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THE EASY EXPENSIVE WAY DOESN'T WORK. WHY NOT TRY THE DIFFICULT CHEAP WAY?

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Scratching below the surface of economic development reveals the complexity we should be trying to manage.

Generally, from a state's perspective, the road to economic development has been one of attracting commercial entities with favorable tax incentives and promises of workforce development initiatives. States have also begun setting aside funds to help their cities and other localities self-determine their economic destinies—often involving incubators, local infrastructure improvements, and direct support for local companies. As a result, economic development organizations collect metrics, primarily of company attraction successes and overall cost per job attracted, although the latter is often complicated by the extended periods over which the incentives and jobs are implemented, leading to media 'exposes' focused on 'where are the jobs?' or 'return on investment.'

Additionally, observations that clustering of commercial and venture capital activities catalyze enviable jobs and economic growth have led cities and states to invest funds in ways intended to encourage business clustering, with state economic development organizations sometimes announcing 'areas of focus'. Unsurprisingly, these areas of focus are mostly the same for all regions, and many commentators have pointed to the improbability of all regions becoming 'life science' or 'nanotechnology' hubs. Nevertheless, life sciences rank high on most local and state wish lists.

Yet, expansion of economies is serious business for all regions. The well-being of the workforce, and everyone associated with this workforce, is directly linked to successful economies. It is unsettling to drive through rural or urban economically 'disadvantaged' areas. This motivates the governmental quest for business development.

However, pouring funds into business attraction, business support, and tax and other credits for investment in business ventures has not yielded the self-sustaining business environments desired. While a wide range of issues are raised to explain disappointing outcomes—workforce skills, available financing, brain drain, local environmental amenities, etc., the underlying problem is more systemic, suggesting that real economic development requires use of a new set of tools based on a significantly different view of the economy.

These ideas are nothing new; they grow naturally from a consideration of the structures and behaviors of societies and economies, and they will be challenging to implement, but they provide a relatively inexpensive (compared to the current approaches) and long-term route to economic growth and national competitive advantage.

The Significance of Complex Network Dynamics for Innovation, Technology Commercialization, and Economic Growth

Innovation: A Fundamental Issue Facing States

Technological innovation activities include all of the scientific, technological, organizational, financial and commercial steps, including investments in new knowledge, which lead to the implementation of technologically new or improved products and processes.[i,ii] Together, these many processes describe the larger state 'innovation system,' "[which] is an important determinant of aggregate productivity and economic growth, countries' comparative advantages, and firms' competitiveness *vis-à-vis* their rivals."[2] It is certain that innovation capacity will define the future competitive advantages of states and regions within the United States. This capacity is manifested in networks of human and institutional interactions. Discovery, Innovation, and Entrepreneurship, all depend on individual scientists, engineers, and business developers as well as many others, who interact via a variety of linked social 'networks.'

"Social networks permeate our social and economic lives [iii]." Through such networks information flows and is processed, resources are provided (or withheld), correlated behaviors are supported—ranging from individual to commercial clustering, and the economic benefits of scaling are captured. Network structures are powerfully supported by rapidly advancing 'information technology', including the hardware, software, and organizational structures providing the informatics and communications resources that the modern world requires for dissemination, storage, and utilization of information. The 'clockspeed' of this ongoing informatics revolution is accelerating, providing us with increasingly powerful (and inexpensive) means through which to capture and enhance the advantages of network behaviors.[iv]

States have both economic and social reasons for optimizing the conditions leading to successful innovation and commercialization and are thus faced with optimizing a wide range of coupled processes leading to commercial activity; but, the variability and complexity of these processes defeats simplistic approaches. Nonetheless, the importance of understanding critical network economic drivers has led to many studies characterizing broadly what is best described as 'innovation systems.'[v]

