Communications of the Association for Information Systems

Volume 20 Article 13

7-31-2007

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Recommended Citation
Passerini, Katia and Fjermestad, Jerry (2007) "AMCIS 2006 Tutorial Paper: A Review of Methods to Assess National Knowledge in the Knowledge Economy," *Communications of the Association for Information Systems*: Vol. 20 , Article 13.
DOI: 10.17705/1CAIS.02013
Available at: https://aisel.aisnet.org/cais/vol20/iss1/13

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AMCIS 2006 TUTORIAL PAPER: A REVIEW OF METHODS TO ASSESS NATIONAL KNOWLEDGE IN THE KNOWLEDGE ECONOMY

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ABSTRACT

The evolving role of knowledge in modern societies has spurred an interest in better evaluating knowledge creation capabilities of a variety of business, non-profit, national or multinational actors. Our field has extensively focused on reviewing knowledge management evaluation and implementation programs at the organizational level. In this paper, which stems from a tutorial presented at AMICS 2006 in Acapulco, we focus on the efforts undertaken by International Development Institutions (IDIs) to assess the role of knowledge as a driver of national wealth and economic development. This paper describes methodological frameworks - such as the "knowledge assessments" - used to evaluate a country's potential to generate new knowledge. Knowledge assessments comprise of qualitative and quantitative exercises to collect benchmarking data on relative national standing in knowledge endowment (the knowledge indexes). The review suggests some open issues and solicits enhancing the predictive capabilities of current models.

Keywords: knowledge economy, knowledge management, knowledge assessment, intellectual assets, international development, knowledge index, scorecards

I. INTRODUCTION

International Development Institutions (IDIs) have long recognized that the creation of knowledge permeates both the economic and social development of nations. This recognition has led them to define strategies to enhance knowledge management programs at the national level. This paper provides a general overview of approaches implemented by IDIs to both identify and nurture knowledge-based development. The paper discusses organizations such as the Organization for the Economic Cooperation and Development (OECD), the European Union, the United Nations, and the World Bank. Similar to many other IDIs, these institutions have undertaken knowledge management projects both internally and within the countries they represent.

A common approach implemented by IDIs is the preliminary analytical assessment of a country's key development indicators as they relate to knowledge generation and endowments. The initial objective of these efforts, which are termed "knowledge assessments," is to benchmark country resources. Each IDI has implemented specific measurement models leading to the definition of different methodologies for conducting national knowledge assessments. These models started

with a focus on traditional performance indicators and slowly integrated measures of human and social development.

We start this tutorial by defining the key elements of the knowledge assessment process implemented by IDIs. Once the key aspects of the process are defined, we specify the measurement systems used by various international economic development players. Finally, we highlight some limitations and suggest additional approaches through the use of a belief-based analytical framework.

II. APPROACHES TO ASSESSING NATIONAL KNOWLEDGE

This section presents a list of approaches used to assess knowledge management (KM) at the national level. Several international organizations devote attention to countries' ability to create, share, and effectively use knowledge. Malhotra [2003a] conducted a review of existing models for measuring knowledge assets (particularly at the "micro" and organizational level of firms) and extended these models to IDIs through an implementation approach based on the balanced scorecard methodology [Kaplan and Norton 2000] which focuses on visioning, learning and growth, processes, relationships, and performance management. We refer to Malhotra's comprehensive review for an articulation of both organizational and national models to measure knowledge assets, including a discussion of Edvisson and Malone's Skandia Navigator [1997]; Sveiby's Intangible Assets Monitor [Sveiby 1997]; Brooking's Technology Broker [Brooking 1996]; and many others. In this paper, we specifically focus on describing approaches espoused by developmental institutions to implement some of the organizational measurement models or to define new models. We present frameworks for national knowledge assessments and include examples from both IDIs and selected countries.

NATIONAL KNOWLEDGE ASSESSMENTS: THE U.S. NATIONAL RESEARCH COUNCIL FRAMEWORK

A "national knowledge assessment" (NKA) is a process for the identification of local drivers of knowledge creation at the level of national economies. It focuses on qualitative and quantitative analyses of country economic and social indicators. The qualitative analyses have the objective to collect observations as well as to enable interactions with local communities to enhance community's understanding and implementation of knowledge management. The quantitative analyses consist of primary data collection and analyses of secondary data available in national databases. The analyses are used to prepare benchmarking reports of national knowledge-based resources.

A comprehensive and actionable example of knowledge assessments is the National Knowledge Assessment Prospectus methodology commissioned by the World Bank to the U.S. National Research Council (NRC) first published in 1996. The NRC-NKA prospectus defines the knowledge assessment activities that introduce the concept of knowledge management through national symposia organized by local governments, virtual case studies, and benchmarking analyses. An in-depth review of this methodological approach to knowledge assessment is part of this tutorial as it sets the stage for a structured approach to conducting knowledge assessment. In its actionable prospectus, the NRC balances quantitative and qualitative analyses and focuses on both hard measurements and soft drivers. For example, the impact of people and processes on the creation of national knowledge, which has extensively been embraced by the development and organizational literature, is a key component of the NRC-NKA methodology. Therefore, the NRC prospectus represents a comprehensive set of guidelines for sound assessment programs which span multiple components: stakeholder involvement (government, academic and private sectors); strategic, tactical and operational planning through the case studies; as well as analytical assessments of fundamental economic drivers. Examples presented later in the paper show that other approaches have clustered more around the definition and assessment of metrics and less on the processes and social involvement themselves. In this context, the NRC-NKA represents a best practice that proposes a holistic approach to evaluating knowledge. Such an

approach is not limited to data gathering but drives collaboration, feedback provision, and consensus building around KM programs.

The national knowledge assessment methodology proposed by NRC [1996] is built on three core components: a) the *National Symposium*; b) *virtual case studies*; and c) *benchmarking analyses* through interviews, focus groups, review of published databases and local, national and international data sources.

a) In the *National Symposium*, academics, government officials, local investors, and entrepreneurs are invited to discuss knowledge-based activities and their implications for the local economy. The national symposium is an opportunity to review how a national knowledge system is affected by the institutions that directly or indirectly regulate the creation and flow of knowledge in a country (notably academic, government, and business communities) and to identify key activities that these stakeholders need to engage with for the promotion of a country's knowledge growth. The NKA model identifies these activities within the six areas listed in Figure 1. Each of these areas is included to achieve a balanced knowledge-based development and comprise the organizational principle by which various projects are evaluated and selected for implementation. For example, the selection of business initiatives that support diffusion and productive use of knowledge (economic and market-driven initiatives) must be balanced with other initiatives in support of knowledge access and assimilation (infrastructure and learning initiatives).
b) The national symposium is followed by the organization of high-level focus groups tasked with defining a series of *virtual case studies* on strategic development opportunities for the creation of knowledge-based enterprises. Local stakeholders and entrepreneurs meet (face-to-face and online) and elaborate potential market initiatives based on their feasibility within the local economy. The objective is to drive new business proposals by leveraging key national strengths.
c) The virtual case study feasibility assessment for the local economy is supported by *benchmarking analyses* put together through the evaluation of data collected through national databases as well as interviews on opportunities and barriers to knowledge development in the benchmarked economy. The interviews run in parallel to a quantitative evaluation of the national development indicators. The data and the interviews clarify and quantify the problems and help validate the recommendations for supporting specific knowledge-based initiatives in a country. The quantitative analyses map key variables to the specific knowledge activities (motivation, creation, access, etc.) defined in the national knowledge system framework (see Figure 1).

