Editor’s Introduction: Scientific and Technical Human Capital

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EDITOR'S INTRODUCTION: BUILDING AND DEPLOYING SCIENTIFIC AND TECHNICAL HUMAN CAPITAL

Barry Bozeman[a], Vincent Mangematin[b]

[a]*School of Public Policy, Research Value Mapping Program, Georgia Institute of Technology, Atlanta, Georgia, USA 30332,* tel: 1 404-894-0093; E-mail: barry.bozeman@pubpolicy.gatech.edu

[b] UMR GAEL INRA-UPMF, BP 47 X 38040 Grenoble Cedex, France, tel 33 476-825-686, E-mail: *vincent@grenoble.inra.fr*, http://www.grenoble.inra.fr

Human capital and social networks are the two pillars supporting scientists' and engineers' ability to contribute knowledge. Throughout their careers, scientists seek to enhance both. Human capital endowments include not only formal education and its representation in credentials but the actual scientific and technical knowledge, craft knowledge and technical skills. In science and technology the deploying of human capital in the production of scientific and technical knowledge is intensely and inevitably social. Science cannot be understood in purely cognitive terms. Social mechanisms undergird not only the production of knowledge but its distribution and use. Scientific and technical journals and conferences are social institutions, as well as intellectual property protections, grants and awards, job placement and career transitions which are governed by social institutions. Social networks are the means by which scientists and engineers traverse social institutions. Indeed, scientists and engineers are as dependent upon social networks as they are upon such tangible scientific tools as electron microscopes, supercomputers and synchrotrons. Research policy and management scholars have long recognized the importance of scientists' and engineers' human capital endowments and their social networks. It is surprising, though, how rarely the two are viewed as part and parcel of a single bundle.

The concept "scientific and technical human capital" (S&T human capital) was developed in recognition of the dynamic interplay between scientists' human capital and their social networks (Bozeman, Dietz, & Gaughan, 2001; Bozeman & Rogers, 2002). We can define S&T human capital as *the sum of scientists' and engineers' scientific and technical knowledge, work relevant skills and social ties and resources* (Bozeman et al., 2001). When the scientist "does science," S&T human capital is what he or she relies on to get the job done. When one employs a researcher what one receives in return is the researcher's labor and S&T human capital. S&T human capital is the unique set of resources the individual brings to his or her own work and to collaborative efforts. S&T human capital includes not only the formal educational endowments usually encompassed in traditional human capital concepts, but also the skills, know-how, "tacit knowledge," and experential knowledge embodied in individual scientists and engineers. Furthermore, S&T human capital includes the social capital-based professional and normative ties that shape scientists' work. Generally, human capital models (Becker, 1962; Schultz, 1963) have developed separately from social capital models (Bourdieu, 1986; Bourdieu & Wacquant, 1992; Coleman, 1988, 1990), but in the practice of science and the career growth of scientists, the two are not easily disentangled.

The concept of scientific and technical human capital bridges fruitfully two different areas of research-research on individual scientific and technical careers and research on the role of the individual in the transfer and diffusion of scientific and technical knowledge Scientific and technical human capital embodied within mobile scientists can be redeployed in new environments, start-ups, firms and other universities or countries. Understood at the level of the individual, S&T human capital refers to the measure of the individual scientist's training, skills and even tacit knowledge (Polanyi, 1967, 1969), as well as the mesure of individual ties to networks and transaction with those in networks. In focusing on the individual, it is often most useful to think of S&T human capital in terms of the scientist's professional life cycle. In their studies of the scientist's life cycle Levin and Stephan (Levin & Stephan, 1991) found two distinct patterns for life cycle productivity, usually measured in publication or citation counts: "those in which output declines with age and those in which output initially increases with age and then eventually declines" (p. 50). There has been relatively little research on scientists' life cycles and explanations generally are post hoc or entirely speculative. According to Stephan and Levin (Stephan & Levin, 1997), the gap in our knowledge of life cycles is in part owing to an inattention to the social dynamics of research processes and a failure to focus on the institutional contexts of these dynamics, that is, the factors central to a S&T human capital model.

