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with
Tools of Economic Analysis & Management

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with
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JEL Classification Code: A11, A12, A13, A20, I21, I23

Keywords: Science, Economics, Education, Research, Training, Innovation, Integration.

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"*Most doctoral programs conform to a model defined in the middle ages.*"

Mark Taylor, *Nature* (April, 2011)

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1. Introduction

The pressing need for transforming the current system of graduate education and research is widely recognized all across the globe. Doctoral programs, with fragmented curricula and ad hoc collaborations, are increasingly losing their relevance outside of academia. This continues to exacerbate an already widening gap between educational supply and occupational demand. To make matters worse, the recent global economic crises have put education and research on a spot facing unprecedented financial challenges. The problem is systemic with complex facets of incomplete information stiffening the boundaries of disciplines. We propose a Hub-and-Spoke (HaS) model of Scientific Collaboration & Innovation with Tools of Economic Analysis & Management (SCITEAM) to identify an effective solution through free and frictionless trans-disciplinary flow of information aligning the value embodied in education with its economic costs.

2. Context

Our vision of a SCITEAM can be illustrated by drawing an analogy between an academic institution and the life functioning of a tree. A mature academic institution spreads its roots, as far as it can, to draw in a diverse pool of talents and educate them

through interactions with scholars linked through widely spread out branches. Scholars in the limelight, like the leaves on a tree, lead the way of synthesizing accessible resources to yield a new generation of scholars who carry the seeds of education and research beyond the reach of the tree which nurtured them. The key to sustaining such an elaborate system lies in its flexibility to expand without boundaries, at the same time, allowing free and frictionless flow of information without any distortion.

Rapidly growing interest in trans-disciplinary research between the fields of economics and other fields, including though certainly not limited to, natural sciences holds significant promise for creative collaborations. For illustration, on the face of the recent sub-prime mortgage bubble, the ensuing financial crisis, and its impact on the world economy, a handful of physicists working on economic problems -- in the young but rapidly growing field of *econophysics* – were among the first to point out that the financial system had undergone changes that made it inherently unstable. Using the theory of complex systems, econophysicists argue that most analyses of the financial and economic system were too simple-minded, as they underestimate the importance of feedback loops and cascading effects. This multidisciplinary field of econophysics continues to rise through the works of physicists addressing a wide range of economic problems to test a variety of novel conceptual approaches deriving from the physical sciences. Along similar lines, the rise of *nanoeconomics*, as an alliance of nanoscience and economics, aims at accelerating the pace of technological change. A relatively younger field of *econochemistry* aims at narrowing the gap between economic theory and reality by drawing on the complex dynamics modeled through oscillatory chemical systems. On another track, a paradigmatic shift in research efforts linking the economy to the environment is advancing through the emerging

field of *bioeconomics* to determine the threshold of economic activity for which a biological system can be efficiently utilized without destroying the conditions for its regeneration and sustainability. This multidisciplinary area of research has at its core the economic activity of nature and promotes imitating and mimicking the biological processes that function to perfection in nature through the processes of evolution, coevolution, cooperation, natural selection, conservation, regeneration and recycling. In sharp contrast with the view that rules and regulations form the essence of the market, bioeconomics focuses on change and innovation based on revolutionary ideas in a dynamic and globalized world. One would, of course, be remiss not to mention the emerging images of *neuroeconomics* (a natural extension of bioeconomics) that continue to unfold a ‘‘black box” using knowledge about brain mechanisms to inform economic theory, reflecting a natural affinity between neuroscience and economics. In addition to being the science of supply, demand, and prices, bio-economics also embraces the science of accounting for the biological, economic, social, environmental and ethical realities of resource depletion, wealth inequality, social inequity, environmental contamination and ethical misconduct.

Consistent with these revolutionary trends, in recognition of the fact that science, technology and economics can neither be separated, nor understood by the traditional "siloed" approach, our effort reaches out for a definitive answer to a fundamental question: How best can the apparently complicated interplay, between the tools of economics and those of natural sciences, be integrated into a seamless synthetic structure through free and frictionless flow of information across disciplines? An efficient solution lies in blending Scientific Collaboration and Innovation (SCI) with Tools of Economic Analysis &

Management (TEAM) through responsive curricular transformation striking a fine balance between research and education.

3. Construct

In a thought-provoking article at the *Nature* (April, 2011), Mark Taylor pointed out: "If doctoral education is to remain viable in the twenty-first century, universities must tear down the walls that separate fields, and establish programs that nourish cross-disciplinary investigation and communication." We lay out an eclectic model of transformative trans-disciplinary research and training that is designed to address the issue of outdated frictions with the economic incentives and constraints in vision. Our construct is founded on the premise that collaborations are scientific if only if they are embedded in an environment of free and frictionless flow of information across all related disciplines which results in an efficient realization of the potential synergies.