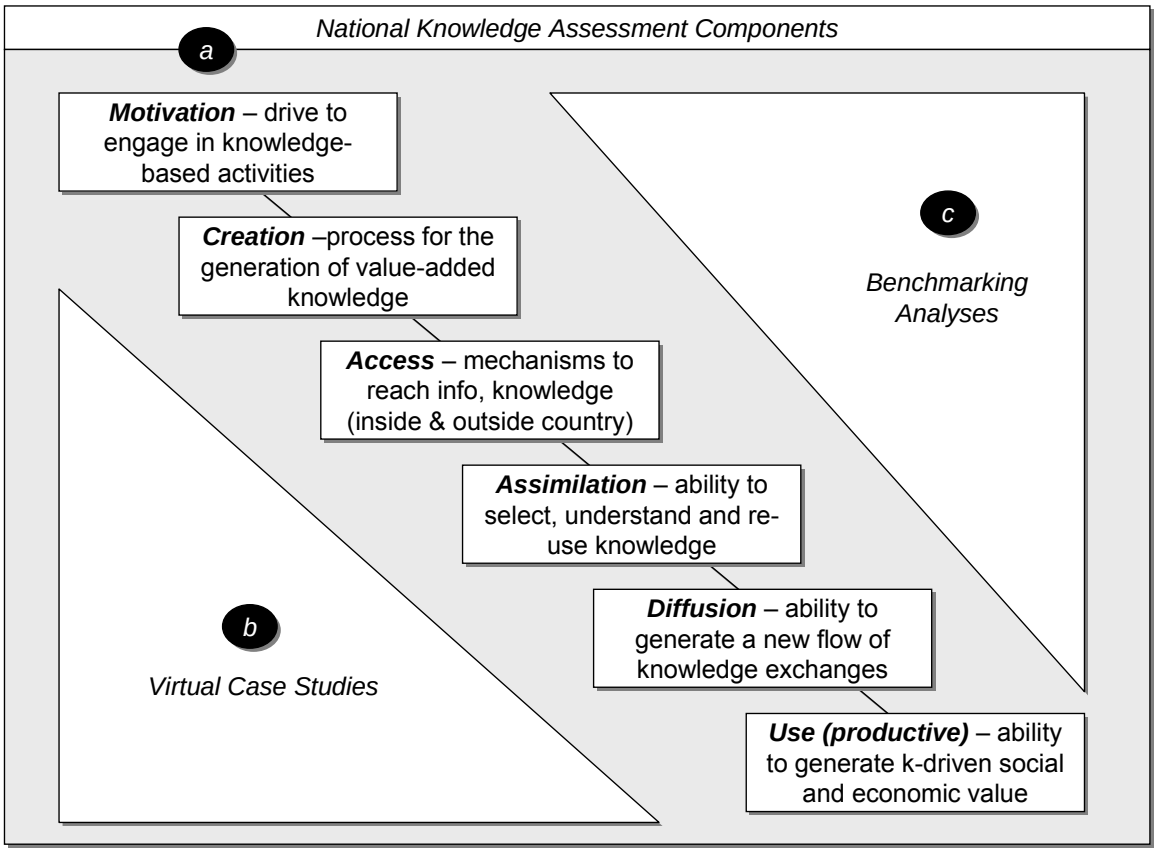
In the benchmarking analyses, data is collected based on the national knowledge assessment components that provide comparative views across countries on a number of key development indicators, such as those listed in Figure 2, which were proposed by the NRC [1996] prospectus. Figure 2 maps the NRC-NKA knowledge assessment drivers to the knowledge creation function they support.

The NKA-NRC model includes both the above indicators and the consensus building and opt-in strategies, such as the national symposium and the virtual case studies, as integrated components of a successful knowledge assessment exercise. More details and suggested metrics and interview questions for each of the knowledge-assessment drivers listed in Figure 2 are available from the NRC Prospectus [NRC 1996] together with a 12-month timeline and work breakdown schedule for the execution of the assessment.

An Example of the NRC-NKA: The South Pacific Islands

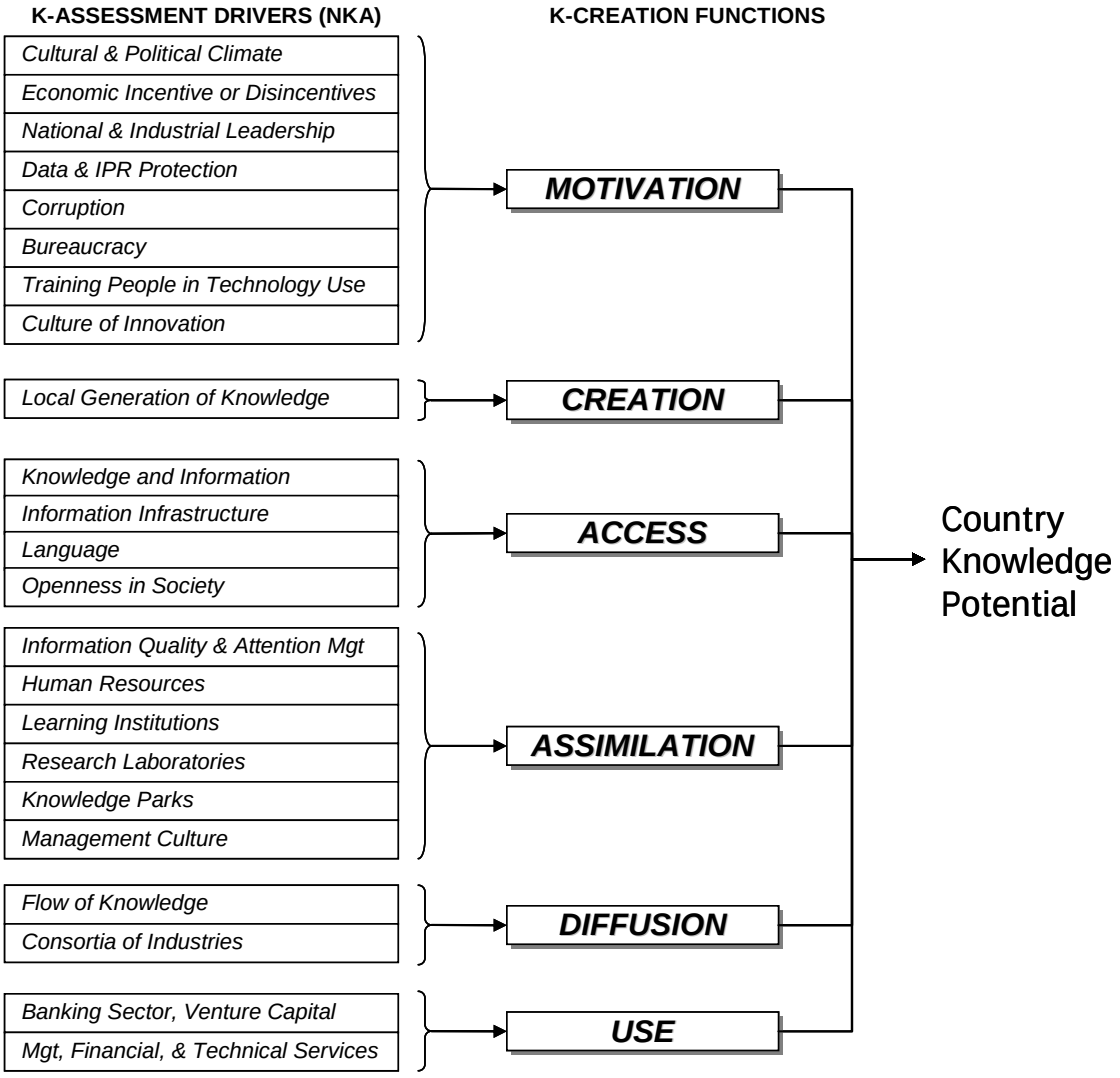
Knowledge assessment exercises are typically undertaken through joint efforts of international organizations, local governments, business, and civil society representatives in selected economies. For example, in 1997-98, the World Bank applied the NKA methodology in a knowledge-assessment exercise in the South Pacific Islands, specifically Fiji, Western Samoa,

and Tonga [SMEC International and CarlBro 1997]. The assessments consisted in a benchmark analysis of information technology use in Pacific Islands. Virtual case studies were developed with local stakeholders to identify investment projects (i.e. the creation of a knowledge park with the University of the South Pacific, the establishment of a Kava Club for preserving traditional medical knowledge, a youth counseling network to prevent brain drain, etc.). After the assessment, in order to gather broader feedback on the initiatives, an Internet conference (think tank) was held to discuss preliminary findings with local stakeholders and international experts worldwide – evaluating the methodology and the results obtained. To discuss feedback from the Internet conference, a "regional symposium" was organized by the World Bank and other local development organizations (Australian Development Bank, Asian Development Bank and European Union). Finally, an in-country stakeholder workshop took place to agree on vision and action plans, including drafting a telecommunication infrastructure deregulation policy document to be implemented thereafter.