Information flows are at the heart of technology-based economic development. Recent evidence [vi], perhaps surprisingly, suggests that publications and academic sector patents are only minor contributors to the flow of technologies into the commercial sector. Formal technology transfer processes fail, often because such transfer is seen from the local academic institutional viewpoint, rather than as an element of a larger network of interacting components, the 'innovation system'; an example of misaligned incentives. Furthermore, the increasingly strained financial interests of the academic community often stand in the way of effective technology transfer.[vii] Instead, the primary route for technology transfer is through consulting and other direct interpersonal interactions, such as joint research and movement of students into the commercial sector. This involvement of personal interactions is the primary force behind observed correlations between commercial sector activity and the proximity of research universities and institutes. Also, there are related observed reciprocal local effects involving the co-location of major research-based commercial sector entities, sometimes called the 'anchor tenant effect.'[viii] Creation of such 'face-to-face' interactions are facilitated by activities fostering partnerships between the state's academic and commercial sectors, as well as between the state's academic institutions. Such considerations motivate a recent upsurge in discussions of the nature and impacts of social and technology-related interaction networks,[7-9] the focus of this discussion.

In sum, the central innovative act can be understood in the context of an actor and his/her interactions with others. In fact, as the density of communications among scientists increases, new kinds of cooperative and coordinate actions are appearing, many of which do not depend on proprietary strategies, like patents, making human creativity and the economics of information itself the core 'organizing' facts of the 'new networked information economy.'[ix] Studies of the evolution of cooperation in social networks further suggest that their static and dynamic structures are central to optimizing productive cooperative interactions[x,xi,xii]. However, the conditions favoring cooperation depend in complex ways on the pay-offs to participants as well as on the detailed structure of the network[xiii].

Impact of the Social Matrix

The social matrix of a region is now understood to be a critical element of a successful regional technology innovation system that creates successful high-technology businesses via both academic sector spin-outs and continuous growth and innovation in the private sector. An effective matrix depends on the presence of a quality academic sector as well as a conducive social structure involving dense networks of personal interactions involving the region's technical and entrepreneurial communities. These personal interactions must be coupled to high labor-market flexibility, provided by a sufficient density of companies, to minimize the career risk posed by the intrinsic instability of start-ups.[xiv] Creating such overlapping 'threshold densities' of networked people and companies presents a major challenge for relatively low technology/commercial-density states. Addressing such issues is a focus of the initial 'network interventions' suggested here.

Unfortunately, functional social matrices are remarkably difficult to create. For instance, only 3-4 successful biotechnology clusters exist. Among other issues, the emergence of these critical networks is typically slow and is often 'seeded' by fortuitous events, as studies of the San Diego biotechnology ecosystem reveal. Furthermore, it has been observed that a region's social interaction network strongly influences the fine-structure of personal contacts between academic and industry scientists that drive technology commercialization.[xv] In sum, successful regions create active marketplaces for ideas, where ideas, capital, and people come together to translate science into economic value.[xvi]

A similar viewpoint has evolved in descriptions of the idea of 'city': "…instead of thinking of cities as sets of spaces, places, locations, we need to think of them as sets of *actions*, *interactions*, and *transactions* that define their rationale and relate to the way scale economies generate wealth in social and economic terms."[xvia]. In this context it is not surprising that the economic success of the city itself is closely linked to the overlapping networks it contains.

Indeed, such considerations suggest that rather than utilize company-specific interventions like investments and loans, state, regional, and local governments could profitably explore network interventions[xvii] as a means of accelerating the growth of meaningful technology commercial clusters. The broad challenges involved in the purposeful use of innovation networks for economic growth should yield to the analytical approaches developed and advocated by the Santa Fe Institute and related organizations.

Nature of the Economy

The conceptual shift from an equilibrium view of the economy to a dynamic and evolving one is well-described in two recent books[xviii], which characterize the behavior of the economy as a complex system consisting of networks of interacting and evolving 'agents'. In fact, the economy involves hierarchies of interacting networks, and it has been only relatively recently that conceptual and computational tools have appeared allowing the behavior of such systems to be explored.

State-level policy systems, embedded in laws and regulations, have profound impacts on economic growth, although the resulting economic 'state' is not a simple reflection of those policies. It is the dynamic complexity of state innovation systems, related policy systems, and the economy that stands between state governors and legislators, their piecemeal enactment of 'economic development initiatives', and the economic growth they desire.

