[simula . research laboratory]

The economic benefits of publicly funded IT-research

and

How research and education on software engineering can contribute to Costa Rica's ICT capability

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Why listen to me ....? (1)

- I do **not** know very much about Costa Rica. Most of what I know is from several reports on the outsourcing industry in Costa Rica.
- I am a software professional and researcher in software engineering, **not** a researcher on the effect of different collaboration strategies between academia and industry or public funding of research.

Why listen to me ....? (2)

- I know, however, something about the funding and collaboration strategy experiences in Norway.
- The successes of Simula Research Laboratory is a result of public funding, efficient organization of research and good collaborations with the IT-industry. There may be something to learn from this.
  - Relevant work – see for example (Richard B. Heeks; 1999) – suggest that the research funding strategies that works in Western countries are about the same as in ”middle income countries with an open economy”, such as Costa Rica.
- As a researcher with long-term connection with Norwegian and international IT-industry, I have first hand experience with collaborations that worked well and those that did not work well.
- I have studied the challenges and opportunities of the IT-industry in many (outsourcing) countries. The IT-export challenges in countries like Poland and Romania may in many ways be similar to your challenges.

Part I: Why funding IT-research?

Is it worthwhile?

Why not let the IT-industry do the necessary research?

Categories of benefits from IT-research

1. Knowledge generation (e.g., knowledge about how to avoid cost overruns in IT-projects)
2. Education and training (e.g., training in empirical methods and critical thinking)
3. Creation of new methods and tools (e.g., tools supporting model-based testing)
4. Increased ability to solve technical problems in industry (e.g., increased skill in how to simulate the activities in the human heart)
5. Creation of new companies (e.g., spin-off companies from research-based insight on team-based work)
6. Provision of information sharing facilities (e.g., through participation in international researchers' networks and access to research publications)

Is it worthwhile to fund research?

- On average, publicly funded research seems to pay off:
  - In a review of studies, Salter & Martin (2001) found that the rates of return to publicly funded R&D typically were between 20 and 50%. This is about the same average return on investment as for privately funded R&D.
- Product generation, Germany: Beise & Stahl (2004):
  - In a postal questionnaire, 2,300 companies were asked whether they had introduced innovations between 1993 and 1995 **that would not have been developed without public research**. … The public-research-based products accounted for approximately 5% of all sales with new products.
- Mansfield (1991) found that some 10% of all industrial innovations in the US relied substantially on academic knowledge.
- Small countries (such as Norway and Costa Rica) seem to benefit from the same research policies compared to larger countries, see Easterly & Kraay (2000).

What about IT-research?

- In the IT-industry, the **process improvement impact** may be even more important than the development of new products.
  - Unfortunately the benefits of process improvement are harder to assess.
- The IMPACT project (www.sigsoft.org/impact/) summarized that: *“Software engineering research has significantly affected software engineering practice.”*
  - Leon J. Osterweil, Carlo Ghezzi, Jeff Kramer, Alexander L. Wolf. Determining the Impact of Software Engineering Research on Practice . *IEEE Computer*, Volume 41, Issue 3, March 2008 Page(s):39 - 49.
  - They provide many examples of substantial impact from the software engineering research on practice.
- The Simula programming language itself (the first object-oriented language) is a good example
  - It was developed by two professors at the Norwegian Computing Center (a research institute) and University of Oslo in the 1960s.
  - Changed the way programmers model and structure computer programs today.

An example of the somtimes complex interaction between academia and IT-industry: Configuration Management

When was it introduced?

	Academic Research	Industrial Research	Industrial Product
1972		SCCS (Bell Labs)	
1976		Diff (Bell Labs)	
1977		Make (Bell Labs)	
1980	Variants, RCS (Purdue)	Change-sets (Xerox Parc)	
1982	Merging, and/or graph (Purdue)		
1983		Change-sets (Aide-de-Camp)	
1984	Selection (Grenoble)		
1985		System model (DSEE)	
1988	Process support (Grenoble)		
	NSE Workspaces (Carnegie Mellon, Sun)		
1990		nDFS file system (Bell Labs)	
1994		Virtual file system and MultiSite (ClearCase)	
1996		Activities (Asgard, Bellcore)	
2000	WebDAV (California, Microsoft, ClearCase, ...)		

"The Impact of Software Engineering Research on Software Engineering Practice" by Alexander Wolf (based on CM work by Jacky Estublier and David Leblang) (2008)

IT-research supports many other fields

"*In the quest for public attention and support, many ”revolutions” are touted as agents of social change and engines of economic development, and justifiable so. What is remarkable about information and communication technology is the way that it invariably lays at the center of these other revolutions. For instance, the promise of biotechnology for the improvement of the environment and human health, and the promise of nanotechnology for the improvement of materials and energy production both depend in critical ways of ICT.*"

– Norwegian Research Council (2002)

BUT, why not let the private IT-companies do the research?