Source: Adapted from National Research Council [1996]

Figure 1. The National Research Council (NRC) National Knowledge Assessment Model (NKA)



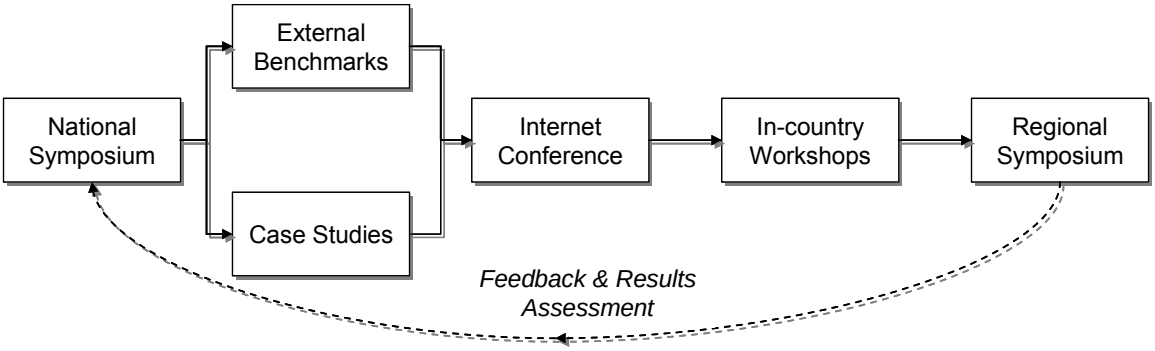
Source: Adapted from National Research Council [1996] and Passerini [2003]

Figure 2. Sample Evaluation Areas Metrics in the NKA Benchmarking Analysis

Figure 3 presents an example of a national knowledge assessment workflow based on the National Knowledge Assessment (NKA) model. Lessons learned from the assessment unveiled the need to redefine measurements by increasing the focus on local culture as the one key component of a country knowledge sharing potential.

The NKA approach and feedback session in the South Pacific, as well as its similar reiterations in Prince Edward Island (Canada) and larger implementations in Mexico [Passerini 2003], showed that the consideration of contextual aspects and local characteristics of knowledge need to supplement measurement exercises to better understand the true value of the assessed economies. In summary, while the NRC-NKA model provided a comprehensive framework to implement knowledge assessment pilot studies in specific countries, it had some limitations. It presented an evaluation model highly driven by structure and infrastructure indicators rather than

culture and local values as relevant knowledge creation drivers, especially for small insular economies. Other approaches to measuring knowledge assets described in the next sessions may in fact suffer, or even exacerbate, this limitation.



Source: Adapted from National Research Council [1996]

Figure 3. South Pacific National Knowledge Assessment Workflow

III. NATIONAL KNOWLEDGE BENCHMARKING ANALYSES

In this section, we review initiatives initiated by selected IDIs that specifically restrict the assessment approach to the third element of the NRC-NKA methodology: the collection of benchmark data. Based on the lessons learned from the holistic NRC-NKA prospectus, we discuss some limitations. In summary, as highlighted in the table at the end of this section, we highlight how these approaches to national knowledge measurement narrowly focus on creating a snapshot of country resources as they relate to knowledge management in a specific point in time (similar to a balance sheet approach).

THE OECD SCIENCE, TECHNOLOGY AND INDUSTRY SCOREBOARD, HUMAN AND SOCIAL CAPITAL

The Organization for Economic Cooperation and Development (OECD) conducts extensive work on the human and social capital aspects of national knowledge systems. The "Measuring What People Know: Human Capital Accounting for the Knowledge Economy" report [OECD 1996] presents country examples of investments in higher education and training and recommends changes in educational policies as a prerequisite to human capital and knowledge development. The report discusses individuals, firms and public sector levels. In addition to higher education (public and private) and expenditures on research and development, the OECD considers investment in software as an important indicator of a country investment in knowledge and its progress toward a knowledge-based economy.

The focal theme of the OECD approach is the identification and elicitation of metrics to assess human capital competencies, learning and development. The 1996 report advocates changes in accounting and educational systems to include human resources values and metrics in the evaluation of local, organizational and national knowledge systems. It presents selected best practices and national initiatives to measure acquired skills. For example, Australia is cited for the introduction of national competence standards through a comprehensive and ambitious reform of the country's vocational and training system. Canada is an example of a government-driven approach to assess prior learning in secondary schools, colleges, and universities with a unique system that recognizes the value of both formal and informal learning. France and the UK are emphasized for the introduction of comprehensive evaluation schemes that extend forma exam-based assessments. The French "assessment centres" evaluate broader competencies achieved

through multiple experiences. The common denominator is the understanding that the evaluation of knowledge creation cannot be isolated from the complexity and richness of individual experiences and, thus, embedded in simple standardized tests. These tests may weakly elicit only a limited portion of individual's creativity and abilities.

In addition to the programmatic framework that advocates the inclusion of human capital metrics in the assessment of knowledge assets, the OECD [2003] uses also its own elaborations of a wide-range of indicators relevant to knowledge-based economies. In particular, it uses science, technology and industry (STI) scoreboards to aggregate categories of knowledge-related variables:

1. *Creation and diffusion of knowledge* (13 key aggregate variables), i.e.

    A1. Investment in knowledge

    A2. Trends in domestic R&D expenditure

    A7. Venture capital

    A13. Scientific publications

    […]

2. *Information economy* (13 key aggregate variables on ICT), i.e.

    B3.1 Telecommunication networks

    B4. Internet subscribers and numbers of secure servers

    […]

3. *Global integration of economic activity* (5 key aggregate variables), i.e.