Thus, states have market and nonmarket interests in the totality of their 'innovation systems'. Such systems involve people and their ideas, entrepreneurs, startup and established businesses, and commercial and financial markets; interacting to create State-level economies. State boundaries are porous, resulting in regionalization of innovation systems, and information technologies and communications ensure that regional innovation systems interact at national and global levels.

Innovation is at once the primary source of economic growth and wealth and a cause of significant workforce and educational system stresses. It is a primary duty of state government to provide a context bringing together the academic, business, and human resources of the state to optimize innovation and growth. While in some cases this requires the state to address specific business-development market failures (for instance, the availability and mobility of venture funds), it is also essential to address limitations imposed on economic growth by gaps in the network of institutional and personal interactions involved in states' innovation systems and to consider possible misalignments of financial and other incentives. When appropriately addressed, such network issues can enhance economic growth without the need for direct public investments into private sector entities.

As challenging as it is to describe the network structure of the economic world around us, this is the path leading to competitive economic advantage. The key economic development act must now be identification of policies and infrastructure needed to take economic advantage of this conceptual framework. Work at the Santa Fe Institute and other institutions has established the needed conceptual and computational foundation for this new effort. As appropriate 'network interventions' and other entirely new economic development tools are devised and tested, it will be possible to accelerate the economic consequences of innovation.

In summary, the social, institutional, and financial systems that underpin business development and the economy consist of networks of interacting people and entities. Such networks are complex in the sense that aggregate network behavior is not predictable from knowledge of its constituent elements and is frequently nonlinear and non-intuitive. Furthermore, the innovation economy consists of hierarchies of such networks; for instance, networks of academic scientists and engineers engaged in discovery research and development, networks of private sector scientists and the companies that house them, networks of financial institutions, networks of policies, regulations, and incentives, networks of information embedded in the past scientific and patent literature and in the evolution of scientific disciplines, and more generally networks of governmental and social elements contributing to 'community structure'. Network and big data analytics are providing the conceptual and computational tools we need in order to begin to make sense of the dynamic behavior of these coupled systems. With such understanding comes the ability to affect these networks, both in terms of their static structures and their dynamic behaviors.

The remainder of these comments address some simple and not so simple approaches to bringing this network approach to bear on real world situations.

Some Initial Approaches to Network Interventions, and Their Consequences

Creation of Network Information HUBS:

The structure of any network involves enumerating who/what elements constitute the network and describing how those elements interact.

Information technologies are having a profound impact on the efficiency [xix] and 'clockspeed'[xx] of the technology-based commercial sector. Similar efficiencies and capacity increases can likely be achieved in the economic development sector through selective utilization of data-gathering and data-analysis tools, supporting both our understanding of the processes basic to the entrepreneurial ecosystem's functionality and its practical use in support of specific entrepreneurial activities. By creating and confederating a set of databases into an easily accessible informatics HUB [xxi], and by applying network analytics and information domain mapping, we can make available to a state's entrepreneurial community the insights and resources needed for effective commercialization of new technologies. In addition, such HUBs will inform local and state- level policy makers as they explore ways to enhance the functionality and interactions of their innovation networks. Importantly, HUBs can provide a collaborative context through which to broaden and intensify the capabilities of the networks themselves, something that can be accomplished by making the innovation network 'self-aware', by communicating with its network elements.

Indiana, Texas, and some other states have begun the process of identifying their 'technology networks', the members of their academic sector with technical expertise that might be relevant to the needs of state businesses, or might be involved in future technology-based business startups, using an automatic database creation tool (www.indure.org Indiana Database for University Research Expertise). A related database of commercial sector technical expertise, MapIN, has been created using an Indiana patent database. Such databases are the foundations of state-level innovation network characterization.