- Small companies cannot afford to do research, although they sometimes benefit very much from it.
- Companies (even the very large) are frequently risk-averse and short-term oriented. The typical situation is therefore a substantial under-investment in IT-research.
  - The free market mechanisms do not in this case lead to the socially optimal investment in research.
  - Williams (1997) concludes that the R&D spent by private firms might only be a quarter of what is socially optimal.
- An optimal investment in IT-research, consequently, assumes publicly funded research.
- Probably more under-investment in IT-research than in most other fields!

What Should Be Done

- There should be substantial public funding of IT-research.
- The funding should support ”*applied, basic research*” [research on basic/core problems of high industrial relevance]. There are amazingly many opportunities for applied, basic research in IT!
- The research institutes receiving funding should collaborate closely with partners in the IT-industry. The IT-industry should be where they get most of the problem understanding and the feedback.
  - The researchers should, however, not act as short-term problem solvers for the IT-companies! The research should be related to core problems.
- Most of the funding should be allocated to the researchers with the best research/innovation record.
  - There should in addition be funding for promising new research groups and researchers.

What Should [not] Be Done

- The funding should enable institutes to recruit and support research talents. Talent is the main factor for research and innovation success. International recruitment of talent is essential for small countries.
  - These talents may also be extremely important for succeeding in software export
- Give freedom, but require ”applied, basic research” on directed topics for most of the funding.
  - Allow some ”high risk of failure, potentially very high benefit”-research
- Provide sufficiently funding to enable the researchers to do realistically scaled empirical studies.
  - Simula’s recognition as an excellent and industry-relevant research institute in software engineering is strongly connected with its ability to conduct large scale realistic experiments with industry participants.
- Program-oriented funding is frequently **not** a good idea, unless the program is stable over many (more than 10 years).

Part 2: The Example of Simula Research Laboratory

Exemplify successful collaboration models between research, education and the IT-industry

In the beginning there was …

- the decision to close down the airport near Oslo (early 1990s)
- political discussions about what to do with the premises of the old airport.
- an industry forum suggesting that an IT-park was a good idea. The ship owner and investor Fred. Olsen – he also produces the Timex watches – was the main initiator of this idea. The idea got political support in 1997.
- the vision was to make the IT-park the most attractive knowledge centre in Europe by the year 2005 and a transfer of Norway into a knowledge society less dependent on export of natural resources. (similar to Costa Rica?)
- a minister of education (a man with only elementary education!) who decided that the IT-park needed a research center.

The Beginning

- In 2001 three research groups (all from the University of Oslo) were selected to form the IT-research center (Simula Research Laboratory):
  - Two of the groups (Software Engineering (SE) and Networks and Distributed systems (ND)) were selected based on the relevance of their topic for the IT-park and the third (Scientific Computing (SC)) based on their scientific quality.
- The research center was (and still is) organized as a limited company owned by several research institutes and the government, who has the main share.
- Many of the researchers keep a 20% position at the university (teaching and supervision).

The Beginning

- The “allowance” from the government has been about 8 mill USD per year.
  - This covered in 2009 about 50% of the funding, the rest is from other types of national research funding, international research programs (EU) and IT-companies.
  - Norwegian salaries are very high: A PhD student costs (after expenses, taxes etc.) about 130 000 USD per year.
- In 2001 the vision of an attractive knowledge center faced problems (e.g., through the .com bubble bursting) and the IT-park development was delayed and consisted mainly in property development.
  - Fortunately, the funding to the IT-research center (Simula Research Laboratory) continued in spite of the other problems.
  - Today, the IT-park is a success with more than 12,000 knowledge workers at the old airport and more is coming.

Achievements of Simula in the 10-year period

- Simula’s future existence has always been dependent on good evaluations!
- Every fifth year we are evaluated by international (independent) experts. The highest evaluation (”excellent”) is very hard to get.
- The evaluations show a very good progress in research quality:
  - 1999-evaluation (pre-Simula): One group was ”excellent” (SC), the other two (SE and ND) were ”good”. [”Good” is not really good, but average or below …]
  - 2004-evaluation: One group is ”excellent” (SC), one group is ”very good, on its way to excellent” (SE), one group is ”good, with some very good elements” (ND).
  - 2009-evaluation: Two groups are ”excellent” (SC and SE), one group is ”very good, with some excellent elements” (ND).
- The Software Engineering (SE) group was recently ranked as the second most productive software and systems research institute worldwide by Journal of Systems and Software.