    C1. Trends in international trade and investment flows

    C2. Cross-border mergers and acquisitions

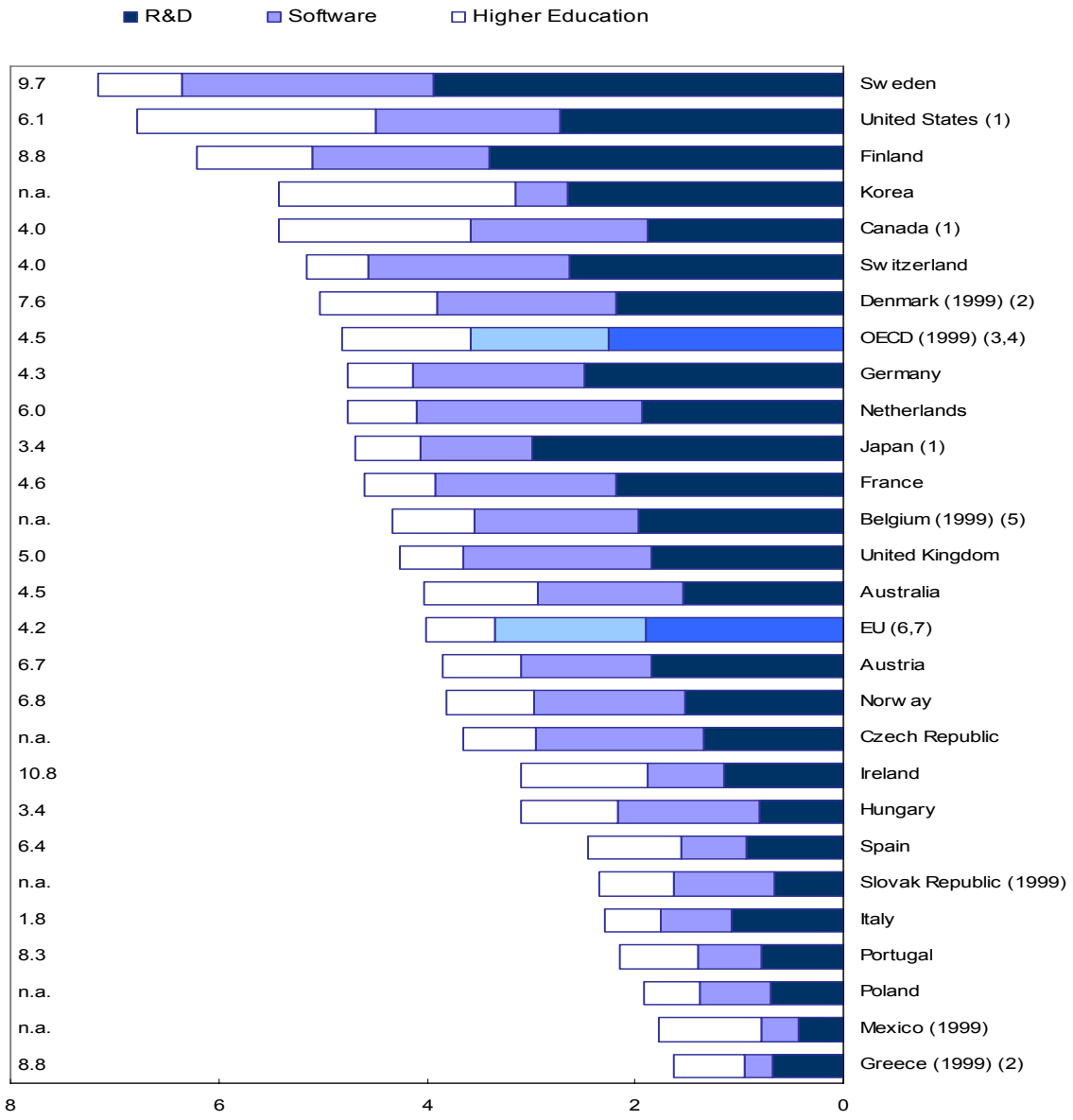
    […]

4. *Productivity and economic structure* (10 key aggregate variables), i.e.

    D1. Differences in inform and productivity

    D10. Entry, exit, and survival of firms

    […]



Source: OECD [2003]: Creation and Diffusion of Knowledge

Figure 4. OECD STI Scoreboards on Investment in Knowledge

Within each of the previous categories, the OECD defines a large subset of variables and presents comparative analyses for each indicator. Figure 4, which is one of the many scoreboards available in the OECD [2003] report, shows variable A.1 (investment in knowledge) as an aggregation of expenditures in software, research and development and higher education.

The OECD continues to undertake initiatives to elicit human capital and social dimensions in STI scoreboards, dimensions currently embedded within measures of country performance. For example, the STI scoreboards released in 2005 [OECD 2005] include additional sections focused

on human resources (knowledge and skills in science and technology; as well as a patent section to identify the value generated by knowledge creation. Specifically:

1. *Human Resources in Science and Technology: Knowledge and Skills* (10 key aggregate variables), i.e.

A1. Flow of University graduates

A2. Foreign Ph.D. students

A3. International mobility

[…]

2. *Patents: Protecting and Commercializing Knowledge* (9 key aggregate variables), i.e.

B1. Patent Intensity

B2. ICT patents

B3. Domestic ownership of foreign innovation

[…]

More recently, OECD Publishing released a viewpoint on how what people know shapes their lives [Keeley 2007]. For the OECD, human capital, which includes knowledge and skills derived from formal and informal education and training experiences, also extends into social capital, which refers to social relationships, norms and mutual behaviors [OECD 1996]. The OECD supports the development of a unified model for measuring social capital. It combines, in a single repository, a list of national reports and approaches on measuring local social capital through, for example, political participation, community involvement, informal networks/sociability, trust, norms, and sanctions. For an interesting and comprehensive discussion on the evaluation of social capital, which is beyond the scope of this tutorial, readers can refer to Healy [2001]. Healy's research summarizes of key efforts in measuring social capital at the international level, highlighting limitations that overlap with the difficulties encountered when trying to define broader metrics for knowledge management itself.

THE EUROPEAN UNION

Also the European Union (EU) focuses on a scorecard approach as a means to evaluate the effectiveness of knowledge management programs. Malhotra [2003a] discusses the knowledge assessment models developed by the European KM forum and identifies the EU's ability to also monitor social and technical aspects of knowledge developments. Veugelers (2005) associates the European Innovation Scoreboards (EIS) to the policy actions and strategic targets that European Union espoused at the European Council of March 2000 in Lisbon.

With the Lisbon strategy, the EU launched a set of integrated structural reforms with the objective of becoming a most competitive knowledge-based economy by 2010. These reforms include:

a) Capital market and product reforms to increase competitiveness;

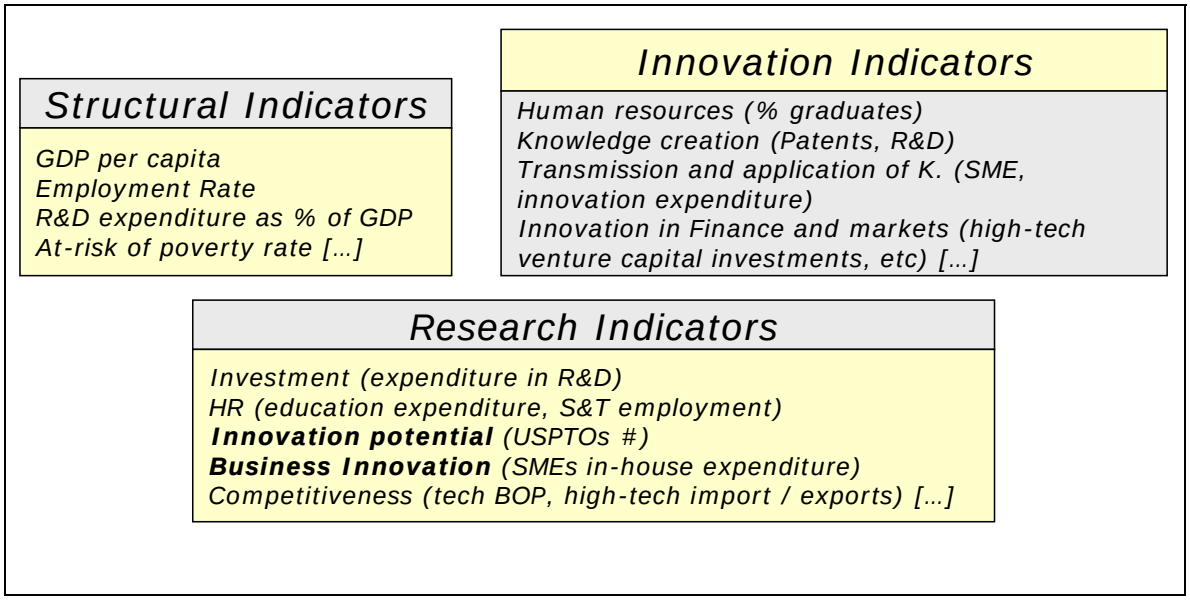
b) Investments in the knowledge-based economy to increase the innovation capacity;

c) Labor market reforms to improve the allocation of human resources and their permanence in the active labor force;

d) Social policy reforms to increase cohesion; and

e) Environmental policy reforms geared toward environmental sustainability.

To monitor progress toward the set Lisbon strategic targets, the EU countries agreed on the continuous assessment of a large set of indicators that track the aggregate value of structural, competitiveness, research and human resources metrics as well as innovation indicators (including innovation potential and business innovation). A small list of the 53 indicators is available in Figure 5, based on Veugelers [2005].



