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BUDGET-PERFORMANCE SIMULATIONS: A PEDAGOGICAL EXAMPLE AND A RESEARCH HYPOTHESIS

Theoretical

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ABSTRACT

Purpose: This paper has two main purposes, the first of which is to present a simple pedagogical example of budget-performance simulations that can be used for instructional purposes. The second purpose is to formulate a research hypothesis about the effects, on the overall performance, of (i) the overall level of physical and academic-managerial human capital investments and (ii) the allocation of resources between physical capital and academic-managerial human capital.

Method: We have employed a system dynamics method so as to construct a simplified setup (model) where some pedagogically illustrative components of the budget are specified and linked to an elementarily exemplified performance function. We have then simulated the investment-based performance trajectories to demonstrate the findings of the paper. We have shown how to undertake a policy-based optimization as well. The method (system dynamics) we have chosen is suitable for the modeling of complexly-interwoven optimization and simulation processes.

Findings: Through simulation and policy-based performance optimization exercises, we have demonstrated that the physical and academic-managerial capital investments matter and there exists an optimal allocation of resources that maximizes the university performance.

Originality: There is a need for a comprehensive and in-depth examination/inquiry of the performance optimization and simulation processes associated with the higher education institutions. This article represents a modest contribution to such an inquiry.

Key Words: Budget, Performance, Simulation

JEL Codes: I20, D23, C61

BÜTÇE-PERFORMANS SİMÜLASYONLARI: PEDAGOJİK BİR ÖRNEK VE BİR ARAŞTIRMA HİPOTEZİ

ÖZET

Amaç: Bu makalede, ilkin, pedagojik bir bütçe-performans simülasyonu örneğinin kurgulanması amaçlanmaktadır. İkinci olarak, fiziki ve akademik-idari beşeri sermaye yatırımlarının ve kaynakların bu yatırım bileşenlerine tahsisinin üniversite performansı üzerindeki muhtemel etkilerinin, bir araştırma hipotezi çerçevesinde, incelenmesi hedeflenmektedir.

Yöntem: Makalede, bir sistem dinamiği yöntemi kullanılmakta ve basit bir yapı çerçevesinde, bir bütçenin örnekleme amaçlı olarak seçilen bazı bileşenleri bir performans fonksiyonu ile ilişkilendirilmekte, sistemin bazı anahtar değişkenlerinin seyrinin nasıl simüle edilebileceği ve politika-temelli performans optimizasyonunun nasıl yapılabileceği gösterilmektedir. Makalede kullanılan yöntem (sistem dinamiği), iç içe geçmiş, karmaşık optimizasyon ve simülasyon süreçlerinin modellenmesi için uygun bir yöntemdir.

Bulgular:¨Makaledeki simülasyon ve optimizasyon alıştırmalarıyla, iki tür bulgu örneklenmektedir: İlkin, yatırım temelli performans yörüngeleri simüle edilerek, fiziki ve beşeri sermaye yatırımlarının fark yaratabileceği gösterilmektedir. İkincisi, nümerik bir örnekle, üniversite performansını maksimize edecek kaynak dağılım(lar)ının varlığı kanıtlanmaktadır.

Özgünlük: Yükseköğretim kurumları ile ilgili performans optimizasyonu ve simülasyonu süreçlerinin kapsamlı ve derinlikli incelemelere ihtiyacı bulunmaktadır. Bu makale, bu tür incelemelere mütevazı bir katkı niteliği taşımaktadır.

Anahtar Kelimeler: Bütçe, Performans, Simülasyon

JEL Sınıflandırması: I20, D23, C61

INTRODUCTION

Simulation is an effective instructional tool that can be used for the purpose of exploring different scenarios for social processes and teaching policy-relevant skills for experimentation. One way to undertake a pedagogically useful and scientifically productive social simulation exercise is to create an initial setup (model) which could be successively (or step-by-step) revised so as take into account the complexities of the real-life processes. The initial setup could be based upon the basic features of the chosen process and additional dynamic, stochastic and strategic dimensions could be incorporated later.

The exercise we will choose for this paper is concerned with budget-and-performance-processes of a teaching-research institution, and as such, is related to the education-and-research-relevant issues, which are fairly complicated and examined in some detail in a wide range of works including Dzisah (2007), Barlas & Diker (2000), Spencer (2001), Ehrenberg (2020), Barlas, Diker & Polat (1997), Hage, Mote & Jordan (2013), Abramo, D'Angelo & Di Costa (2014), Ivanov, Markusova & Mindeli (2016), Hayrinen-Alestalo & Peltola (2006), Kara (2007, 2013a,b, 2015, 2018), Metcalfe (2010), Lach & Schankerman (2008), Munoz (2016), Parilli & Elola (2012), Owen-Smith (2018), Ramos-Vielba & Fernandez-Esquinas (2012), Simai (2003), Shin (2009) and Wang, Chen, Weiping, Wang, Guo & Li-Ying (2020).

In this paper, we will not analyze the rich spectrum of the issues in the literature. Instead, we will focus on a particular task of demonstrating simulation in a pedagogically useful and scientifically productive manner. We will undertake two basic tasks. First, we will construct a simple pedagogically useful budget-performance model and simulate the trajectories of budget surplus and overall university performance. In the context of this model, we illustrate policy optimization as well. Second, we formulate a research hypothesis concerning the effects, on the overall university performance, of the overall levels and decompositions of university-related capital such as physical and academic-managerial human capital. We demonstrate that the overall levels of physical and academic-managerial human capital investments matter and there exist particular allocations of resources (and hence investments) between physical capital and academic-managerial human capital that maximize the overall university performance. In view of the focus on the performance improvements in the modern educational and scientific practices, the exercise/model and the research hypothesis presented in the paper could be judged to be of both theoretical and practical significance. The following section presents the pedagogical model/exercise and the research hypothesis and the concluding section points out the possible extensions.

