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A Simple Mathematical Model of Technological Transfer with Two Competing Followers (A Preliminary Result)

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ABSTRACT

In this paper we develop a mathematical model of technology transfer from a leader to two competing follower. We assume that the competition takes place in the accessing process of the source of the technology being transfered. We model the process in the form of a dynamical system and use a standard analysis of its equilibria and their stability properties. We found that both competing parties are able to reach their respective upper limit of the technological development regardless the presence of the competition, but with different rate of the technological progress.
Key words: technology transfer, competition, dynamical system.

1. INTRODUCTION

1.1. Sub Title for Introduction

Technology transfer is a process of the implementation of scientific/technological information developed in one area into another area. Equivalently it is defined as a process of migration and redeployment of technology from one area into different area (Bar-Zakay, 1971; Souder et al., 1990; Ramanathan, 1994). The process of technology transfer is usually done either by a market oriented mechanism, e.g. purchasing, licensing, etc., or a non market oriented mechanism, e.g. academic journal, industrial fair, etc. (Pachamuthu, 2011) and it is mainly involving three components in the process, namely: the technology, the owner of the technology (also called as a leader, transferor, or donor), and the recepient (also called as a follower, transferee, or receiver). Furthermore, the process usually forms a complex system comprising many related aspects, such as the properties of the technology being transfered, the transferor capability of tranferring, and the transferee capability of adapting the technology (Goc, 2002; Lee et al. 2010).

Competition occurs in many aspect in our life. It can be defined as a contest between two individu or parties in gaining their respective objective, such as a territory to live or resources to support their life in biological context or recognition and social status in sociological context. Competition is regarded as a major tenet both in industries and economies. Often multiple firms occur for the same set of customers. Competition could drives to good quality products and/or services.

Competition could appear in many form in different areas. In industrial and economical context the use of the term competition is also prominent, even back to the nineteenth, for example the Cournot competition, the Bertrand competition, the Stackelberg competition etc. Here is a brief description of these different kind of competition. The Cournot competition describes the contest between two suppliers of spring water in a duopoly market (van Berg et al., 2012). The Bertrand competition describes interactions among firms that set prices for their customers who make decision to choose quantities based on the prices set (Bertrand, 1883). The Stackelberg competition is a strategic game in which a follower firm

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moves sequentially by following the move of a leader firm (Stackelberg, 2011).

In regards to technology transfer, new competition rules for technology transfer agreements have been created by the European Commission to regulate a good practice in the technology transfer implementation (Mariniello and Antonielli, 2013). This fact is among the reason to develop a technological transfer model considering competition among related parties. Specifically, in this paper we develop a mathematical model of technology transfer from a leader to two competing followers. We assume that the competition takes place in the accessing process of the source of the technology being transfered. We model the process in the form of a dynamical system and use a standard analysis of its equilibria and their stability properties. The details of the model are described in Section 2.

2. THEORETICAL BACKGROUND

Recently Husniah and Supriatna (2016) have developed a new mathematical model to decribe the transfer of technology by modifying and revising the know Raz and Assa model (1988). They are capable to reveal that the origin Raz and Assa model exhibit a paradoxial property, which hampers the use of the model to the case where the follower has a higher indigeneous ability than the leader. They revised the model to remove the paradox and hence giving a wider class of applications. In this paper we develop a technology transfer model by considering that there a two followers which interact competitively. We follow the above mentioned Husniah and Supriatna method in which the details are presented in Section 3.

