Available online at www.sciencedirect.com

ScienceDirect

Procedia - Social and Behavioral Sciences 237 (2017) 882 – 886

Procedia
Social and Behavioral Sciences

7th International Conference on Intercultural Education "Education, Health and ICT for a Transcultural World", EDUHEM 2016, 15-17 June 2016, Almeria, Spain

Simulations of information technology-induced teaching performance in cross-disciplinary settings: a model and an application

Ahmet Kara*

Istanbul Commerce University, Imrahor Cad 90, 34445, Istanbul, Turkey

Abstract

The purpose of this paper is to analyze the dynamic trajectory of teaching performance in cross-disciplinary settings. We take into account the effects of information technology as well as interactions among different disciplines/subjects so as to theorize about possible ways to improve teaching performance. It turns out that, depending on the extent of the effectiveness of information technology and the degree of complementarities among the subjects taught, teaching performance could have different trajectories over time. Contingent upon the amount of resources devoted to teaching, university administrators could choose a path among different trajectories, a path that is most compatible with their institutional objectives.

© 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Peer-review under responsibility of the organizing committee of EDUHEM 2016.

Keywords: Simulations of teaching performance, cross-disciplinary effects, information technology.

1. Introduction

Education is one of the central processes that have shaped the direction of inquiry into the complex social systems/institutions in the last quarter of a century. Among the social systems and structures in question, universities have been a primary focus of attention in the scholarly study of educational phenomena and practices. In this paper,

* Corresponding author. Tel (university).: +90 4440413/4303.
E-mail address: kara2010@ticaret.edu.tr

1877-0428 © 2017 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of EDUHEM 2016.
doi:10.1016/j.sbspro.2017.02.123

we will analyze one subset of these phenomena involving teaching quality and performance in cross-disciplinary settings.

There are a number of works in the literature exploring or analyzing different dimensions of educational (as well as economic and social) institutions and processes. Among these works are Abdullah, Jaafar and Taib (2013), Barlas & Diker (2000), Barlas, Diker, Polat (1997), Fedderke and Luiz (2008), Grayson (2004), Jaffe (1989), Kara (2011, 2013a, 2013b, 2014), Singell and Tang (2013), Spencer (2001), and Walton, Tornatzky & Eveland (1986).

Topics covered in the literature, which are strikingly rich in content, include, but are not limited to, system-theoretic analysis of the higher educational processes (Barlas & Diker, 2000; Barlas, Diker, Polat,1997; Kara, 2011, 2013a, 2013b, 2014), the role of human capital in the development of institutions (Fedderke & Luiz, 2008), the effect of human capital on job outcomes (Grayson, 2004), the ranking of human capital indicators (Abdullah, Jaafar & Taib, 2013), the relation between human capital and leadership in universities (Singell & Tang, 2013), the relevance of university-based scientific research to private high-technology firms (Spencer, 2001), real effects of academic research (Jaffe, 1989) and research management at the university departments (Walton, Tornatzky & Eveland,1986).

Despite the rich coverage of the issues in the literature, there are many issues that need further explorations. Among these is the issue of the dynamics of teaching quality and performance within the university systems. We need models that explore how dynamics of such phenomena plays out over time.

In this paper, we will develop a simple system dynamics-based model that describes the possible trajectories of teaching quality and performance over time. The second section will develop the model. The third section presents the simulations.

2. The Model†

Consider a representative higher educational institution, such as a university, that engages in educational activities/services in n fields. Educational services/activities prepare undergraduate students for their careers after graduation. For the purpose of simplicity, we will consider two fields/subjects, denoted by 1 and 2. The quantity demanded for the educational service in a field 1 at time t (D_{1t}) depends on the level of teaching quality for the service 1 at time t (x_{1t}), the level of the teaching quality for the service 2 at time t (x_{2t}), the relative price of the service 1 at time t (P_{1t}), incomes of the customers of the service 1 at time t (M_{1t}), the level of the use of information technology in the instruction of the service 1 at time t (T_{1t}),