Creation of "Intermediary Organizations":

John H. Marburger, Science Advisor to President Bush, noted the importance of 'bridging institutions', which act as intermediaries closing gaps among actors in the innovation system: "Enhancing technology diffusion among actors, then promoting extension and technical-assistance programs, is a role of government and bridging organizations."[xxii] Such a bridging role provides an environment that allows researchers to communicate, share ideas, and collaborate across disciplines.[xxiii] To this point, the 2005 NAS study of interdisciplinary research recommended "explor[ing] alternative administrative structures and business models that facilitate interdisciplinary research across traditional organizational structures." This recommendation explicitly acknowledges the interdependence of the actors in any innovation system.[xxiv]

The extraordinary power of bridge structures, linking individuals, disciplinary communities, organizational types, and hierarchies lies in the manner in which these levels will interact in complex and nonlinear ways to yield creative activity. Such observations again acknowledge the impact of the more basic communication networks, which are the patterns of contact that are created by the flow of messages among communicators.[xxv]

A useful institutional model for a bridge organization is the academy of sciences. There is a long history of such organizations and the convening and communications power they wield, for instance: the *US National Academy of Sciences* (founded in 1863, legislation signed by Abraham Lincoln); the *Royal Society* (began officially in 1660 during the reign of Charles II); *Leopoldina* (originally formed in Germany in 1652); *The Medicon Valley Academy* (Alliance) (a 'cluster' organization for the Danish-Swedish life science community); and the *NY Academy of Sciences* (formed originally as the Lyceum in 1817). By functioning as an 'intermediary organization' such an academy serves to convene the technical community in a venue outside of the usual academic or commercial workplace settings to form an active interpersonal network capable of exercising technical and advisory roles and optimizing internal network communications. It is possible to broaden the mandates of academies beyond pure research to include technologists and technology commercialization interests in order to broaden the resulting technology network to address economic development concerns.

Consequences

These very simple network interventions are based on two assumptions—that it is important to (*1*) make the networks involved in innovation processes 'self-aware', and (*2*) provide social frameworks enabling the formation of denser person-to-person contacts. The former provides new avenues for cooperation and builds local and regional technology 'muscle tone'. The latter is a vehicle enabling change, coordinated action, and rapid dissemination of new technologies. Both approaches enhance the permeability of the academic/commercial interface.

While these assumptions evolve from retrospective studies of economic and social processes, they require real-world data and complex systems analysis for their validation. State and federal sources can provide much of the data needed to generate the essential static network maps. For example, geospatial technology maps/data bases can be developed as described above for INdure and MapIN, or utilizing a variety of other data warehousing/visualization tools[xxvi].

State Departments of Workforce Development and Secretaries of State can provide company and workforce information. Models of varying degrees of granularity exist for the non-equilibrium economy[xxvii]. Tools exist for analysis of legal and policy network behaviors[xxviii].

In their simplest instantiation, static maps can yield insights into: clustering of commercial and workforce activities, the state of technology/product evolution and utilization in specific locales and regions, gaps in technical or manufacturing capacity, and the like. Beyond geospatial mapping, it is possible to superimpose dynamic studies of the evolution of technologies (from the published, patent, and federal agency awards data) to expose systemic success/failure to adopt new technologies or anticipate the future availability of technologies[xxix]. From these obvious examples, it is clear that available information provides a rich basis for understanding a state's innovation network and suggesting basic network interventions.

Ultimately, though, it is the complex, non-linear, behavior of networks that is likely to yield the greatest returns on invested capital and policy development. Managing complexity for purposeful economic development ends requires the use of dynamic models, which are under development in the private and academic sectors. States will need to share their network data and current policy structures with organizations like the SFI with the shared intention of implementing models that explore the range of outcomes of suggested policy changes. These dynamic models will provide an objective basis for crucial economic development decisions at all levels of a state's economy. The predictions of these models in real world situations will provide essential feedback for refinement of both models and potential interventions.

It is likely possible to move in this 'network economic development' direction without additional state funds targeting economic development, though it will require rebalancing the activities of state governmental agencies and their objectives.

Ultimately, the network intervention approach should require considerably fewer financial inputs from the state than current company attraction and development approaches.

End Notes:

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