Source: Adapted from Veugelers [2005]

Figure 5. EU Indicators of Knowledge-Based Growth (53 total)

The European Innovation Scoreboards (EIS) assessment model is only a benchmark approach. To succeed, systemic reforms addressing the various EU challenges (aging, enlargement, and globalization) need to be deployed. Moreover, Veugelers notes that the midpoint evaluation of 2004 shows that the strategic targets established in Lisbon 2000 are far from being achieved, especially in the area of research and development. Only two countries in Europe topped R&D expenditure as exceeding 3 percent of gross-domestic product (Finland and Sweden), a major misalignment with the Lisbon's recognition that value creation and higher growth is dependent on innovation and research investments. Overall, it appears that the complex and comprehensive assessment framework established to track progress toward the knowledge-based economy might have been overly broad and ambitious. It paved the need for a less systemic and sustainable plan of action towards the creation of the knowledge society [Veugelers 2005] focusing, for example, on building stronger innovation capabilities.

THE UNITED NATIONS

Based on the earlier sections' discussion that describes substantial differences in the measurement approaches among different organizations, it is no surprise that also within the United Nations (UN), which is an organization of multiple organizations, such differences persist. For example, Malhotra [2003a] briefly describes the parallel efforts of the United National Economic Commission for Europe (UNECE) that has focused its evaluation of knowledge assets on intellectual property assets (inventions) and rights (patents) as well as market valuation of companies and R&D outcomes. Other UN agencies like the International Telecommunications Union (ITU) are more focused on measuring information and communication technologies (ICT) indicators and benchmarking countries mobile technologies adoption and use. Other specialized

agencies may focus on measuring innovation and e-commerce indicators and drivers (for example, the United Nations Development Program – UNDP – and the United Nations Industrial Development Organization – UNIDO).

Plenty of metrics and benchmarking analyses are proposed by each international agency, with overlapping yet different models and synthetic analyses. Despite the differences, the models show consistency in the selection of KM-drivers in information and communication technologies (ICT) as well as access, policy environment, usage, social and cultural infrastructure and education/literacy. For the United Nations Conference on Trade and Development (UNCTAD) has identified a list of key variables that concur to form ICT indices, which in turn are key contributors to knowledge creation [Malhotra 2003a]. UNCTAD [2003] describes indexes and correlations among a number of related indicators. It classifies countries based on ICT endowment. Figure 6 presents key metrics and data sources of the UNCTAD model.

Index/dimension	Indicators	Sources
1. Connectivity	• Internet hosts per capita • Number of PCs per capita • Telephone mainlines per capita • Cellular subscribers per capita	All data series from ITU (deflated by UNSD population data and compared with World Bank data for accuracy check)
2. Access	• Internet users per capita • Literacy (% population) • GDP per capita • Cost of a local call	ITU UNSD World Bank ITU
3. Policy	• Presence of Internet exchange • Competition in local loop telecoms • Competition in domestic long-distance • Competition in ISP market	UNCTAD research ITU ITU ITU
Usage: Telecom traffic	• International incoming telecom traffic(minutes per capita) • International outgoing telecom traffic(minutes per capita)	ITU ITU

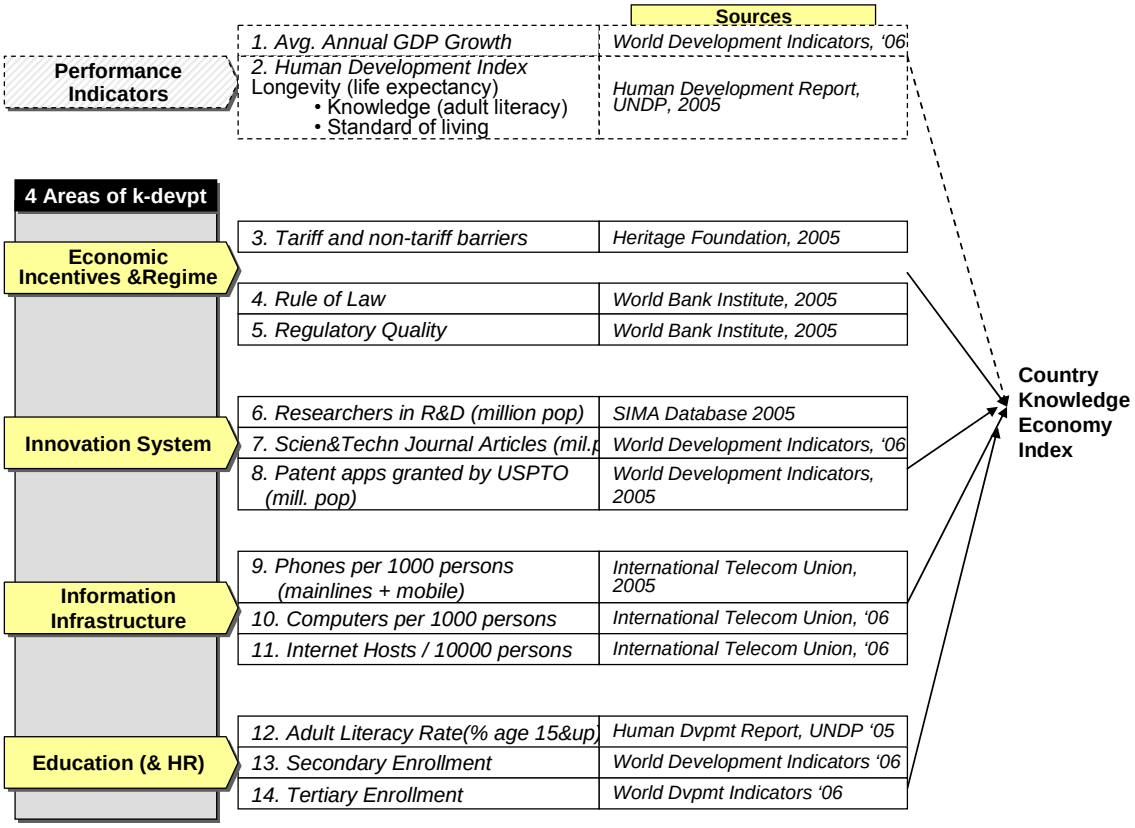
Source: UNCTAD [2003] pg. 9

Figure 6. UNCTAD Indicators of ICT-Index

Driven by a programmatic and strategic planning process similar to the European Union Lisbon Strategy, also the United Nations defined broad development goals to further knowledge-based development (the so-called Millennium Development goals or MDGs). The UN is attempting to become a more integrated institution where data and benchmarks collected by each agency can be easily accessed by the other agencies and client countries. Agencies, such as for example the United Nations Population Fund (UNFPA), are following through the directive of creating 'One United Nations' by developing tools to elicit and track knowledge indicators in the field of human population health and well-being. These tools will be easily transferable and accessible, providing achievement visibility along the critical human resources development areas relevant to UNFPA programs.

THE WORLD BANK KNOWLEDGE ASSESSMENT MODEL (KAM)

The KAM (Knowledge Assessment Model) is a globally accessible measurement framework. It is an open java-based Web-system that facilitates global access to data, ease of use and interactivity [WBI 2005]. The KAM evaluates countries based on their relative standing and structural/qualitative indicators of performance on four key areas that drive knowledge development. These areas include the (1) *incentives system* based on the economic and institutional regime that provide the resources and the structural environment for the dissemination and use of knowledge (for example, by supporting entrepreneurship and the protection of intellectual property rights). A knowledge economy also relies on the (2) *innovation system* which is represented by the local opportunities to exploit existing know-how and create new knowledge thorough knowledge intensive products and services (such as for example high-tech products). The affluence of research centers, research universities, and high investments in research and development are all factors that contribute to the innovation system. A knowledge economy is built on a strong (3) *education system* to ensure that the skills of the population and the formal education levels guarantee the effective use and sharing of knowledge. Finally, a key underlying resource for the thriving of a knowledge society is identified in a robust (4) *information infrastructure* that is the existence of efficient and accessible communication channels that facilitate the sharing, dissemination and processing of data, information, and knowledge.