3. RESEARCH METHOD

Following Husniah and Supriatna (2016), we assume that in the absence of technology transfer both the leader and the followers have a logistic curve of technological development as a function of time, i.e. $X_L(t)$ for the leader and $X_{Fi}(t)$ with *i*=1,2 for the followers, respectively. The full equations in the presence of competition are given by:

$$\frac{dX_L(t)}{dt} = k_L X_L(t)\left(1-\frac{X_L(t)}{u_L}\right), \qquad (1)$$

$$\frac{dX_{F1}(t)}{dt} = \left(1+(1-C_1)k_T \max\left(0,(X_L(t)-X_{F1}(t))\right)\right)Y_{F1}, \qquad (2)$$

$$\frac{dX_{F2}(t)}{dt} = \left(1+(1-C_2)k_T \max\left(0,(X_L(t)-X_{F2}(t))\right)\right)Y_{F2}, \qquad (3)$$

where $Y_{F1} = k_{F1}X_{F1}(t)\left(1-\frac{X_{F1}(t)}{u_{F1}}\right)$, and $Y_{F2} = k_{F2}X_{F2}(t)\left(1-\frac{X_{F2}(t)}{u_{F2}}\right)$.

The notations and their descriptions are the same as in Husniah and Supriatna (2016) as shown in Table 1.

Table 1. Notation and Description

Notation	Description
$X_L(t)$	the measure of technological development for the leader
$X_{Fi}(t)$	the measure of technological development for the follower
k_L	the indigenous ability of the leader to develop
u_L	the upper limit of the technological development of the leader
k_F	the indigenous ability of the follower to develop
u_F	the upper limit of the technological development of the follower
k_T	the technology transfer rate

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The following section gives a preliminary result from the analysis of the model using dynamical system approach.

4. RESULT AND DISCUSSION

The following graphs illustrate the behavior of the solution of the system discussed above. They are obtained by using the following data set of parameter values: .... which assuming that one of the follower is more competitive than the other.

The system has ten equilibria as shown in Figure 1. One of the equilibria is predicted to be stable as shown in Figures 2 and 3. These figures shows the vector field and the first ten steps of trajectories of the more competitive follower for different initial levels of technological development. Compared to the less competitive follower in Figure 3, this trajectory is ahead. However eventually both followers are able to reach their respective upper bound of the technological development (Figure 4 and Figure 5).

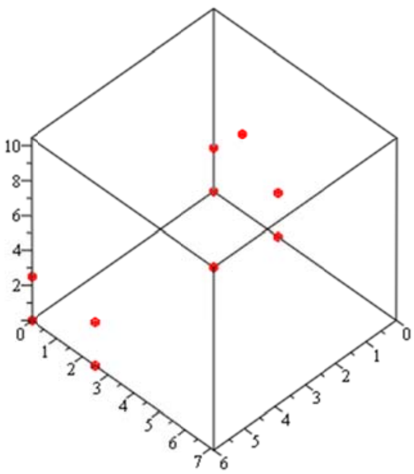

Figure 1. The resulting equilibria for the system. One of the equilibrium is predicted to be stable as seen in its vector field diagram in Figure 2 to Figure 5.

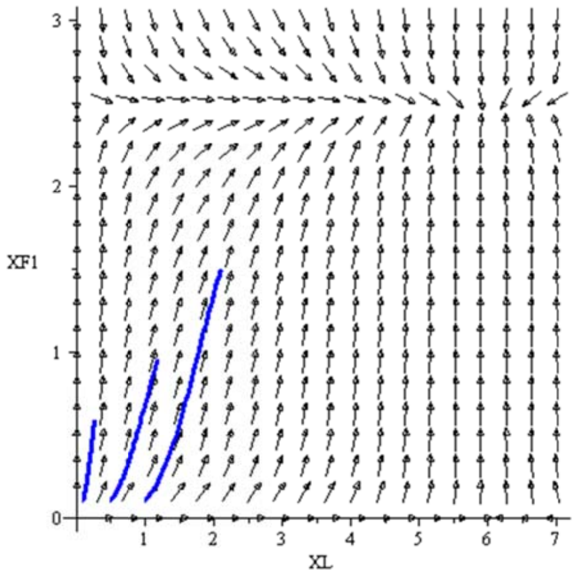

Figure 2. The vector field and the first ten steps of trajectories of the more competitive follower for different initial levels of technological development.