THE CONCEPTUAL/THEORETICAL FRAMEWORK AND THE METHOD

Consider a hypothetical foundation (waqf)-based/established educational institution (e.g., a university) engaging in teaching and research. The institution is assumed to have a certain amount of financial assets (FA_t) which could be negative at the beginning of the period (at t=0), representing an initial debt. The yearly revenues of the institution at time t (YR_t) have three main components associated with educational activities (ER_t), research/project activities (RR_t) and foundation-provided yearly funds and private donations (VR_t). The yearly expenditures at time t (YE_t) also have a number of components associated with teaching (EE_t), research/projects (RE_t), advertising (AE_t), interest payments (IE_t) and some other/residual expenditure (OE_t).

$YR_t=ER_t+RR_t+VR_t$. (1)

$YE_t=EE_t+RE_t+AE_t+IE_t+OE_t$. (2)

Educational revenues depend mainly on the number of individuals receiving the institution-provided educational services (q_t) and tuitions (p_t). q_t is a function of tuitions, advertising expenditures and some stochastic factor (u). Tuitions change over time at a rate either equal or proportional to the inflation rate (r). Research/project revenues will be taken to be a function of the research/project expenditures. The amount of the foundation-provided funds and donations is assumed to be proportional to the total expenditures.

$ER_t = q_t.p_t$. (3)

$q_t= \alpha_1+\alpha_2.p_t+\alpha_3.AE_t+u$. (4)

$p_t =(1+r)^t.p_0$, where p_0 is the tuition at t=0. (5)

$RR_t= \beta_0+\beta_1.RE_t$. (6)

$VR_t = \gamma.YE_t$. (7)

Educational expenditures grow over time at a rate equal or proportional to the inflation rate. The research/project expenditures will be taken to be proportional to the educational expenditures, with a proportionality coefficient (z) to be determined through optimization[1] Advertising (and social) expenditures are also proportional to the educational expenditures. The proportions associated with research/project and advertising expenditures are assumed to add up to a certain policy-specified, predetermined constant (k). $k.ER_t$ is the amount of discretionary fund to be allocated for research and other purposes. Interest payments depend on the amount of debt and the interest rate (s), which is adjusted with respect to the inflation rate and some stochastic factor. Other expenditures grow over time at a rate equal to the inflation rate.

[1] Some of the projects could be financed through profit-and-loss sharing arrangements, which would introduce a stochastic element into the picture. For some complications associated with profit-and-loss sharing arrangements, see Kara (2001).

$EE_t = EE_0.(1+r)^t$, where EE_0 is the educational expenditures at t=0. (8)

$RE_t = z.EE_t$. (9)

$AE_t = (k\text{-}z).EE_t$. (10)

$IE_t = - s.FA_t$, where FA_t is assumed to be negative at t=0, representing an initial amount of debt. $s = s_0 + r$, s_0 is the interest rate at t=0. (11)

$OE_t = OE_0.(1+r)^t$, where OE_0 is the other expenditures at t=0. (12)

The overall performance of the university at t (OP_t) is assumed to be measured on the basis of teaching performance at t (TP_t), which is assumed to depend on the number of individuals receiving educational services at t, and research/project performance at t (RP_t), which is assumed to be a function of the research/project expenditures at t and some stochastic factor (v). The number of publications will be taken to be a proxy for the research/project performance.

$TP_t = q_t$. (13)

$RP_t = \theta.RE_t+v$. (14)

We will assume that the overall performance is a logarithmic function of the teaching and research performances.

$OP_t =\delta_1.\ln(TP_t)+\delta_2.\ln(RP_t)$, (15)

where the values of δ_1 and δ_2 are assigned by the administrators on the basis of the relative priorities of teaching and research.[2]

For simulation purposes, we will use the method of system dynamics, which, for the setup (system) we have, requires the specification of the stock variable, the flow variable, the auxiliary variables and the possible feedback loop(s) within the system. In the current system, the amount of financial assets is the stock variable, the change of which depends on the budget surplus, which is the flow variable. Other variables in the system are auxiliary variables. There are a number of feedback loops within the system, one of which is as follows. The amount of financial assets influences the interest component of the setup, which eventually influences the budget surplus which, in turn, influences the amount of financial assets.

The sketch of the causal connections/links embodied in the setup is presented in Figure 1.

[2] The institution may have multiple and potentially juncture-dependent preferences, which require more complicated optimal decision making processes. For an account of the issues of multiple/multidimensional preferences and associated complexities in economic theory, see Kara (1996, 2009).