The concept of S&T human capital highlights the role of individual in the circulation and transfer of scientific, technologic and even managerial knowledge. Mangematin and Robin (Mangematin & Robin, 2004) underline the role of junior researchers in the circulation of tacit knowledge between research groups through post docs and early mobility. The acquisition of tacit knowledge that allows the development of skills involves not only the replication of experiments carried out elsewhere but also the temporary or permanent employment of a researcher. Almedia and Kogut (Almeida & Kogut, 1999) and Agrawal et al. (Agrawal, Cockburn, & McHale, 2003) have similar results when analysing invention done by engineers. Through the identity of inventor in patent, they show that the inter-organisation circulation of knowledge is based on the circulation of engineers from one firm to another. In the same vein, Florin et al. (Florin, Lubatkin, & Schulze, 2003) show that S&T human capital affect a new venture's ability to accumulate financial capital during its growth stages (before an initial public offering). S&T human capital takes stock of scientists' and engineers' capacity. It is the amalgamation of the cognitive functioning, social learning and skills that permits them to both create and disseminate knowledge in different contexts, academia and economic sector (firms, start-ups, etc.). S&T human capital is the reservoir of knowledge, both technical and social, scientists and engineers bring to their work. Much of this capital, especially that aspect that is interpersonal and social, is embedded in social and professional networks. These networks integrate and shape scientific work, providing knowledge of scientists' and engineers' work activity, helping with job opportunities and job mobility and providing indications about possible applications for scientific and technical work products. In these broader networks, S&T human capital includes actors in the technical enterprise who are users and developers of science and technology rather than creators, individuals in firms who appropriate knowledge and bring it to the marketplace.

The aim of this special issue is to go further previous analysis in terms of careers (Mangematin, 2001) by integrating the role of individual mobility in the circulation of knowledge and understanding how S&T human capital is deployed in different contexts. Since the production of scientific knowledge is by definition social, many of the requisite skills belong to social or political realms rather than cognitive ones. For example, knowledge of how to manage a team of junior researchers, post-docs and graduate students is part of S&T human capital. Knowledge of the expertise of other scientists (and their degree of willingness to share it) is part of S&T human capital. An increasingly important aspect of S&T human capital is knowledge of the workings of the funding institutions that may provide resources for one’s work. A concern for these elements of S&T human capital in no way discounts the importance of the more traditional aspects of individual scientists’ talents, such as the ability to conduct computer simulations of geological fracture patterns or the ability to draw from knowledge of surface chemistry to predict chemical reactions in new ceramic materials. It is simply the case that the S&T human capital concept recognizes that in modern science being scientifically brilliant is only necessary, not sufficient. In most fields, a brilliant scientist who cannot recruit, work with, or communicate with colleagues or who cannot attract resources or manage them once obtained, is not a heroic figure but a tenure casualty or one or another variety of underachiever. Even in the more focused concern of traditional human capital- pay levels as surrogates for performance- the S&T human capital concept provides deeper understanding the human capital alone.

Each of the papers included in this volume explores various aspects of S&T human capital and its impacts on scientific and technical careers, institutions, research capacity and performance. The first set of four papers (S. Davenport, J. Porac et al., M. Gaugham and S. Robin and E. Corley and B. Bozeman) examines different configurations of S&T human capital along the academic researcher and research group life cycles. In “Panic and Panacea: Brain Drain and Science and Technology Human Capital Policy,” Sally Davenport considers the flow S&T human capital though “brain drain” and the implications for scientific and technical capacity of a brain drain “moral panic” in New Zealand. By constrasting two models (brain drain and S&T human capital policy), she shows the need to reframe our understanding of nations’ S&T human capital and capacity because of the diminishing importance of geographic boundaries and national affiliation. She thus underlines the difficulties of isolated nations to increase their knowledge base.

Monica Gaughan and Stephane Robin (“National science training policy and early scientific careers in France and the United States”) examine a different aspect of scientific careers and S&T human capital, using aggregate data about individual academic scientists to compare academic scientific training in, respectively, France and the United States. French policy generally supports the individual graduate student directly through national grants, whereas U.S. graduate students most often are funded by federal support through research grants to faculty researchers. They use duration models to predict entry into a permanent academic position and find that academic science labor markets work very differently in France than in the U.S., chiefly as a result of funding traditions. In the U.S. France delay or deter academic careers, but have no impact on entry in the US. Interestingly, in the U.S., obtaining training from a national fellowship (compared to a research assistantship or other university funding) actually reduces the probability of making the transition.