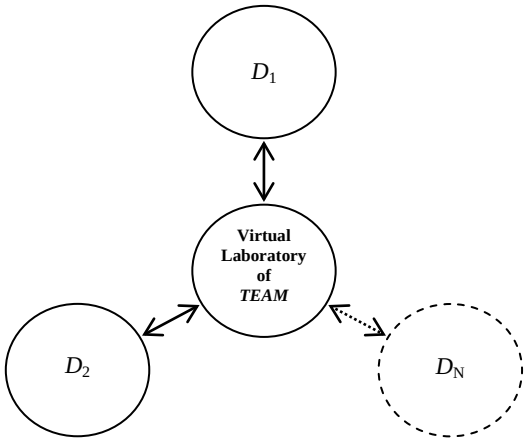

Figure 1: A HaS Design of Integrated Graduate Education, Research, and Training

[Note: $D_j : j = (1,2,...,N)$ stands for any one of the N existing areas of research and training holding the potential for Scientific Collaboration & Innovation with Tools of Economic Analysis & Management]

The thematic basis of our SCITEAM model can be depicted in a structural representation (figure 1 above) of a HaS design that revolves around a Virtual Laboratory (VL) of economic analysis and management, balancing the centrifugal and centripetal forces of education and research aimed at scientific collaboration and innovation, that integrates .

The analytical foundation, of the efficiency of SCITEAM-VL mechanism for integrating graduate education, research, and training (GERT), builds on the principle of comparative advantage. Stylize GERT as a recurring activity over generations ($G_t: \ t = 0,1,2,...,\infty$). Consider a competitive (composed of atomistic institutions) academic world of 2 disciplines ($D_j: \ j = 1,2$) *each* endowed with E hours of effort from scholars who conduct GERT (subject to unit effort requirements, $e_i^j: \ i, j = 1,2$, i.e. the hours of effort required to support one unit of GERT) in 2 areas ($A_i: \ i = 1,2$). $i \neq k$, $e_{ik}^j = \left(\lambda e_i^j + (1-\lambda) e_k^j\right)$ be the unit effort requirement, where $\lambda \in (0,1)$, for any collaboration (A_{12}) without the possibility of integration across disciplines.

The principle of comparative advantage promises gains from efficiency when D_i specializes in $A_i \ \forall \ \frac{e_1}{e_2} \in \left(\frac{e_1^1}{e_2^1}, \frac{e_1^2}{e_2^2}\right)$, where e_i is the shadow price for each unit of the services provided by those conducting GERT in A_i at an *integrated* equilibrium without the VL. Absent an effective redistribution mechanism, that partially extracts the gains from the "winners" to ensure sufficient compensation for the "losers" leaving no one worse-off, potential "losers" will resist *integration* with the help of "walls" that arbitrarily "separate"

areas (and allowing only unscientific collaborations) by obstructing free and frictionless flow of information.

The SCITEAM-VL mechanism, in comparison, can not only replicate the integrated equilibrium but also extend the gains by breaking the information barriers and, at the same time, make room for scientific collaborations. For illustration, let $e_1^1 = 1 = e_2^2$ and $e_2^1 = 2 = e_1^2$. Figure 2 below depicts the gains from the SCITEAM-VL mechanism even without collaborations.

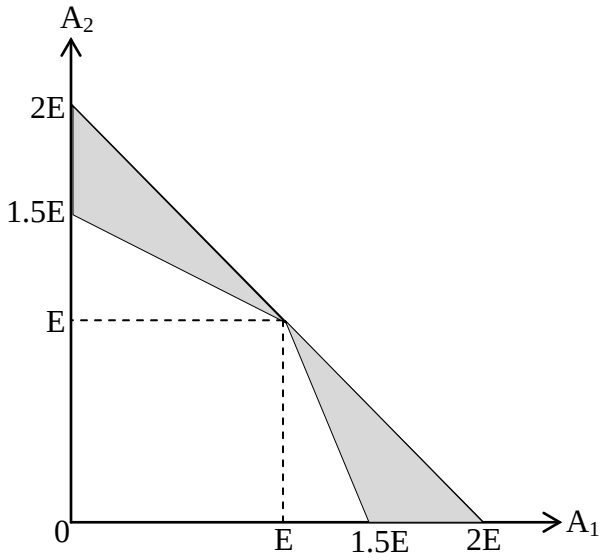

Figure 2: Shaded Area Captures
G_T's Potential Gain $\forall T \in (1,2,...,\infty)$ from VL without collaboration

It may be noted that $e_{ik} = \left(\lambda \min\left\{e_1^1, e_2^1\right\} + (1-\lambda)\min\left\{e_1^1, e_2^1\right\}\right)$ is the source of any additional efficiency gains from scientific collaborations. For simplicity of exposition, let $\lambda = \frac{1}{2}$, as we use figure 3 below to depict the gains from the SCITEAM-VL mechanism with collaborations.