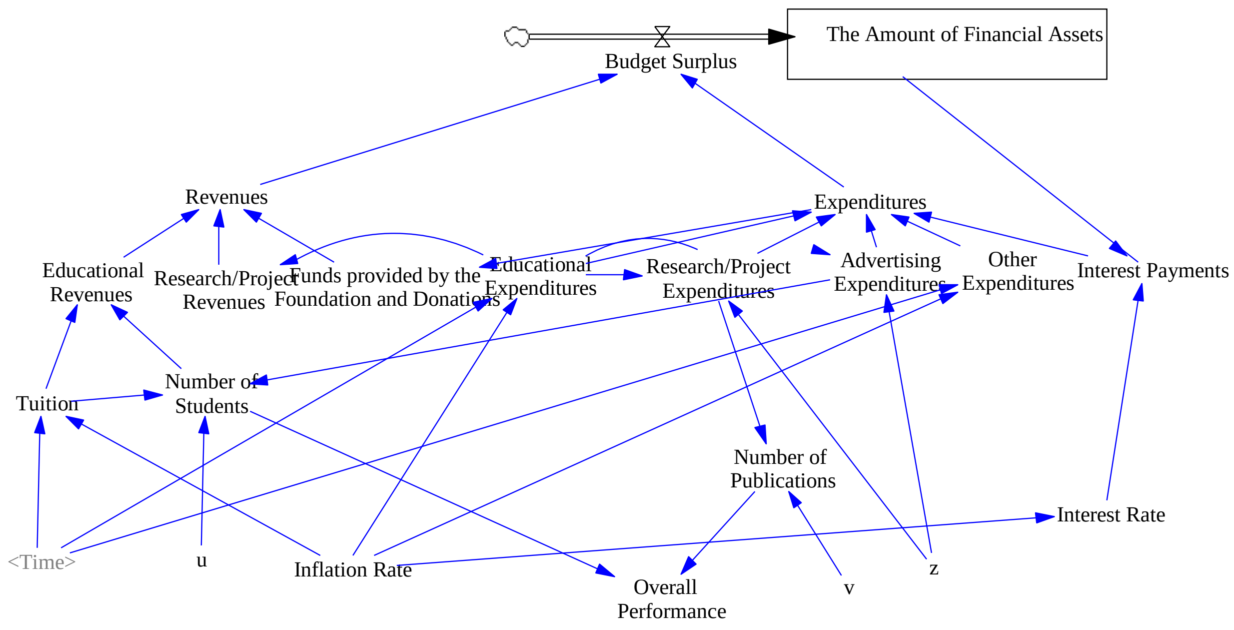

Figure 1. The simulation diagram.

FINDINGS

To simulate the trajectories of the variables in the system, let us choose the following parameter values: The initial value of the financial assets = -100000, α_1=6500, α_2 =40.α_3 =0.1, u = RANDOM NORMAL(-500, 500, 0, 250, 0)[3], r =0.05, p_0 =50, β_0= 2500, β_1 = 0.9, γ = 0.1, EE_0 = 150000, k = 0.3. s_0 = 0.03, OE_0 = 100000, θ = 0.01, v = RANDOM NORMAL (-50, 50, 0, 25, 0). δ_1 = 0.6, δ_2 = 0.4. The initial z = 0.1. Initial time = 0. Final time = 10. Time unit = year.

The simulated trajectories of the budget surplus and overall performance for the chosen period are as follows (Figure 2 and Figure 3):

[3] That is to say, the minimum, maximum, mean and standard deviation of u are -500, 500, 0 and 250, respectively. The seed value is taken to be zero.

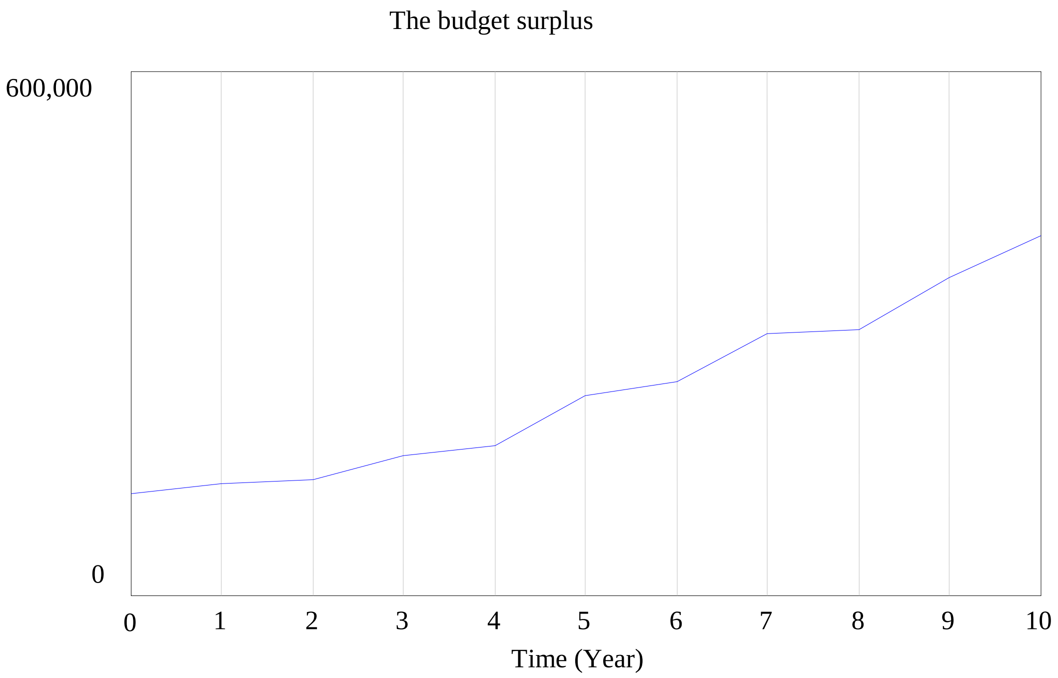

Figure 2. The budget surplus trajectory.

