5. Validation

3.5.1. Structural Validity

Examining the structural validity of a model requires clear and reasonable understanding of how the model and its components (state and rate variables and parameter) work. For doing so, experts and experienced people in steel market area and especially rod bar in Iran Ministry of Commerce have been interviewed. According to the derived knowledge, we can validate the structure of the model.

3.5.2. Forecast Validity

If the model prediction is sufficiently similar to actual behavior of the system, the prediction model is valid. Similarly the model was executed with the existing statistics. Then by comparing results of the model and comparing it with reference graphs the power and the forecasting validity of the model was found. In proposed model the rod bar market has growth and fluctuations. The growth is based on and related to many variables of the model. Prices increase because of inflation and demand increases with population and industry growth. So production capacity increases in all product types and so on. In this research according to the approach followed in economic science, we separated these two factors and only focused on analyzing the rod bar market fluctuations. Therefore our model does not include population growth, economic growth or inflation. So for testing the behavior of the model we have to consider the short time run to be able to ignore growth factor to some extent.

Local and global market price analysis:

In testing the model regarding the price we can investigate two points. First impact of increase of global prices on local prices. As depicted in Figure 8, the global price strongly affects local prices. Reference graph (Figure 3) shows combined growth and fluctuation whereas in current article only fluctuations has been investigated therefore we have cut off growth from the current reference model and have focused only on price fluctuations as shown in Figure 8.

The most important in price fluctuations of the rod bar is the period of its fluctuations. The fluctuation period of the rod bar in turbulent market of Iran is about 9 months to one year and this amount in the model (Figure 9 shows one of its simulations after the global price shock) is approximately 12 month. If we measure the time distance between the two fluctuations prices in reference graph it will be 9 month the same as the amount extracted from the model.

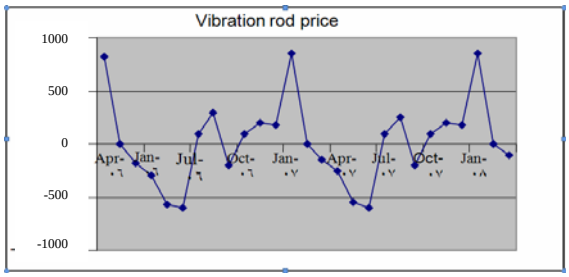

Fig. 8. Reference graph

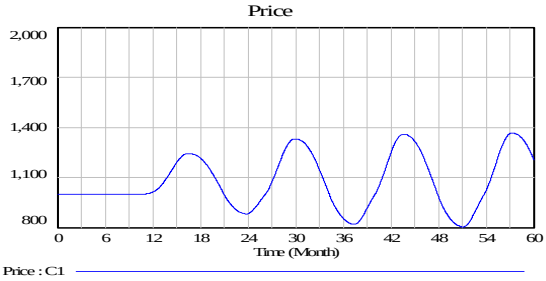

Fig. 9. Reference model (comparison retailer price, exchange price and global price)

2- Export and import analysis: these two variables can not be studied precisely because the included demand growth is not studies in our model. However by shortening the time interval these variables can be investigated to some extent.

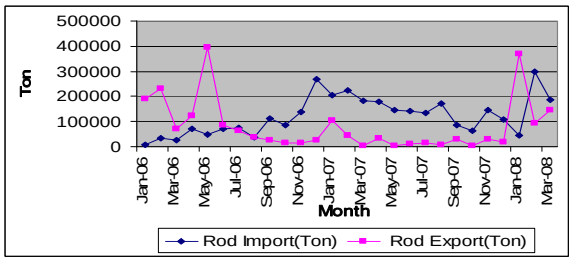

Fig. 10. Reference model (comparison of rod import and export)

Figure 10 has three characteristics which will be explained respectively below:

1. Fluctuation period in reference model:

Export and import graphs have nearly 3 fluctuation periods in three months. This graph in each export and import trend has three peaks. Similarly between the simulated graph number 7 and the reference model number 3 shows validity of the model.

2. Maximum frequency between exports and imports:

Export and import peak times are repeated frequently. Meaning that in a specific time interval export maximizes and in next peak the import maximizes. Each of the import and export reach maximum point with delay. By matching the simulated graph and reference graph accuracy of the model is shown.