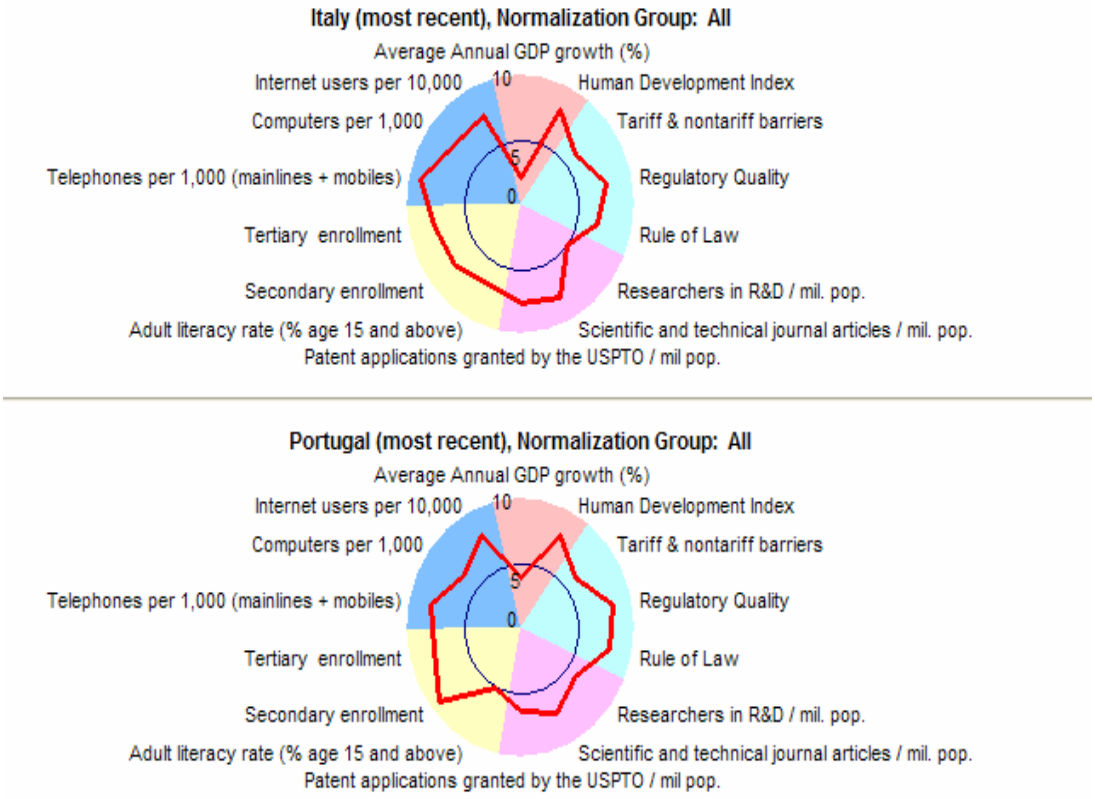
Source: World Development Institute [2005] and Passerini [2003]

Figure 7. KAM Scorecard (12+2 Variables)

The World Bank KAM model [WBI 2005] is based on a set of about 80 variables (structural quantitative indicators as well as qualitative indices). A subset of these variables is used to determine cross-country comparisons through a basic scorecard with fourteen indicators: 12 variables considered as proxies for knowledge development and two additional performance variables that represent the relative size of countries (Figure 7).

The scorecard identifies a Knowledge Economy Index (KEI) - the average of the performance scores of a country or region in all four KE pillars (economic incentives regime, education, innovation and information communications and technology) – and the Knowledge Index (KI) - the simple average of the performance of a region or country in education, innovation and information communications and technology. In the scorecard, countries are compared through a normalization procedure which is based on the relative ranking of the set of country compared assessed on a scale of 1 to 10.

The KAM interactive scorecard is publicly accessible on the World Development Institute Web site to enable interactive cross-country visualizations of relative scores based on normalization calculations derived from all the countries assessed or based on relative comparison among regional blocks (Western Europe, G8, etc.). Spider diagrams quickly identify low and high variables for each of the measurement category (Figure 8).



Source: Radar Graph created from the World Development Institute [2005] interactive Web site

Figure 8. KAM Comparison Diagrams

While the KAM represents a commendable effort, and one that guarantees not only access to the sources of information but international agreement on the set of measurements used, there are some limitations. First, the number of countries varies over time (from 1998 the number has increased yearly based on the increased availability of structural data). Since the comparisons are normalized on relative ranks among countries, the index may present variance from year to year that is due to a measurement issue rather than a real growth event. In addition, the number of total indicators considered in the analysis continue to grow and vary each year (from 66, 76, to 80 and more variables). This also affects the predictive power of the index which is a synthesis of a key subset of variables. Finally, and more importantly, the index reflects an ex-post picture and does not provide guidance for regulatory changes. Cause and effect is not ascertained and the relative predictive power of the index is not validated. Bontis [2004] discussed the relative role played by a set of structural variables that are embedded in the KAM macro-indicators, with a specific focus on the analysis of the intellectual capital index benchmarking of Arabic countries. However, more work is needed to ascertain causality within the KAM model. Regardless of these limitations, the KAM remains a comprehensive measurement system undertaken to identify key drivers of knowledge society.

ADVANTAGES AND LIMITATIONS OF INTERNATIONAL DEVELOPMENT APPROACHES

Table 1 presents a summary of the qualitative and qualitative methodologies adopted by development institutions, non-profit organizations and governments to evaluate the capabilities of knowledge-intensive nations.

It is important to note that the frameworks listed in Table 1 may also differ by scope of the implementation. For example, virtual case studies (the identification of knowledge management initiatives and opportunities) and benchmarking may have a focused location-specific component, while symposia and scorecards may have national or multinational outreach. Advantages and limitations of the approaches discussed in this section are also summarized in the table.

Table 1. Summary of Knowledge Assessment Examples

Organization	*Methods*	*Advantages*	*Limitations*
National Research Council-US	National Knowledge Assessment Methodology (NKA Prospectus)	Systematic holistic approach that balances data collection with interviews and consensus building	Benchmarking approach does not take into sufficient account local culture
OECD	Science and Technology Indicators (STI) Scoreboards	High consideration of human and social development indicators	Limited data accessibility and no user-friendly / re-usable scorecards
European Union	European Innovation Scoreboards and Lisbon 2000 Indicators	Measurement framework developed within a systemic strategic planning process	Ambitious and broad plan that may not be actionable or sustainable in a short-timeframe
United Nations	ICT-Index; Intellectual Property; e-Readiness index	The ICT index presents clear interrelation and correlation of variables	Limited integration and data re-utilization
World Bank	Knowledge Assessment Methods (KAM)	User-friendly model readily accessible to the public	Limited prediction models and difficult multi-year data aggregation

IV. GRAPHICAL APPROACHES

Several of the approaches discussed earlier are limited in their predictive capabilities. Graphical and belief-based analytical approaches can be applied to identify a dynamic and predictive model (the Bayesian network analysis). Recently, the interest in Bayesian statistics and Bayesian network analysis has increased. Advanced research of Bayesian networks is yielding promising results in several areas such as speech and handwriting recognition, junk mail filtering, targeted advertising, data mining natural language processing text classification, and text clustering for knowledge management, collaborative filtering, intelligent agents, and search engine technologies [Heckerman 2004] and pharmaceutical research, healthcare systems, and control systems.

UNDERPINNINGS OF BAYESIAN ANALYSIS

Bayesian analysis is based on "the interpretation of probability, according to which probabilities encode degrees of belief about events in the world, and data are used to strengthen, update or weaken those degrees of belief" [Pearl 2000, p.11]. A Bayesian network is a graphical model that displays probabilistic relationships among variables [Heckerman 1999]. Bayesian networks' strengths lie in their: 1) ability to show dependencies among variables as well as effectively deal with missing data; 2) iterative mapping of causal relationships to make predictions about any consequences from interventions; and 3) representation and combination of prior knowledge and data to show both causal and probabilistic views [Heckerman 1999; Heckerman et al. 2004]

Traditional statistics - later referred as to "classical inferential models" - are based on the assumption that a population of interest can be inferred from a sample of the population. As the sample size goes down, the error associated with making inferences, validating or invalidating a hypothesis goes up. Numerous techniques have been developed to deal with the errors associated with these analyses. These techniques state the level of confidence that can be placed on these inferences. For example, the *z-test* can be used to derive the probability, for the hypothesized populations mean, that the sample mean would be greater than the average of observations in the data set, i.e., the observed mean [Niedermayer 2003].