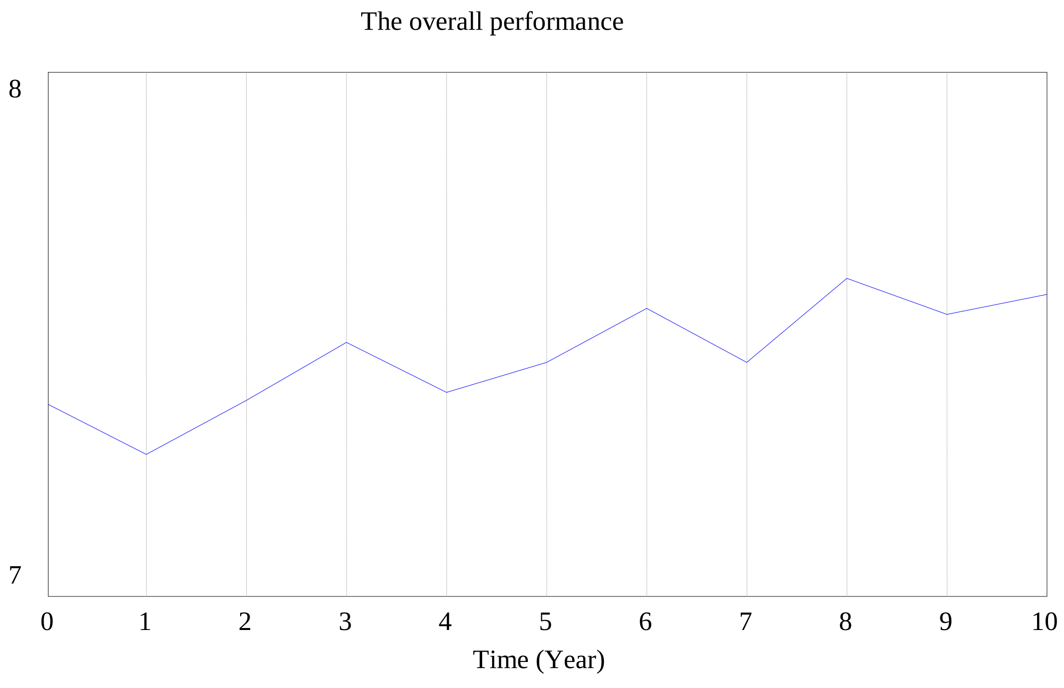

Figure 3. The overall performance trajectory

Clearly, the budget surplus and overall performance trajectories display upward trends over time.

Are these trajectories the “best possible”/“optimal” ones for the institution? The answer to this question depends on the particular optimization problem the institution chooses. Suppose that the institution tries to find the overall-performance-maximizing value (or values) of z. Using the optimization capabilities of VENSIM DSS in this stochastic setup, we find that z=0.2 maximizes the overall performance. If we re-simulate the overall performance with z=0.2, we get the following trajectory (Figure 4).

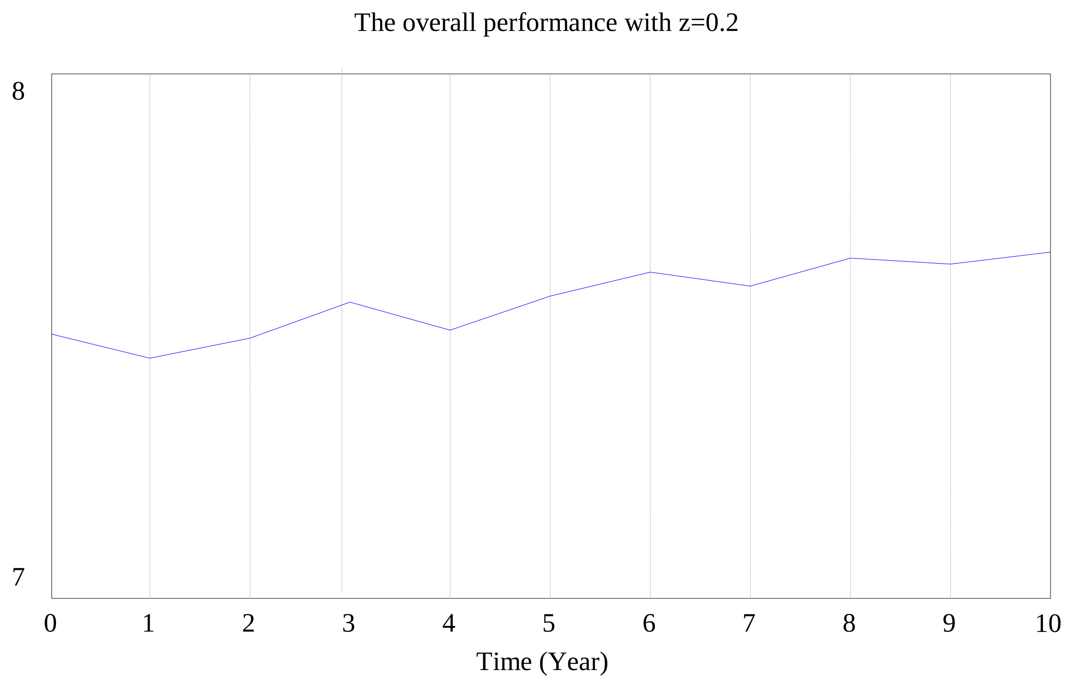

Figure 4. The overall performance trajectory with z=0.2.