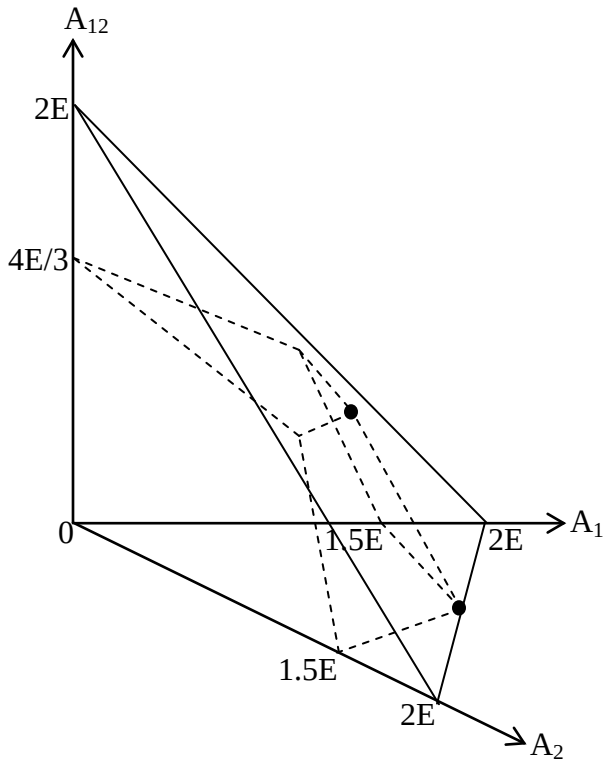

Figure 3: Space between Solid-outlined Surface and Broken-outlined Surface Captures G_T's Potential Gain $\forall T \in (1,2,...,\infty)$ from VL with collaboration

The conception of our hub-and-spoke construct stems from the cognizance of the logistics that have a proven record of revolutionary impact on the economic efficiency of the transportation sector, health care industry, financial services, pharmaceuticals, auto manufactures, electronic commerce, as well as information technology. The merit of our approach is firmly rooted in the concept of *economies of flow* with efficiency increasing as the number of branches multiply. Scholars across disciplines can connect through the hub of a virtual laboratory equipped with the tools of Economic Analysis and Management. The HaS construct will ensure an efficient transfer, transformation, and integration of information between apparently heterogeneous branches of education and research. The aim is to rapidly process and integrate information, flowing to and from the branches and the hub, and form a fully functional educational infrastructure that can create a seamless

academic environment for research and innovation. Our choice of the hub stems rather naturally from the rich body of time-tested tools that economic analysis and management offer for efficient balancing between means and ends and retains the elasticity of connecting to additional branches.

The organizational structure of our HaS model can be streamlined through a parallel chain of command maintaining distinct, though often interrelated, lines of responsibilities. An effective use of the parallel chain of command can increase the efficiency of an educational organization much like enabling separate and parallel processing to take place in the two hemispheres can increase brain efficiency. The right brain focuses on networking and has bottom-up control while the left brain focuses on hierarchy and has top-down control: collectively, a lateralized brain is a more efficient processor. The organizational role of scholars is likely to resemble the right hemisphere and will have a bottom up approach as they interact directly and network in decision making processes, in mentoring, and in nurturing their day to day actions. Their role emphasizes flexibility and discretion as part of an extended family of researchers and educators. The administrators will personify stability and controls much like the left brain and will actively participate in designing policies. By mapping the specialization of each hemisphere of the human brain to the parallel leadership chains of command, our SCITEAM approach will help scholars and administrators to appreciate their complementary role in any academic organization toward augmenting efficiency.

4. Conclusion

Evidence of multidisciplinary research initiatives is abundant across the globe. However, these initiatives do not typically adopt (Martin and Umberger (2003), Ciaccia (2011), Rao (2011), Sauermann and Roach (2012)) the integrative and frictionless scientific approach that is central to our SCITEAM construct of research and training. Our HaS model for SCITEAM challenges the intellectual merit of the outdated "one size fits all" approach that fails to direct education and research on a sustainable path. Our model revolves around a transparent lens of economic analysis and management, balancing the centrifugal and centripetal forces of education and research, to integrate scientific collaboration that will support this millennium's sustainable innovations. The hub, embedded in a virtual laboratory of economic analysis and management, is instrumental for integrating innovation through scientific collaboration across disciplines. We believe our multidisciplinary approach will empower a new generation of scholars to lead sustainable innovation through the acquisition of transferable skills complementing their core areas of expertise. We envision our model will succeed in aligning the value embodied in education, through increased efficiencies, with economic cost. We hope our construct will foster constructive debate motivated by the need to create a collaborative environment for graduate studies with a sense of cohesiveness.

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