Innovation Metrics: Measurement to Insight

White Paper

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There is an urgent the need for better innovation metrics to reflect today's knowledge based, dynamic and globally networked economy and to ensure that the US continues to be the most fertile and attractive environment for innovation in the world. High quality, relevant and more timely innovation metrics will enhance public understanding, help policymakers benchmark the nation's innovation performance, and thereby improve policymaking and business strategies.

1. Issue Definition

Economic studies during the past several decades have concluded that technology innovation (and related capital and human investment) contributes nearly half of the nation's productivity, economic growth and standard of living. It is thus imperative that government and business leadership pay the utmost attention to the role of innovation in US growth, competitiveness and quality of life.

One explanation for the policy attention deficit is the lack of metrics that adequately describe the nation's innovation ecosystem and the relationships of various attributes – from knowledge inputs to transforming processes to ultimate outcomes. Sound policy analysis and decision-making requires credible, timely and relevant measurements. "What you get is what you measure." Bad metrics can lead to bad diagnosis which in turn results in bad or poorly designed policies with unintended consequences.

Innovation is defined as follows:

"Innovation is a process through which the nation creates and transforms new knowledge and technologies into useful products, services and processes for national and global markets – leading to both value creation for stakeholders and higher standards of living."

This definition respects the fact that innovation is a complex and multidimensional activity that cannot be measured directly or with a single indicator. The drive for improved indicators stems from the understanding that currently available measurements largely reflect the industrial era and less so the knowledge economy unfolding around us: they largely reflect products and artifacts rather than ideas and processes. The drive for improved indicators also reflects certain 'truths' established by the socio-economic analysis of technological advance and innovation during the past 2-3 decades:

1. Innovation is much more than technology – many other complementary resources are essential for market success;

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2. Like human health, there isn't any single measurement adequate to capture innovation' multiplicity of features;
3. The drive for innovation must include consideration of the demand side which determines the rate of investment and diffusion (take-up) of new products and services.
4. Non-linear dynamics characterize the entire innovation value chain end-to-end at the national level and at the firm level.

The nation should aggressively engage in a government wide effort, coordinated internationally, to develop innovation metrics that look beyond innovation inputs and toward outcomes as well as, and quite importantly, innovation processes. An up to date view requires more attention to the demand for innovation, customer value creation and global markets; and, to related determinants such as knowledge process flows, interfirm linkages, government policy environment and the infrastructure for innovation. Such a multi-dimensional view will assist policymakers understand the dynamics of innovation, surface policy implications and better inform those who must make decisions impacting the innovation process.

2. Enhanced, Better Indicators

National measurement of innovation today is based on an old paradigm of an industrial economy and for the most part measuring inputs to innovation (R&D expenditures, education expenditures, capital investment) and intermediate outputs (publications, patents, workforce size and experience, innovative products). For a long time, innovation has been perceived an activity involving almost entirely individual actors, including inventors and firms. Innovation was viewed linearly, starting with fundamental research and proceeding successively to applied research, development, prototyping, pilot production, market entry, and continuing through the diffusion of new products and production processes. Services were conspicuously absent in traditional approaches. Accordingly, innovation measurement tended to be focused on *products* and related *production systems.*

More recently there has been significant progress in delineating the multiplicity of resources required for innovation, the non-linearity of the innovation process, the quite different and variegated meaning of innovation in service sectors, and the innovators' connection to and dependence on the global competitive market forces and their immediate socio-economic and institutional environment.

An expanded series of "real-time" metrics is needed reflecting the new paradigm of a knowledge based networked economy to guide innovation policies and illuminate the uncertainties, choices and outcomes of government policy and business decisions. We need to push hard towards doing a better job in measuring knowledge inputs and flows, the process of innovation, the demand for innovation, services innovation, and the intersection of manufacturing and services that are increasingly integrated in advanced economies.

We do not need to start from scratch. The advancements in understanding the process of technological advance and innovation and their role in the socio-economic environments of modern societies during the past couple of decades have resulted in significant improvements

in the availability, breadth, and usefulness of science, technology and innovation (STI) indicators.

STI indicators can be roughly categorized into four 'generations', progressively becoming more complex and meaningful as illustrated in Table 1.