The overall performance values over time slightly improve. Thus, setting the policy parameter optimally makes some difference.

Depending on the weights of teaching and research (δ_1, δ_2) in the performance function of the university, the optimal value of z changes. In the set of parameters above, $\delta_1 = 0.6$ and $\delta_2 = 0.4$ indicate a relatively higher weight for teaching. If we change these weights so as to have a weight of 0.4 for teaching and a weight of 0.6 for research, the optimal value of z becomes 0.29. Thus, the higher is the weight associated with research, the higher is the optimally-assigned, research-related fraction of the discretionary fund.

Simulation exercises could be extended to incorporate the effects of various aggregated or disaggregated forms of capital on the university performance. For illustration purposes, suppose that the institution's academic-managerial human capital at t (HK_t) directly influences the number of individuals (q_t) receiving educational services and the number of publications (RP_t) produced. The new equations for q_t and RP_t are as follows.

$$q_t^* = \alpha_1+\alpha_2.p_t+\alpha_3.AE_t+ \alpha_3.HK_t+u. \quad (16)$$

$$RP_t^* = \theta_1.RE_t+ \theta_2.HK_t+v. \quad (17)$$

A simulation diagram with a human capital dimension is given in Figure 5 below.

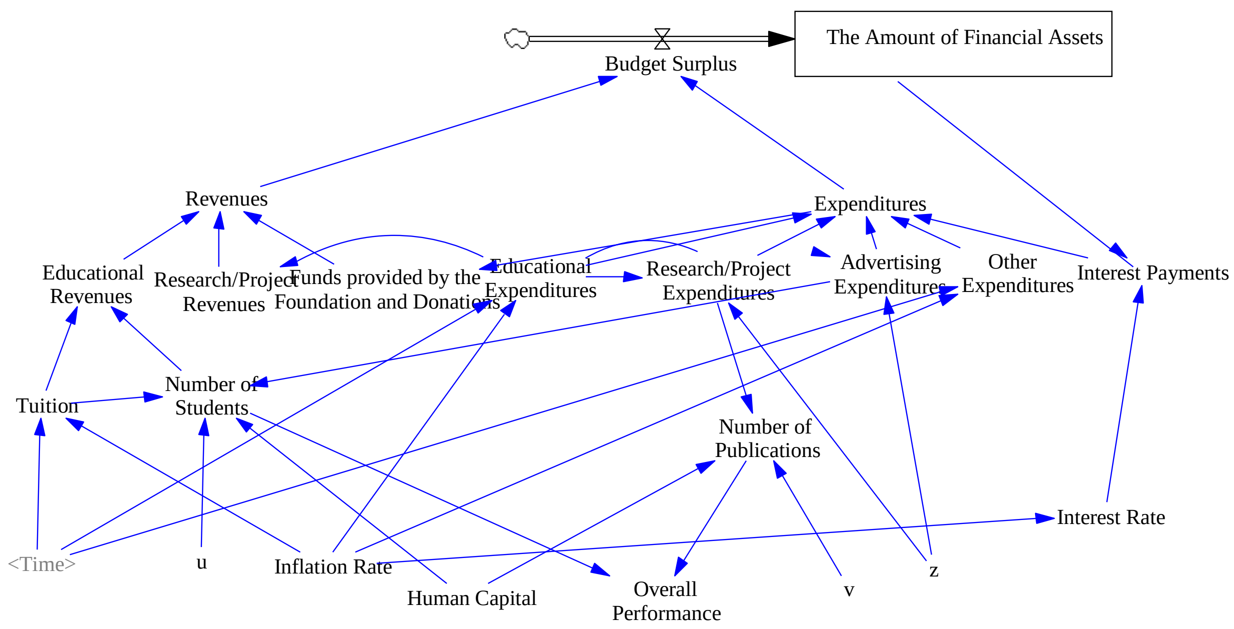

Figure 5. The simulation diagram with a human capital dimension[4]

For simulation purposes, suppose that, in addition to the parameter values associated with Figure 1, α_3 = 200, θ_1 = 0.01, θ_2= 20 and the value of HK_t = 5.[5] The human capital-incorporated overall performance trajectory associated with these parameter values is as follows (Figure 6).

[4] Please note that HK_t is introduced here as an auxiliary variable. Alternatively, it could be incorporated into the system as a stock variable as well.
[5] HK_t representing the knowledge, ability and competences of academic and other personnel could be measured in various ways, the details of which will not be explored here.