i.e., $D_{1t} = f^{D1}(x_{1t}, x_{2t}, P_{1t}, M_{1t}, T_{1t})$,

which is a quality-dependent demand function for the teaching service 1. $P_{it} \in (0,\infty)$, $M_{it} \in (0,\infty)$. By construction, x_{1t}, x_{2t}, T_{1t} take on values between 0 and 7, i.e., $x_{1t} \in (0,7]$, $x_{2t} \in (0,7]$, and $T_{1t} \in (0,7]$. $D^{T}_{1t} \in (0,\infty)$. We will further assume that price (P_{1t}) is linearly dependent on quality (x_{1t}).

Let S_{1t} denote the quantity supplied for the educational service 1 at time t, which is a function of the level of teaching quality for the service 1 at time t (x_{1t}), the relative price of the service 1 at time t (P_{1t}), and the level of the use of information technology in the instruction of the service 1 at time t (T_{1t}),

i.e., $S_{1t} = f^{S1}(x_{1t}, P_{1t}, T_{1t})$.

$S_{1t} \in (0,\infty)$.

† The model developed here benefits from Kara (2014) which presents a linear model. The model in this paper does, however, include multiplicative and other terms and is structured for a different purpose.

We will assume that the quality-dependent demand and supply functions are of the following forms:

$$D_{1t} = \alpha_0 + \alpha_1 x_{1t} + \alpha_2 x_{2t} + \alpha_3 P_{1t} + \alpha_4 M_{1t} + \alpha_5 T_{1t} + \alpha_6 x_{2t} \,.\, T_{1t} + u_{1t}$$

and

$$S_{1t} = \beta_0 + \beta_1 x_{1t} + \beta_2 P_{1t} + \beta_3 T_{1t} + \beta_4 T_{1t}^2 + v_{1t},$$

where u_{1t} and v_{1t} are independent normally distributed white noise stochastic terms uncorrelated over time. They have zero means and constant variances σ_{u1}^2 and σ_{v1}^2 respectively.

To model the trajectory of teaching quality for service 1 over time, the movement over time of teaching quality for 1 will be assumed to be proportional to the excess demand for quality,

i.e., $x_{1t+1} - x_{1t} = k\,(D_{1t} - S_{1t})$,

where k is the coefficient of adjustment.

This is nothing but a dynamic adjustment equation for teaching quality for service 1. Substituting the expressions for D_{1t} and S_{1t} specified above, setting the values of P_{1t}, M_{1t} and T_{1t} to their average values P_{1t}^{avr}, M_{1t}^{avr} and T_{1t}^{avr}, and rearranging the terms in the equation, we get,

$$x_{1t+1} + (-1-k(\alpha_1 - \beta_1))\, x_{1t} = k(\alpha_0 - \beta_0 + \alpha_2 x_{2t} + (\alpha_3 - \beta_2) P_{1t}^{avr} + \alpha_4 M_{1t}^{avr} + (\alpha_5 - \beta_3) T_{1t}^{avr}$$

$$+\alpha_6 x_{2t}. T_{1t}^{avr} - \beta_4 (T_{1t}^{avr})^2 + u_{1t} - v_{1t}),$$

which is one of the stochastic difference equations that we will employ in the simulations in Section III.

We will propose the following demand-and-supply set up for service 2. The quantity demanded for the educational service in a field 2 at time t (D_{2t}) depends on the level of teaching quality for service 2 at time t (x_{1t}), the relative price of the service 2 at time t (P_{2t}), incomes of the customers of service 1 at time t (M_{2t}), the level of the use of information technology in the instruction of service 1 at time t (T_{2t}),

i.e., $D_{2t} = f^{D2}\,(x_{2t}, P_{2t}, M_{2t}, T_{2t})$,

which is a quality-dependent demand function for the teaching service 2. $P_{2t} \in (0,\infty)$, $M_{2t} \in (0,\infty)$. By construction, x_{2t} , T_{2t} take on values between 0 and 7, i.e., $x_{2t} \in (0,7]$, and $T_{2t} \in (0,7]$. $D_{2t} \in (0,\infty)$. We will further assume that price (P_{2t}) is linearly dependent on quality (x_{2t}).