Table 1: Evolution of Innovation Metrics by Generation (Examples)

1st Generation Input Indicators (1950s-60s)	2nd Generation Output indicators (1970s-80s)	3rd Generation Innovation Indicators (1990s)	4th Generation Process Indicators (2000 + emerging focus)
• R&D expenditures • S&T Personnel • Capital • Tech intensity •	• Patents • Publications • Products • Quality Change • •	• Innovation surveys • Indexing • Benchmarking innovation capacity •	• Knowledge • Intangibles • Networks • Demand • Clusters • Management techniques • Risk/Return • System Dynamics •

- The ***first generation*** of metrics reflected a linear conception of innovation focusing on ***inputs*** such as R&D investment, education expenditure, capital expenditure, research personnel, university graduates, technological intensity, and the like.

- The **second generation** complemented input indicators by accounting for the ***intermediate outputs*** of S&T activities. Typical examples include patent counts, scientific publications, counts of new products and processes, high-tech trade.

- The **third generation** is focused on a richer set of ***innovation indicators and indexes*** based on surveys and integration of publicly available data. The primary focus is on benchmarking and rank ordering a nation's capacity to innovate. A main difficulty at the moment is the validity of international data comparisons and incorporating service sector innovations (where the process is the product) into the surveys.

All these indicators fit into the classic economist's mold of a production function, $Y = f(X)$, where X is a set of inputs and the Y stands for the innovation output. The middle part (function f) dealing with the transformation of one into the other is still largely untouched, a 'black box', in terms of meaningful indicators. While some of the information collected through various country innovation surveys is heading that direction by trying to pull in qualitative information on agent behavior, there is no question that a fourth generation of STI indicators is required for sound policy and strategy development.

Relevant ***fourth generation*** metrics currently at an embryonic stage include:

- **Knowledge indicators**. We still count machinery, tons of steel, transactions, number of PhDs, patents. We should rather account for the knowledge that underlies their

creation and the ways it is developed and diffused. A multi-layered concept like knowledge, however, can only be captured by composite indicators that may include composite knowledge investment indicators and composite performance indicators.

- **Networks**. A striking feature of contemporary innovation is that hardly any organization can innovate alone. Most innovations involve a multitude of organizations. This is especially the case for the most knowledge-intensive, complex technologies. We can only hope to get a handle on a knowledge-based, networked economy if we can understand networks. This is possible only through composite network indicators accounting for both contractual agreements like strategic partnerships, intellectual property licensing and for informal collaboration and knowledge exchange such as working relationships of individuals across organizations (e.g., clusters). Such networks are not just regional, but also national and global.

- **Conditions for innovation**. Economic demand, public policy environment, infrastructure conditions, social attitudes and cultural factors are critical for successful innovation. What is called for here is building systemic innovation metrics that capture the context in which organizations form and match expectations and capabilities to innovate. Hundreds of such indicators could be imagined, of course, but what is called for primarily are indicators that 'intelligently' (a) describe the main characteristics of the innovation system and its dynamics and (b) look forward in anticipation of likely broad developments (e.g., balanced scorecards, mapping of general purpose technologies, monitoring demand shifts and global innovation patterns, technology option accounting, etc).

To the extent that they exist, these 4th generation metrics of the knowledge based networked economy remain ad hoc and are, thus, of limited analytical value. They can be improved only through a concerted, coordinated and internationally visible effort. The phenomenon we are examining (innovation) is inherently international. We cannot confine metrics to any one country. Many innovative companies have acquired global logic: going with national indicators only would misrepresent what is going on.

- US should tap and extract the expertise of international organizations that conduct extensive research and innovation metrics work, such as the OECD and European Commission.
- US innovation metrics initiatives should capture the experience other nation's innovation surveys with respect to business sector targets, sample size, variable definitions, data collection methods, analysis procedures and dissemination techniques.
- Metrics definitions and innovation models need to be harmonized or at least made comparable internationally for benchmarking purposes.

Opportunity to Apply New Policy and Strategy Analysis Tools

An expanded set of innovation metrics opens up a major opportunity to apply new analytic tools for assessing policy and strategic choices.