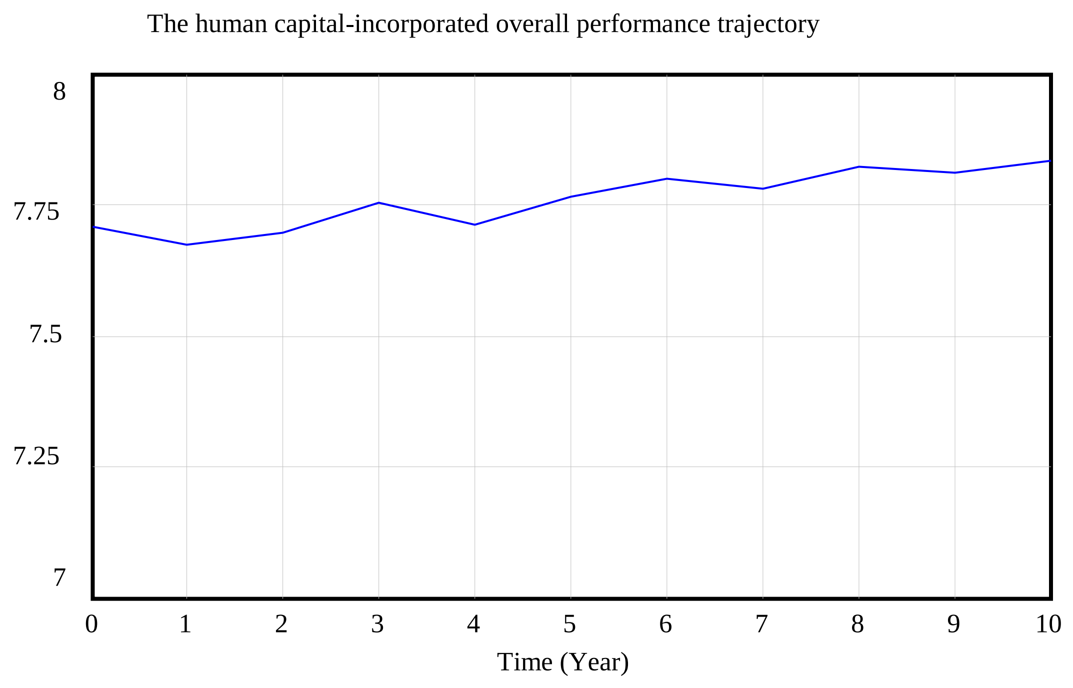

Figure 6. The human capital-incorporated overall performance trajectory

The overall performance trajectory in Figure 6 represents higher values of overall performance compared to the trajectory in Figure 4, illustrating the positive effect of human capital on the overall performance. We can illustrate the possible effects of other types of capital, such as physical capital and social capital, on the university performance in a similar manner.

Instead of exploring the individual effects, on the overall university performance, of all different types of capital, we will explore the effects of some key underlying factors, namely, investments in various forms of capital and allocations of resources between/among those forms of capitals. This will be the subject matter of the research hypothesis we will put forward in the final part of the paper. We will formulate a research hypothesis concerning the effects, on the university performance, of (i) the overall level of investments in physical and academic-managerial human capital and (ii) research allocations between these different types of capital. We will add a new component to the overall expenditures, namely capital investment expenditures (CIE_t), which is assumed to have two components: physical capital investment expenditures (PCE_t) and academic-managerial human capital investment expenditures (HCE_t). Capital investment expenditures are a fraction (w_2) of the amount of financial assets. w_1 percent of the amount of financial assets is allocated to the physical capital investment expenditures and w_2-w_1 percent is allocated to the academic-managerial human capital investment expenditures.

$$CIE_t = PCE_t + HCE_t. \quad (18)$$

$$PCE_t = w_1.FA_t. \quad (19)$$

$$HCE_t = \text{IF THEN ELSE } (FA_t>0,(w_2-w_1).FA_t, 0). \quad (20)$$

The overall level of physical and academic-managerial human capital investment expenditures will influence the teaching performance and the research performance. The revised equations for teaching and research performances are as follows:

$$TP_t^{revised} = \alpha_1+\alpha_2.p_t+\alpha_3.AE_t+ \alpha_4.HCE_t+\alpha_5.PCE_t + u. \quad (21)$$

$$RP_t^{revised} = \theta_1.RE_t+ \theta_2.HCE_t+\theta_3.PCEt +v. \quad (22)$$

We will re-construct the simulation diagram so as to take into account the new variables and the relationships. Please note that, for the sake of illustrating an alternative which is slightly different than the one shown above, the interest component in the model is incorporated as a revenue rather than expenditure item (Depending on whether FA_t is positive or negative, it could be a revenue or an expenditure.) The new diagram is presented in Figure 7.