Let S_{2t} denote the quantity supplied for the educational service 2 at time t, which is a function of the level of teaching quality for the service 2 at time t (x_{2t}), the relative price of the service 2 at time t (P_{2t}), and the level of the use of information technology in the instruction of the service 2 at time t (T_{2t}),

i.e., $S_{2t} = f^{S2}\,(x_{2t}, P_{2t}, T_{2t})$.

$S_{2t} \in (0,\infty)$.

We will assume that the quality-dependent demand and supply functions for 2 are of the following forms:

$D_{2t} = \theta_0 + \theta_1 . x_{2t} + \theta_2 . P_{2t} + \theta_3 M_{2t} + \theta_4 T_{2t} + u_{2t}$

and

$S_{2t} = \delta_0 + \delta_1 . x_{2t} + \delta_2 P_{2t} + \delta_3 T_{2t} + \delta_4 T_{2t}^2 + v_{2t}$,

where u_{2t} and v_{2t} are independent normally distributed white noise stochastic terms uncorrelated over time. They have zero means and constant variances σ_{u2}^2 and σ_{v2}^2 respectively.

To model the trajectory of teaching quality for service 2 over time, we will assume that the movement over time of teaching quality is proportional to the associated excess demand,

i.e., $x_{2t+1} - x_{2t} = k^* (D_{2t} - S_{2t})$,

where k^* is the coefficient of adjustment.

This is of course a dynamic adjustment equation for teaching quality for service 2. Substituting the expressions for D_{2t} and S_{2t} specified above, setting the values of P_{2t}, M_{2t} and T_{2t} to their average values P_{2t}^{avr}, M_{2t}^{avr} and T_{2t}^{avr}, and rearranging the terms in the equation, we get,

$x_{2t+1} + (-1 - k^*(\theta_1 - \delta_1)) x_{2t} = k^*(\theta_0 - \delta_0 + (\theta_1 - \delta_1) P_{1t}^{avr} + \theta_3 . M_{2t}^{avr} + *(\theta_4 - \delta_3) T_{2t}^{avr}$

$- \delta_4 . (T_{2t}^{avr})^2 + u_{2t} - v_{2t})$,

which is the stochastic difference equation describing the movement of teaching quality for service 2 over time.

The two stochastic difference equations we have derived above will serve as a basis for the simulations that we will undertake in the following section.

3. Sımulatıons‡

We will make use of system dynamics method to carry out simulations for teaching quality. The method takes stocks, flows and auxiliary variables as the building blocks and requires that multiple causal connections among the variables be specified mostly in the form of feedback relations or structures. In our model we take the designated teaching qualities as the stocks, the change of which are described as the flow variables. Other variables are of the auxiliary type playing key roles in specifying the feedback relations within the system.

Educational services/activities evolve over time through demand and supply and the adjustment dynamic specified in the model. In addition to teaching quality, we will posit a new concept, namely teaching performance, which we will define in a peculiar manner to represent a form of "quality-adjusted quantity". Teaching performance for i at time t: $yit = xit.Sit$, i=1,2. For simulation purposes, let: $\alpha_0 = 1$, $\alpha_1 = 0.8$, $\alpha_2 = 0.7$, $\alpha_3 = -0.6$, $\alpha_4 = 0.5$, $\alpha_5 = 0.4$, $\alpha_6 = 0.5$, $\beta_0 = 1$, $\beta_1 = 0.8$, $\beta_2 = 0.7$, $\beta_3 = 0.6$, $\beta_4 = 0.01$, k = 0.02, $P_{1t}^{avr} = 2$, $M_{1t}^{avr} = 2$ and $T_{1t}^{avr} = 4$. The initial $x_{1t} = 2$, the initial $x_{2t} = 2$. $\theta_0 = 1$, $\theta_1 = 0.8$, $\theta_2 = -0.7$, $\theta_3 = 0.6$, $\theta_4 = 1$, $1 = 0$, $\delta_1 = 0.8$, $\delta_2 = 0.7$, $\delta_3 = 0.3$, $\delta_4 = 0.05$, k* = 0.01, $P_{2t}^{avr} = 2$, $M_{2t}^{avr} = 2$ and $T_{2t}^{avr} = 4$. u_{it} and vz_{jt} are normally distributed stochastic terms with zero means and unit standard deviations.