Joseph F. Porac and his co-authors (“Human Capital Heterogeneity, Collaborative Relationships, and Publication Patterns in a Multidisciplinary Scientific Alliance: A Comparative Case Study of Two Scientific Teams”) examines two teams of researchers who are part of a multi-university scientific alliance. Scientists in one team share similar scholarly backgrounds and work in a well established paradigm, while scientists in the second team have different backgrounds and work in an emergent discipline. They find that the alliance increased the productivity of both teams, but the more heterogeneous team’s productivity increase was higher. They conclude by examining the implication of the heterogeneity of S&T human capital on group performances.

Finally, in another paper exploring university researchers' collaboration patterns, Barry Bozeman and Elizabeth Corley ("Scientists' Collaboration Strategies: Implications for S&T Human Capital") examine data from 451 scientists and engineers at academic research centers in the United States. They seek to determine reasons and preferences for collaboration among researchers, focusing particularly on a "mentor" role in collaboration. Those pursuing a mentor strategy are likely to be tenured; to collaborate with women; and, to have a favorable view about industry and research on industrial applications. Regarding the number of reported collaborators, those who have larger grants have more collaborators. The authors also examine collaboration "cosmopolitanism," the extent to which scientists collaborate with members of their own research group as opposed to researchers in settings more distant in either geography or institutional setting (other universities, researchers in industry, researchers in other nations). They find that most researchers are not particularly cosmopolitan in their selection of collaborators, but those who are more cosmopolitan tend to have large grants. A major policy implication is that there is great variance in the extent to which various forms and categories of collaborations enhance or generate S&T human capital.

The second set of three papers (F. Murray, D. Catherine et al. and A. Oliver) analyse how S&T human capital can be converted into economic and financial capital through firm creation. David Catherine, Frederic Corolleur, Myriam Carrere and Vincent Mangematin (Turning Scientific and Technological human Capital into economic capital: The experience of Biotech start-ups in France) examine the application of S&T human capital in their study of 132 founders of 62 French biotechnology firms. Their analysis shows that scientists who have the greatest reputation and scientific visibility, as determined empirically through publications and estimates of academic status, play a S&T human capital role analogous to the role of investors and financial capital. The scientists bring scientific results as a form of capital and deploy their S&T human capital strategically in their roles as company advisors. However, the eminent scientists are only partially involved in the firm, typically retaining a full-time position in academia and contrary to financial capital investors, they take no risk as the intellectual investment does not destroy their scientific and technical human capital. By contrast, less famous scientists generally play a different role, contributing less S&T human capital to the firm, but typically taking a larger role in its day-to-day management, often including a full-time position with the firm.

Likewise focusing on biotechnology firms, Amalya L. Oliver ("Biotechnology Entrepreneurial Scientists and their Collaborations") examines inter-institutional scientific collaborations in biotechnology, arguing that collaboration networks are vital to the advance of the industry. The paper focuses particularly on the S&T human capital and associated characteristics of the entrepreneurial scientists who link universities and biotechnology companies. Fiona Murray's article ("The Role of Academic Inventors in Entrepreneurial Firms: Sharing the laboratory life") is in many respects a complement to the Oliver's paper. Murray uses a S&T human capital perspective to develop a model of an inventor's role in commercialization. The model focuses on the mechanisms an inventor can use to facilitate movement of scientific ideas from an academic setting to a firm. One means by which knowledge diffuses is the inventor brings S&T human capital directly to the firm by such means as joining the firm as chief scientific officer or through consulting. But another means of deploying S&T human capital occurs when scientists exploits their network positions to build relationships between his social network and the firm. Murray finds that the inventor's network has two distinctive elements: the first is a local laboratory network that is shaped by the specific career experiences of the inventor training in different laboratories and building his or her own laboratory; the second is a cosmopolitan network of widely dispersed peers. Each of these has distinctive implications for importing knowledge and technical skills.

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