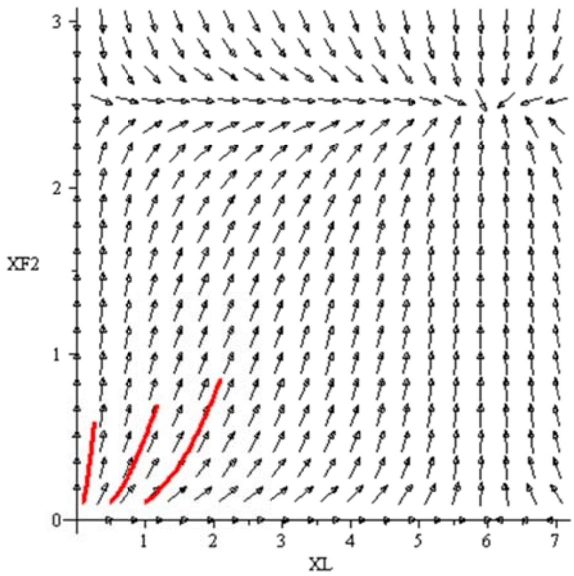

Figure 3. The vector field and the first ten steps of trajectories of the less competitive follower for different initial levels of technological development.

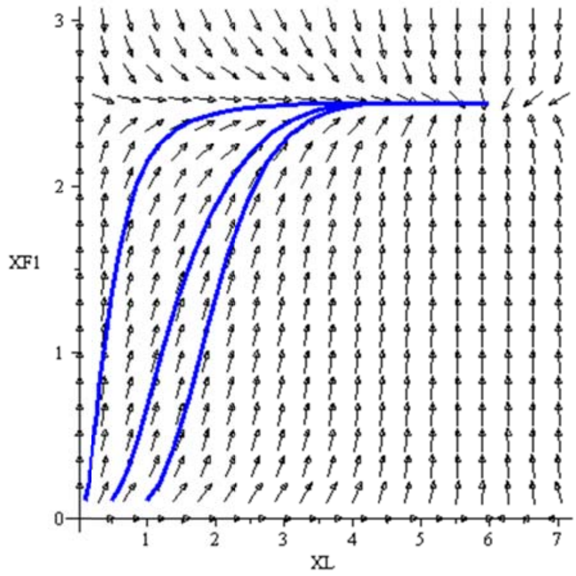

Figure 4. The vector field and the full trajectories of the more competitive follower for different initial levels of technological development.

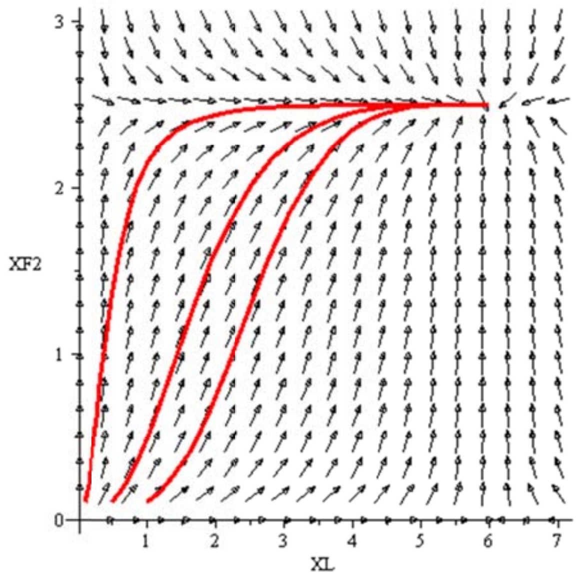

Figure 5. The vector field and the full trajectories of the less competitive follower for different initial levels of technological development.

5. CONCLUSION

In this paper we develop a mathematical model of technology transfer from a leader to two competing follower which takes form as a system of nonlinear differential equations. We assume that the competition takes place in the accessing process of the source of the technology being transfered. We model the process in the form of a dynamical system and use a standard analysis of its equilibria and their stability properties. We found a preliminary result that both competing parties are able to reach their respective upper limit of the technological development regardless the presence of the competition, but with different rate of the technological progress. The implementiation of the model is clearly forseen in many areas of technology transfer as long as the parameters in the model are available. Further investigation need to explore to disclose more properties of the solution of the system

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