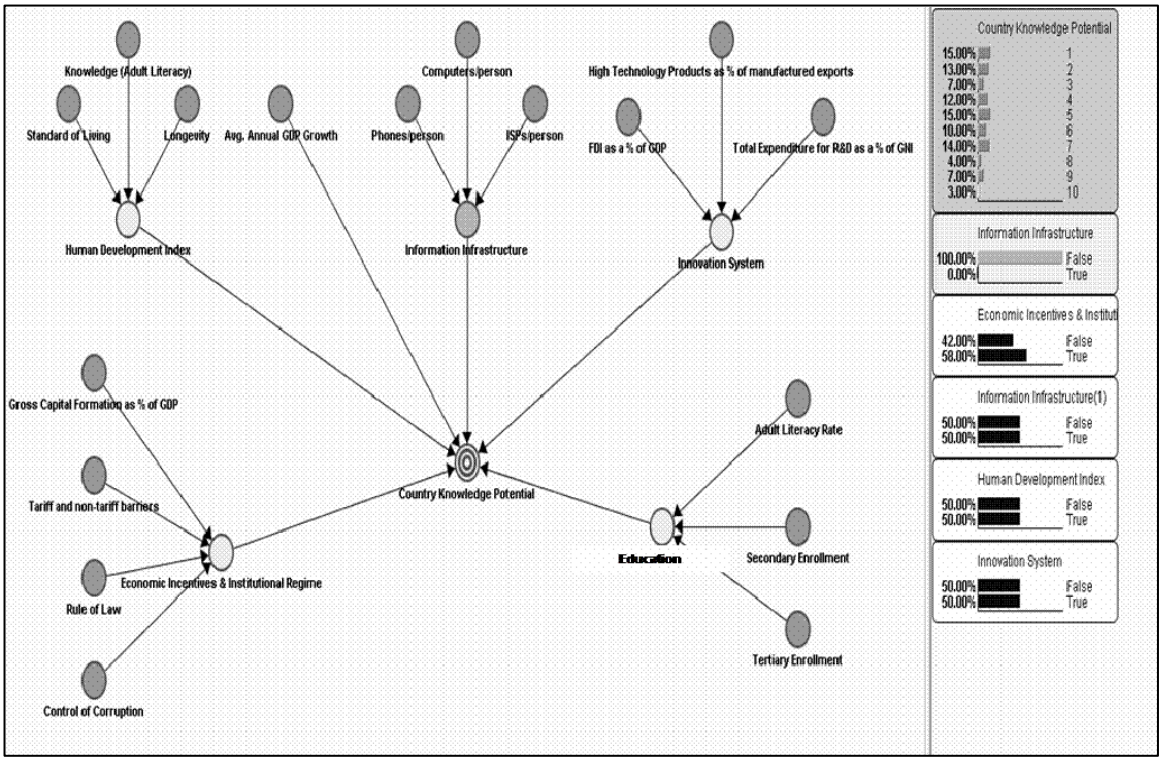
Unlike Bayesian analysis, "classical inferential models" do not allow prior knowledge (in the form of historical data) to be included in the calculations [Howson and Urbach 1993; Niedermayer 2003]. This fundamentally important concept, namely incorporating and updating "prior" data, is where the Bayesian approach brings its major advantage. The Bayes theorem was developed in the 18th century by Reverend Thomas Bayes. A common criticism of the Bayesian theory is that "the component probabilities – the likelihood and especially the priors - of a Bayes' theorem calculation are often not readily computable, because the data are too vague or too numerous and diverse…" [Howson and Urbach 1993 p. 431]. The effective use of Bayes theory started being applied in the early 1980s with the use of Bayesian networks and decision graphs which are more algorithmic. Also, Bayesian software such as BayesiaLab, Bayesware, Bayes Discoverer and many others are now available to readily run analyses of the influence paths between nodes, algorithms, mutual information maps, and more [Bayesia S.A. 2004].

The Bayes theory is stated as follows: $\underbrace{P(H\|E,c)}_{\text{Posterior Probability}} = \frac{\overbrace{P(H\|c)}^{\text{prior probability of H given c alone}} \times \overbrace{P(E\|H,c)}^{\text{Likelihood}}}{\underbrace{P(E\|c)}_{\text{Normalizing/Scaling factor}}}$	**H**: Hypothesis where **E** : Given Additional Evidence **c** : Background Context

The *posterior probability* is defined as the probability of **H** after considering the effect of **E** on **c**. This is sometimes called as the Bayesian conditionalization. The posterior probability provides a way to tell researchers how to change their beliefs on their hypotheses based on new data/evidence [Neapolitan 2004]. The *likelihood* is defined as the probability of the evidence based on the assumption that the hypothesis **H** and the background information **c** are true.

Bayesian networks can be used to identify a "model" among observed data, that is, a set of processes that explain the relationships among the observed data and "can be used to reason about new problems, for prediction, diagnosis, and classification" [Bayesware Limited 2003]. A Bayesian network is visualized through a graph with "nodes" and "arcs." Nodes represent stochastic variables where the assignment of a value to a variable is represented by a probability distribution (literally, if variable X is equal to a specific value, or is observed, Bayesian networks can elicit the changes to the conditional probabilities that other variable values would change). A value assignment to a variable is referred to as the state of the variable [Bayesware Limited 2003]. Arcs, or arrowheads, show the casual dependencies among the variables.

Bayesian analysis applications are increasingly more popular. Just to cite a few studies, Mostafa et al. [1997] apply this approach to track user interests' shift. Jaronski et al. [2004] employed a Bayesian approach depended on both data and prior knowledge to build an impact model and make predictions for revisits/loyalty based on the user socio-demographic data. Their findings demonstrated that using the Bayesian approach makes such analysis feasible and effective. Weld et al. [2003] apply these techniques to the personalization of Web-based interfaces.



Source: Passerini and Cakici [2004]

Figure 9. Graphical Approaches to Modeling Knowledge Assets

BAYESIAN NETWORKS APPLICATIONS FOR KNOWLEDGE ASSESSMENTS

Bayesian analysis can be effectively applied to the knowledge assessment model (KAM). In the example presented in this tutorial, Bayesian networks and decision graphs are used to map the relationships between KAM variables, the knowledge drivers, and a country's knowledge potential (dependent variable). The Bayesian network structure visualizes the relationships among variables and elicits interactions effects within the underlying dataset.

Figure 9 shows a simple Bayesian network that models the World Bank KAM scorecard variables. The relationship between the areas of knowledge development and the causal relationships are represented by arcs or arrows, and variables are represented as nodes (circles). The model starts with the "expert" view and assumption (i.e. based on the KAM relationships and scorecards groupings) and progressively readjusts itself based on the probability distribution of multiyear data, which is extensively available in the KAM database or in international databases that are released each year, such as the World Development Indicators [2006]. Inputting additional data from multiple years continues to improve the model and reveals causal relationships with and between the variables and the macro-development areas. Additional data obtained by different simulation methods can be applied to the model to assess the predictive capabilities of the final model for KAM.

In Figure 9, the Country Knowledge Potential is identified by the Target Node, shown with circle rings. Knowing any of the variables current value (or the "state of a variable" as defined earlier), a new set of probability distributions can be calculated for all the child nodes. The power of the Bayesian model is the elicitation of the impact of economical, social, and political changes (expressed through sets of probability distributions over multiple years) on knowledge-creation activities.