3. Gap between export and import:

Focus of government policies during last years has been on consumer protection and market adjustment through direct and indirect interventions. It means that during the past years government has enacted laws to restrict export and import. Therefore export which causes deficit or price increase locally is minimized. Even in a point steel export required license from the ministry of mines and industries with permission of ministry of commerce. The above analysis shows market adjustment by government through steel imports when the market requires steel and minimizes its export. Even in the reference graph we can see that the maximum and minimum point of import and export move in the opposite direction. Results of running simulated model for a global price shock is illustrated in figure 11.

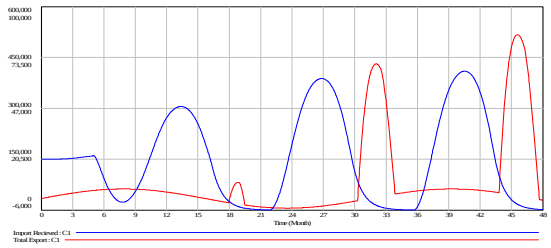

Fig. 11. Comparison trend of rod import and export derived from the model

As it is shown the fluctuation period is nearly one year. Also whenever import is at maximum point, export is at minimum point and vise versa. However the important point is that the shocks in the real market affected from global prices, oil prices, demand and the others. But this phenomenon influences fluctuation period of the model and basic behaviors. For instance if in a three year interval the price of oil increases highly (like the current situation of Iran) and global prices face shock, the behavior of export and import is shown in figure 12.

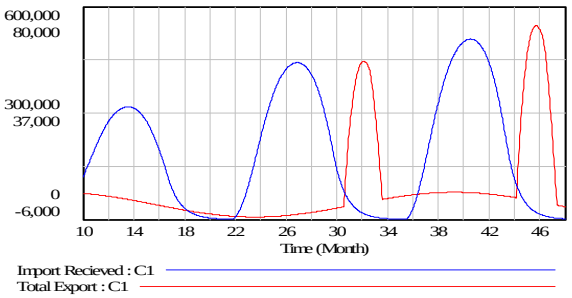

Fig. 12. Comparison trend of rod import and export derived form the model

4. Leverage Points of Model

Leverage points are very high influential points on model. It means that small change in these variables has a great impact on the system. Delays are one of the most important leverage points of the model and result of these analyses were explained in sensitivity analysis section. But to identify leverage points, we change the value of variables which had been placed with predefined values. This practice will continue until the system shows a different behavior. The point where the model with small change of that variable shows a different trend is considered as leverage point. In model it had been assumed the desired and saved stock amount is 5 times more than the quantity of demand. This shows that whatever demand was available, 5 times of it will be available in stock. In case the stock is 5 times more than the demand (primary mode model), value of imported product and trend of producer's rate is shown in Figures 13 and 14.

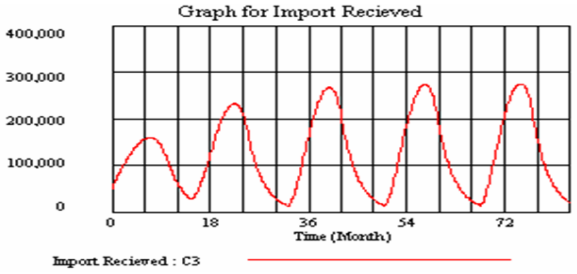

Fig. 13. Rod import before inventory decrease

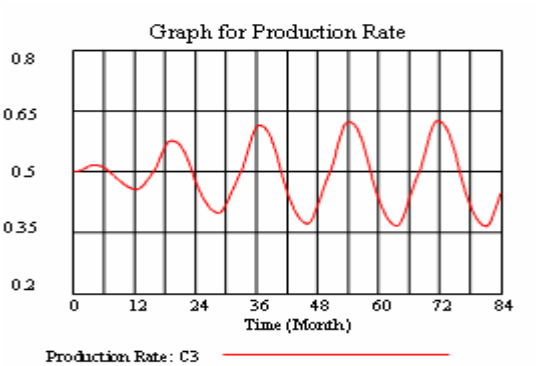

Fig. 14. Private production before decrease

But when the value for this variable was reduced to 1, Process and behaviors related to import and production rates are quite different. Figures 15 and 16 show import trend decreases with descending rate and products rate reduces in moment and does not show a regular and oscillating behavior and after a while it increases in an exponential manner.