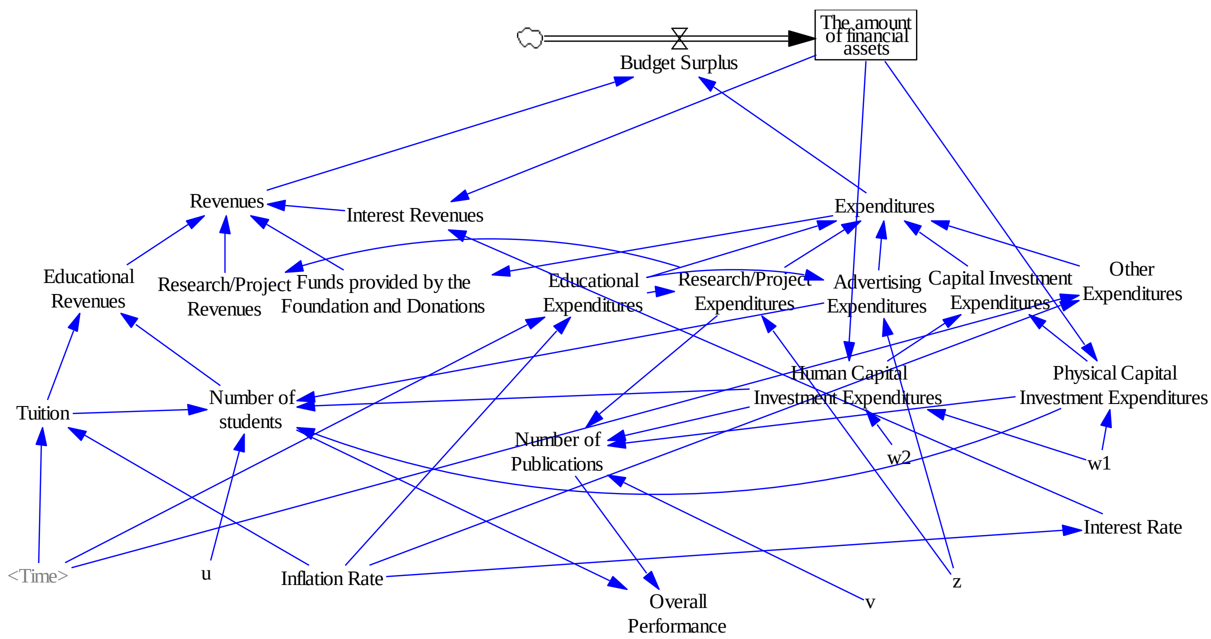

Figure 7. The physical-and-human-capital-investment-incorporated simulation diagram

Our research hypothesis is that the overall level of capital investments matters and there exists at least one particular allocation of investment between physical capital and academic-managerial human capital that maximizes the overall university performance.

To analyze and exemplify the effects of the overall capital investments on the university performance, we will use the simulation setup described in Figure 7, which includes many of the relationships that exist in Figure 1. There are, however, some additional parameters, the values of which we set in the following manner: $\alpha_4 = 0.023$, $\alpha_5 = 0.03$, $\theta_2 = 0.002$, $\theta_3 = 0.001$, $w_2 = 0.2$, w_1 is to be determined through optimization.

The new overall performance trajectory with capital investments is displayed in Figure 8.

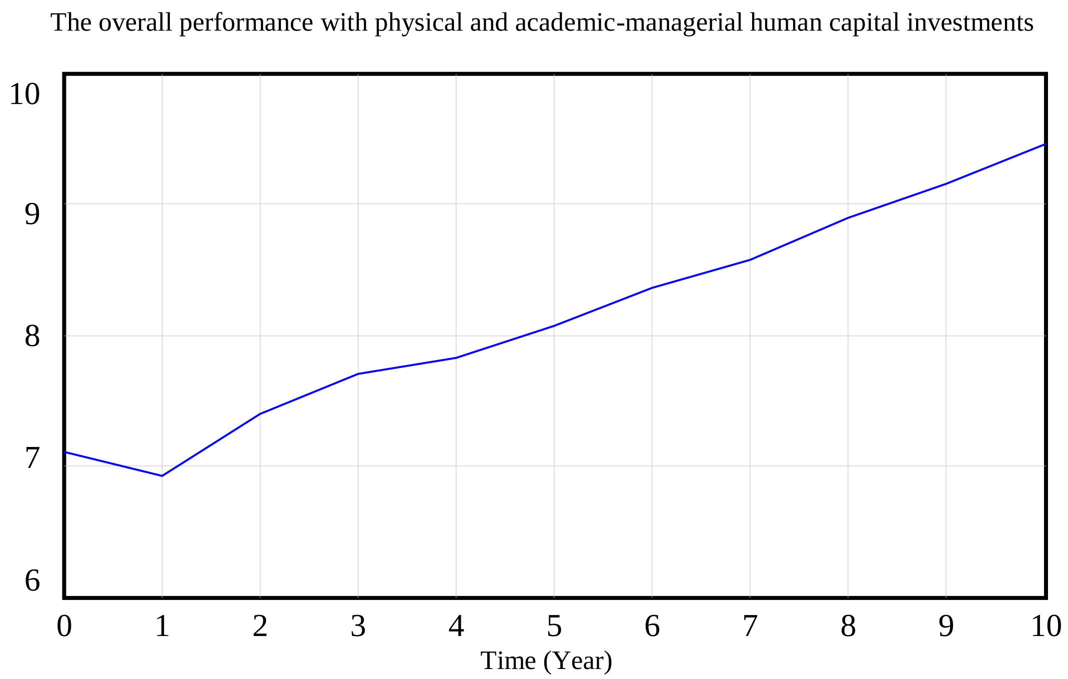

Figure 8. The overall performance trajectory with capital investments

In contrast with the previous overall performance trajectories, the trajectory in Figure 8 has a "steep trend", indicating that the physical and academic-managerial human capital investments lead to considerable increases in the overall performance over time. Thus capital investments matter.

Could decompositions of capital investments between physical and academic-managerial human capital make a difference as well? To answer this question, we will try to find whether there exists an (optimal) allocation of resources that maximizes the overall university performance. To find the performance-maximizing value(s) of the decomposition between these different types of capital investments, we now introduce w_1 into the system as a decision variable. Thus in addition to z, w_1 will function as an optimization instrument in the model. We will maximize the overall performance with respect to both w_1 and z. Using the optimization capabilities of VENSIM DSS, we find that, with these parameter values, the overall performance is maximized at $w_1 = 0.0658375$, exemplifying the existence of a performance-maximizing resource allocation between physical and human capital.[6]

CONCLUDING REMARKS

This paper undertakes two main tasks. First, it presents a pedagogical example of an interlinked simulation and optimization for decision making processes of an institution engaging in teaching and research. By the very nature of the pedagogical exercise, the constructed setup is simple and does not take into account many complexities encountered in real-life institutional decision making processes. Many of these complexities, however, could be incorporated into the setup presented here. For instance, in addition to the case of human capital exemplified above (in Figure 5), non-human capital dimensions of teaching, research and managerial processes could be taken into account by properly representing these different dimensions of capital as stock variables, which could be connected to the other variables in the system. Various components of the budget could be revised and detailed so that the budget resembles to the real-life examples encountered in practice. Dynamic, stochastic and strategic dimensions within the institution as well as interactions with the environment could be incorporated into the model as well.