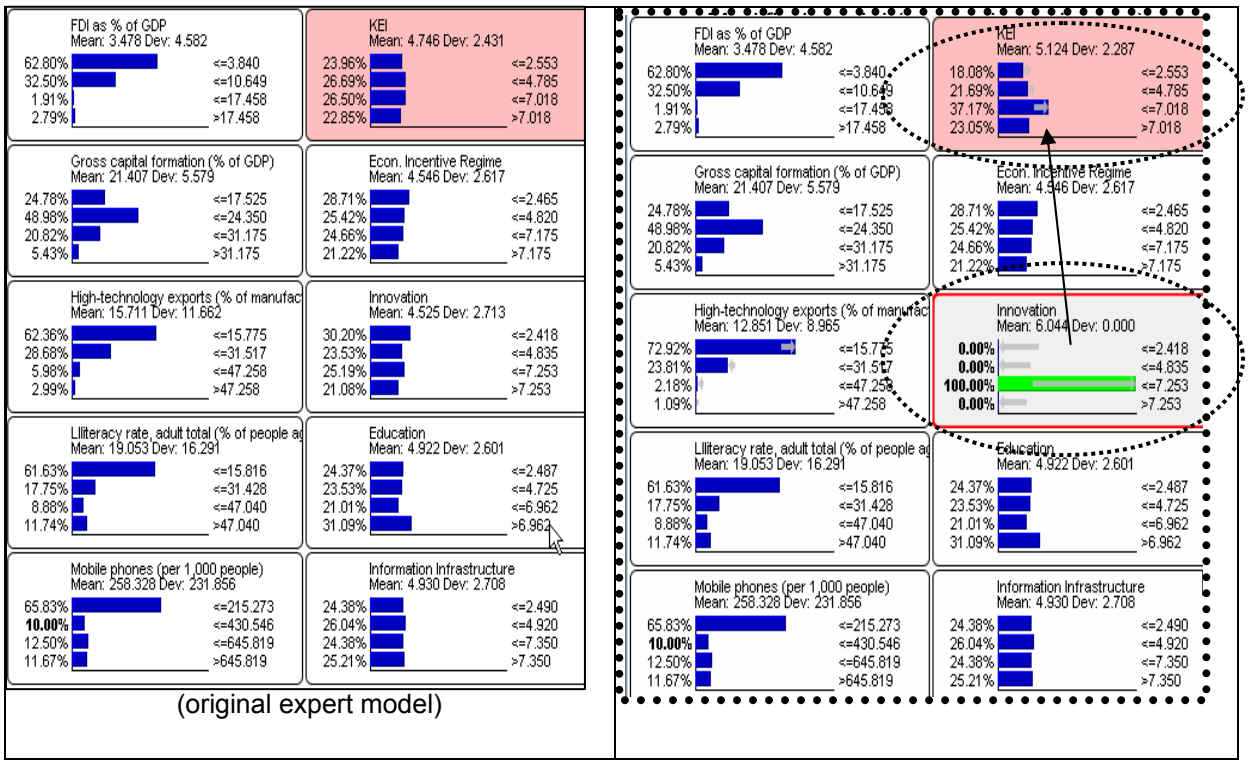


Figure 10. BayesiaLab Conditional Probability Distributions Output

This model can be used to determine the impact of a change in a variable caused by a political decision, a cultural norm shift, an economical policy decision, a trade law and educational system change on the country's knowledge potential. For example, Figure 10 (left) shows the probability distribution of the variables listed in Figure 9 based on a sample set of dummy data extrapolated from the World Development Indicators [2006]. Figure 10 (right) represents how the probability distribution of the target dependent variable, the country knowledge economy index (KEI), changes when the state of a variable (in this case innovation level) is known (right). When the innovation index is <= 7.253 (in the 10-point ranking scale of the normalized World Bank KAM assessment methodology), the conditional probability that KEI is <=7.018 increases of about 10 percent, while lower level of KEI value's probabilities decrease. This (not actual as based on dummy data) notion implies that changes in innovation level impact KEI. At the same time, the graphs (generated with BayesiaLab software) show the relative conditional probability changes in other variables, while the original causal models is updated based on new data or data from multiple years.

V. SUMMARY AND OPEN ISSUES

This paper reviewed models for the evaluation of countries knowledge assets and programs that affect their potential to generate new knowledge. It described national approached adopted by IDIs with the objective of presenting a holistic view. The paper suggests that knowledge assessments should be conducted before and after knowledge management programs as they are powerful tools for identifying gaps and driving new policy approaches.

Some issues remain open. First, how do we agree on a common set of metrics? The number of alternative models shows that there is no agreement on how to clearly evaluate knowledge assets and national knowledge management programs. Second, how do we better integrate social and human capital dimensions? It has become clear that measuring knowledge assets and knowledge management programs on pure economic development variables undermines the whole complexity and richness of knowledge. While economic and performance indicators should continue to be identified, the focus on social, human, and cognitive measures should be further developed.

Finally, and probably where the information systems community could substantially offer support, how do we make the evaluation models more visible and accessible to the public? The World Bank interactive KAM java-based Web site offers an example of a highly user-friendly system. Supporting data integration and visualization across organizations could further support access and encourage the analysis on correlations and predictive capabilities of the indices. Such visibility and integration may in fact be within the development agendas of the IDIs and an area of possible joint research and application opportunities for information systems and management researchers.

ACKNOWLEDGEMENTS

The authors would like to thank the reviewers and editors for the insightful suggestions that contributed to reframing the examples and discussion presented in the tutorial. Many thanks also to Dr. Kemal Cakici, George Washington University, for his contribution to defining Bayesian network analysis applications for knowledge assessments.

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APPENDIX I

Following is a list of useful links to obtain more information about the assessment models presented in the paper. All links are current as of 7/10/2007.

Organization	*Methods*
National Research Council-US	National Knowledge Assessment Methodology (NKA Prospectus)
Useful Links	
→ NKA Prospectus Web Page http://www.nap.edu/catalog/9528.html also available in HTML format at http://books.nap.edu/html/prospectus/	

Organization	*Methods*

OECD	Science and Technology Indicators (STI) Scoreboards
Useful Links	
→ OECD Measuring What People Know. Human Capital Accounting for the K-Economy http://www.oecd.org/LongAbstract/0,3425,en_2649_34543_33702586_119699_1_1_1,00.html → Science, Technology and Industry Scoreboard 2003 - Towards a knowledge-based economy 2003 http://www.oecd.org/document/21/0,3343,en_2825_497105_16683413_1_1_1_1,00.html → Science, Technology and Industry Scoreboard 2005 - Executive Summary http://www.oecd.org/dataoecd/59/52/35465901.pdf and full report http://www.oecd.org/document/43/0,3343,en_2649_33703_35455595_1_1_1_1,00.html	

Organization	*Methods*
European Union	European Innovation Scoreboards and Lisbon 2000 Indicators
Useful Links	
→ European Innovation Scoreboards 2006 Report http://www.proinno-europe.eu/doc/EIS2006_final.pdf and European Innovation Scoreboards 2006 Web Site http://trendchart.cordis.lu/scoreboards/scoreboard2005/index.cfm → Lisbon Indicators and Evaluation http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1133,47800773,1133_47802558&_dad=portal&_schema=PORTAL	

Organization	*Methods*
United Nations	ICT-Index; Intellectual Property; e-Readiness index
Useful Links	
→ UNCDAT Information and Communication Technology Development Indices Report http://www.unctad.org/en/docs/iteipc20031_en.pdf → International Telecommunication Union (ITU) Indicators http://www.itu.int/ITU-D/ict/ → UNFPA Population Indicators http://www.unfpa.org/swp/2005/english/indicators/index.htm	

Organization	*Methods*
World Bank	Knowledge Assessment Methods (KAM)
Useful Links	
→ World Bank KAM Web Site and related links http://web.worldbank.org/WBSITE/EXTERNAL/WBI/WBIPROGRAMS/KFDLP/EXTUNIKAM/0,,menuPK:1414738~pagePK:64168427~piPK:64168435~theSitePK:1414721,00.html	

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Communications of the Association for Information Systems

ISSN: 1529-3181