- **Growth Accounting**—economists will be able to better estimate the nation's productivity performance in terms of contributing factors and outputs, particularly in regard to knowledge inputs, process factors and quality changes in both products and services.
- **Knowledge Economy**—new kinds of composite knowledge investment indicators and performance indicators will improve the resource allocation decisions for R&D, education and capital resources.
- **Financial Reporting—**financial reports to government regulatory agencies, the public and analysts could provide a balanced scorecard of physical as well as intangible assets.
- **Valuation of Innovation**—intellectual capital metrics and measures of future uncertainly will help business leaders and financial markets to better value "intangible assets" , R&D and venture capital investments and predict outcomes with greater clarity.
- **System Dynamics**—expanding the range of "real-time" innovation metrics would help build more robust systems dynamics models and simulations of alternative policy scenarios.
- **General Purpose Technology (GPT)**—metrics can improve our analysis of the dynamics of GPTs which set the stage for incremental innovation and have the inherent potential for pervasive application in a wide variety of industries, and generate complementary innovation.
- **Tech-led Regional Development and Clusters**—allow decision makers currently focused on strengthening inputs to regional innovation infrastructures toward improving the efficiency, rate and output of innovation through enhancing collaborative industry-university mechanisms for commercialization.

3. Stakeholders and Implementation Factors

The major stakeholders involved in the design, collection and dissemination of innovation metrics include:

- ***US government statistical agencies*** which include the Bureau of Census, the Bureau of Economic Analysis, the National Science Foundation (Science and Engineering Indicators), the Bureau of Labor Statistics, and the Department of Education.
- ***Financial Standards and Reporting Entities*** have an interest in accounting for intangibles, innovation and risk. Domestic firms that are registrants with the *Securities and Exchange Commission (SEC)* must file financial reports using U.S. generally accepted accounting principles (GAAP). The *Financial Accounting Standards Board(FASB)* is focused on improving standards of financial accounting and reporting for the guidance and education of the public, including issuers, auditors, and users of financial information. The U.S. is one of seven national accounting standard setters that have an *International Accounting Standards Board (IASB)* Member resident in their jurisdiction. The IASB Constitution envisages a "partnership" between the IASB and these national bodies as they work together to achieve the convergence of accounting standards world-wide.

- ***Trade and professional associations*** which include the Industrial Research Institute, the Semiconductor Industry Association, the National Association of Manufacturers, the National Academies and hundreds of other associations that collect data on behalf of their members.
- ***State and local agencies*** that collect repurpose and disseminate information on the innovation infrastructure and economic performance of regional economies.
- ***University, private research centers and consultants*** which survey, integrate and analyze technology, market and financial trends, generally organized on an industry or regional basis.
- ***International organizations*** of which major work is being done by the Organization of Economic Cooperation and Development (OECD), the European Commission, United Nations agencies, the World Economic Forum, and the World Bank. In addition, numerous national governments (primarily OECD member countries) have started systematic innovation indicators projects and high level policy initiatives to position their nations at the forefront of innovative performance.

In order to maximize the validity and comparability of innovation metrics and minimize data collection redundancy, the US effort should be extensively coordinated with all these stakeholders.

4. Benefits and Costs of the Recommendation

Major Benefits

- Establish the case and importance of the innovation to economic growth and competitiveness.
- Enable further progress in our understanding of the complex phenomenon of innovation which has been severely constrained on the empirical side due to the lack of appropriable metrics to complex concepts. In particular, close major needs in the study of innovation in services and allow in-depth analysis of the networked, knowledge economy at all levels
- Improve policymaking to create a better innovation environment to drive economic growth, standard of living, employment and business competitiveness
- Focus policymaker attention to critical issues, innovation barriers and alternative policy responses
- Benchmark US innovation performance regionally and internationally
- Signal emerging opportunities and threats
- Provide significantly improved, better calibrated data for investment analysis and risk management
- Establish accountability and evaluation criteria
- Expand public awareness and understanding of the role of innovation

Major Cost Elements

- It is recommended that a detailed cost analysis for innovation modeling, metrics design, data collection, synthesis and dissemination be conducted to test the feasibility and refine the implementation strategy.