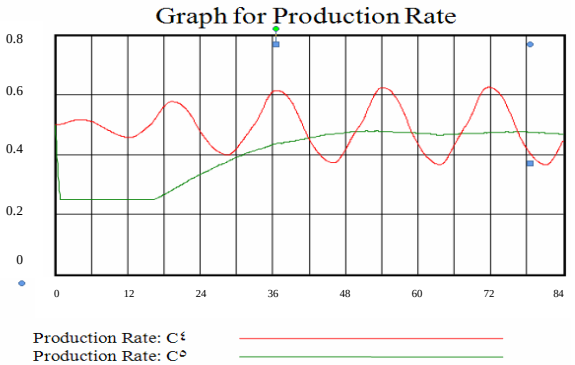

Fig. 15. Private sector production trend

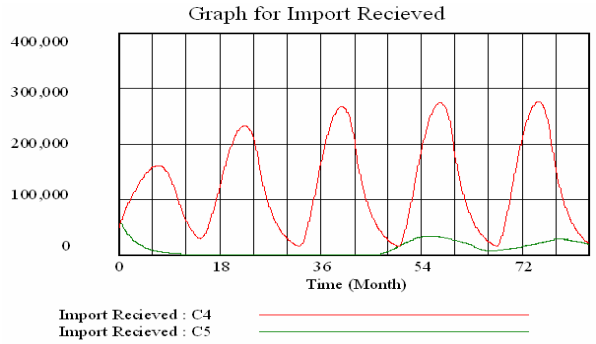

Fig. 16. Rod import trend

It could be inferred that with change in inventory level form 2 to 1, variable's behavior changes completely. In fact, amount of warehouse's inventory should save more than one times to prevent market tension. Therefore ministry of commerce should maintain the value of market inventory more than 2 times of demand quantity.

5. Conclusion

Dynamic extraction of confronting issues to reach simulation model and analysis of present and future of economic and social systems has become important more and more due to change in traditional mechanisms governing economic markets and development of solutions in capital markets. Today, one of the major topics of interest of researchers, economists and financial analysts is elaboration of price fluctuations and trends. Different views have been created in this area. Regarding the strategic role of metals in economic development in Iran, it is necessary to make policies in this area based on a scientific and precise method. Any effort to develop appropriate strategies to reach the desired goals in this industry is valuable. Due to Complexity and dynamics of the rod bar market behavior, and influence of different variables affected by different decision a systematic and multilateral understanding of the truth is necessary. The importance of this issue is multiplied due to the government policies in housing sector and increase of private sector investments in this area and also because of economic development which has been defined in long term programs of Islamic Republic of Iran (the third and fourth development program). Effective decision making in real world, derived from limited rationality related to retrospect and linear view of problems. Involved decision makers in market adjustment area in different levels of government follow the same traditional linear thinking separately.

Dominant thinking of involved organizations believes that with system decomposition and dividing that rod bar market to smaller components and then improving that components, we can get better results. This point of view at this complex and dynamic system, resulting in more effort and less results that are typically seen in the economic system and it has been named under the title of political resistance.

Decision makers in these areas often seek short-term results and as often can be seen, the fear exists that their short-term decisions made result in inappropriate long term results. Of the purpose of this research is creation and development of systematic thinking in governmental organizations especially ministry of commerce. The main result of this article is "dynamic simulation of rod bar market and viewing its behavior over time" which can be used as a model for market analysis of any product!

In this article simulation model based on real data has been created which identifies and predicts behavior of variables and market fluctuations. Model sensitivity analysis was done based on change in exogenous variables of system and delays that existed in real model showed that these delays are sometimes outside the time and place of our decision making area. Steel market model was created with supply-chain approach. The rod bar market model produced has quadratic delay. A degree of delay is from import order time to entering the products to markets. The second delay occurred when products entered into market till they reach to retailers. In fact the model contains quadratic delay. Global price is one of the influential variables on market fluctuations. Because the global price is determined with external mechanisms and Iran can not influence global prices due to lack of significant world market therefore exogenous variables such as global prices have fluctuating effect on rod bar supply chain. Internal price loop and its ratio to global prices determine the import quantity.

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