Second, the paper formulates a research hypothesis concerning the effects of the levels and decompositions between the physical and academic-managerial capital on the overall university performance. It shows, through a simulated physical-and-academic-managerial-human-capital-incorporated trajectory, that the overall capital investments matter. Moreover, it is shown that there exists an allocation of resources between physical and academic-managerial human capital that is performance-maximizing. This hypothesis could be refined further to explore the discipline-specific performance effects of the sub-components of different types of capital in disciplinarily decomposed settings. Such a disaggregated analysis of the performance effects of various forms of capital could reveal additional avenues for improvement, which may be worthy of further inquiry.

[6] For a similar optimization problem, see Kara (2020).

REFERENCES

Abramo, G., D'Angelo, C.A.& Di Costa, F. (2014). Investigating returns to scope of research fields in universities. *Higher Education*, 68 (1), 69-85.

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 education into the 21st century (Proceedings of 15th International System Dynamics Conference*). Istanbul: Boğaziçi University Press.

Dzisah, J. (2007). Institutional transformations in the regime of knowledge production: The University as a catalyst for the science-based knowledge economy. *Asian Journal of Social Science*, 35(1), 126-140.

Ehrenberg, R. G. (2020). *Akademinin yönetimi: Modern Üniversite'de sorunlu kim?* KüreYayınları.

Hage, J., Mote, J.E. & Jordan, G. B. (2013). Ideas, innovations, and networks: a new policy model based on the evolution of knowledge. *Policy Sciences (Special Issue: Protecting and Sustaining Indigenous People's Traditional Environmental knowledge and Cultural Practice),* 46(2), 199-216.

Häyrinen-Alestalo, M. & Peltola, U. (2006). The problem of a market-oriented university. *Higher Education*, 52(2), 251-281.

Ivanov, V.V., Markusova, V.A. & Mindeli, L.E. (2016). Government investments and the publishing activity of higher educational institutions: Bibliometric analysis. *Herald of the Russian Academy of Sciences*, 86 (4), 314-321.

Kara, A. (1996). The *Economic self as a multidimensional complexity: Towards a critique and reconstruction of economic theory*. Ph. D. Dissertation, University of Massachusetts at Amherst. Microfilm version, *UMI*.

Kara, A. (2001). On the efficiency of the financial institutions of profit and loss sharing. *Journal of Economic & Social Research*, 3(2), 99-104.

Kara, A. (2007). Discrete stochastic dynamics of income inequality in education. *Discrete Dynamics in Nature and Society*, 2007(1), 1-15.

Kara, A. (2009). Implications of multiple preferences for a deconstructive critique and a reconstructive revision of economic theory. *Journal of Economic & Social Research*, 11(1), 69-78.

Kara, A. (2013a). Dynamics of education and technology in higher education. *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. (2015). Simulations of technology-induced and crisis-led stochastic and chaotic fluctuations in higher education processes. *Educational Sciences: Theory & Practice*, 15(2), 303-312.

Kara, A. (2018). Escaping mediocre-quality, low-productivity, low-Performance traps at universities in developing countries: A human capital-based structural equation model with system-dynamics simulations. *Educational Sciences: Theory & Practice*, 18(3), 541-559.

Kara, A (2020). An exploratory note on the efficient university management. *Istanbul Ticaret Üniversitesi Sosyal Bilimler Dergisi,* 19 (Sabri Orman Özel Sayısı): 394-403.

Lach, S. & Schankerman, M. (2008). Incentives and invention in universities. *The RAND Journal of Economics*, 39(2), 403-433.

Metcalfe, J. S. (2010). University and business relations: Connecting the knowledge economy. *Minerva*, 48(1), 5-33.

Munoz, D.A. (2016). Assessing the research efficiency of higher education institutions in Chile: A data envelopment analysis approach. *International Journal of Educational Management*, 30 (6), 809-825.

Owen-Smith, J. (2018). *Research universities and the public good: Discovery for an uncertain future (Innovation and technology in the world economy)*. Stanford Business Books.

Parrilli, M.D. & Elola, A. (2012). The strength of science and technology drivers for SME innovation. *Small Business Economics*, 39(4), 897-907.

Ramos-Vielba, I. & Fernández-Esquinas, M. (2012). Beneath the tip of the iceberg: exploring the multiple forms of university—industry linkages. *Higher Education*, 64(2), 237-265.

Shin, J.C. (2009). Building world-class research university: The brain Korea 21 project. *Higher Education*, 58(5), 669-688.

Simai, M. (2003). Knowledge, research, development and innovations: Some ideas from a research program. *Society and Economy*, 25(3), 305-319.

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.

Wang, Y., Chen, Y., Weiping, L., Wang, T., Guo, L. & Li-Ying, J. (2020). Funding research in universities: Do government resources act as a complement or substitute to industry funding? *Economic Research*, 33 (1), 1377-1393.