‡ Programs ranging from MATLAB to VENSIM could be used for simulation purposes. We have used VENSIM.

By virtue of the presence of both deterministic and stochastic factors in the dynamics of the variables, the trajectories of teaching quality, teaching performance and the cross-effects display stochastic fluctuations around deterministic trends.

Two points on the trajectories may need to be noted. First increases in the use of technology lead to upward shifts in the trajectories of teaching quality and performance, signifying the positive impact of information technology on the teaching quality and performance. Second, changes in the teaching quality for subject 2 are positively associated with the changes in the teaching quality for subject 1, demonstrating, within the causal structure of the model, the positive cross-influence of x2t on x1t. Depending on the degree of complementarities between subjects, the cross-influence curve as well as the usual trajectories could vary.

University administrators could make use of these trajectories in their university-wide dynamic optimization problems so as to determine the optimal values of possible teaching-related policy parameters.

Acknowledgements

The author acknowledges financial support from Istanbul Commerce University.

References

Abdullah,L., Jaafar, S. & Taib,I. (2013). Ranking of Human Capital Indicators using Analytic Hierarchy Process, *Procedia-Social and Behavioral Sciences* 107, 22-28.

Barlas, Y. & Diker V. (2000). A Dynamic Simulation Game for Strategic University Management, *Simulation and Gaming*, 31(3), 331-358.

Barlas, Y. , Diker, V. & Polat, S. (eds.), (1997). Systems Approach to Learning and Educationinto the 21st Century *(Proceedings of 15th International System Dynamics Conference.* Istanbul: Boğaziçi University Press.

Fedderke, J.W & Luiz, J.M. (2008). Does Human Capital Generate Social and Institutional Capital? Exploring Evidence from South African Time Series Data, *Oxford EconomicPapers*, 60 (4), 649-682.

Grayson, J. P. (2004). Social Dynamics, University Experiences, and Graduates' Job Outcomes, *British Journal of Sociology of Education*, 25 (5), *609-627*.

Jaffe, A.B. (1989). Real Effects of Academic Research, *The American Economic Review*, 79 (5), 957-970.

Kara, A. (2011). *Modeling social processes*, Istanbul Commerce University, Mimeo.

Kara, A. **(**2013a). Dynamics of Performance and Technology in Higher Education: An Applied Stochastic Model and a Case Study. *Hacettepe Journal of Mathematics and Statistics* 42 (1), 87-99.

Kara, A. (2013b). Educational Technology and Human Capital, *Procedia – Social and Behavioral Sciences*, 106, 970 – 979.

Kara, A. (2014*). A System Dynamics-Based Decision Support Model for Universities*. Istanbul Commerce University, Mimeo.

OECD. (2001).*The Well-Being of Nations: The Role of Human and Social Capital*. OECD, Paris.

Singell, L.D. & Tang, H-H. (2013). Pomp and circumstance: University presidents and the role of human capital in determining who leads U.S. research institutions, *Economics of Education Review*, 32, 219–233.

Spencer, J. W. (2001). How Relevant Is University-Based Scientific Research to Private High-Technology Firms? A United States-Japan Comparison, *The Academy of Management Journal*, 44 (2), 432-440.

Walton, A. L., Tornatzky, L. G. & Eveland, J. D. (1986). Research Management at the University Department, *Science &Technology Studies*, 4 (3/4), 35-38.