Achievements of Simula in the 10-year period

- Seven companies generated in the period (none of them, however, are big successes, yet …)
- Substantial (but difficult to measure) impact on software processes in the Norwegian software industry (and worldwide).
  - Examples of very high return of investment, e.g., related to our fault prediction and testing research.
- An increase in external funding (from industry and government) enabled an increase in number of employees, now at more than100.
- Simula's reputation has the last years enabled the attraction of international highly recognized software engineering researchers:
  - Strong industry background/understanding
  - Strong research record
  - Dedicated to research goals corresponding with Simula's goal

The platform of Simula's success

- Full-time research! *[at least that is the goal ….]*
- Basic, applied research.
- Quality culture
- Organization of activities are more like those in private companies, e.g., less bureaucratic hiring processes.
- Free research in within a directed topic.
- Good contact with the politicians - explaining them why we are doing what we are doing and what they get from their investments.
- Creation of new businesses based on our research.
- Good PhD-students, recruited internationally.
- **Strong collaboration with the industry. They fund more and more of our research, without we becoming consultants.**

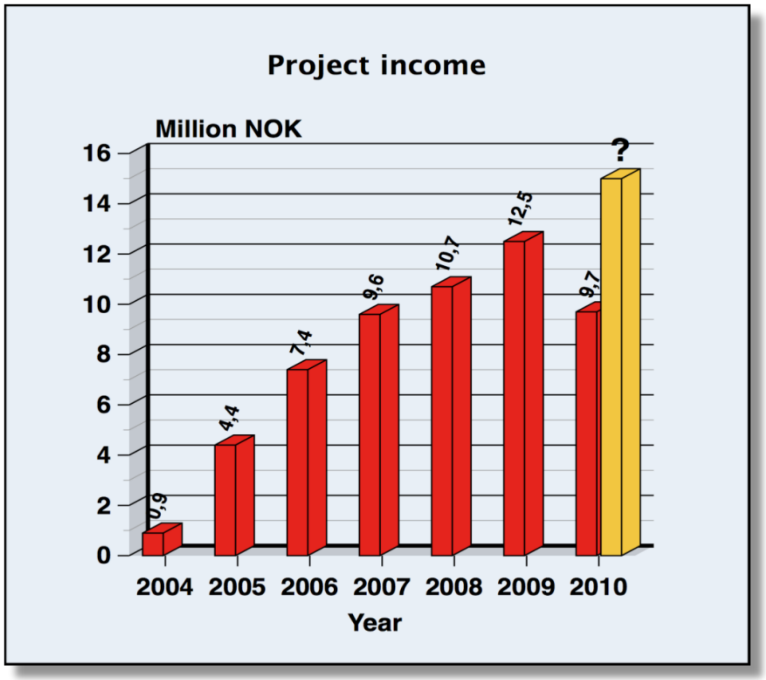
How we do our research ….

"*Our aim is to conduct long-term basic research with a clear view to application of the research results. The projects focus on fundamental and complex challenges that are important for society at large.*"

Projects that are interesting, but not sufficiently fundamental or without an important applications will not be started, even when there is funding available. [*well, this is at least the ideal – there are exceptions ….*]

Example 1: Collaboration with the Oil Industry Scientific Computing

- Focus on hydrocarbon exploration
- 100% funded by Statoil. Total 45 MNOK (8-9 Mill USD) by end of 2009.
- Long-term research goals, that require both basic and applied research on computation (50/50). The applied part generated a spin-off company.
- Collaboration enabled through the SC group's world-leading research on numerical methods and software for solving partial differential equations.



Example 2: Testing of software

- Det Norske Veritas (DNV) provides certificates for the Maritime and Energy sector
- The safety of, for example, the vessels/ships depends on the software for the steering and navigation.
- The SE group at Simula collaborate with DNV on methods for providing evidence for the safety of the software and other issues related to verification and validation of embedded software.
- DNV finance the research (PhD-students, etc.) made by Simula personnel.
  - Research on core problems (e.g., how to provide evidence of software safety).
  - Nevertheless, highly applied.

Example 3: My Own Research on Effort Estimation

- **Basic research problem**: Better understanding of the mental processes involved in estimation of time and effort.
- **Applied research problem** (the “same” problem): How to get software developers to estimate the required effort more realistically
  - Average overrun is about 30% and about 70% believe they are better-than-average.
- **Typical collaboration models**:
  - Action research (Case studies/process improvement) to improve problem understanding and evaluate proposed methods and tools
  - Controlled experiments in field settings
  - Controlled experiments in laboratory settings with software professionals
  - Surveys on industry conferences
  - Advisory work and industry seminars in Norway to transfer results
- Different problems and phases of require different types of collaborations with the industry.

Example 3: My Own Research on Effort Estimation

- Transfer of results to the IT-industry
  - Direct transfer to industry partners collaborating with us
  - On industry conferences and in industry magazines
  - Monthly column in Computerworld (Norway)
  - Misc.: Web-site with resources on effort estimation, Wikipedia page, a Special Interest Group on effort estimation, ….

Part 3:

The IT Outsourcing Industry, and Its Collaboration with the Academia in Costa Rica

The Possible Role of Evidence-Based Software Engineering

Main sources:

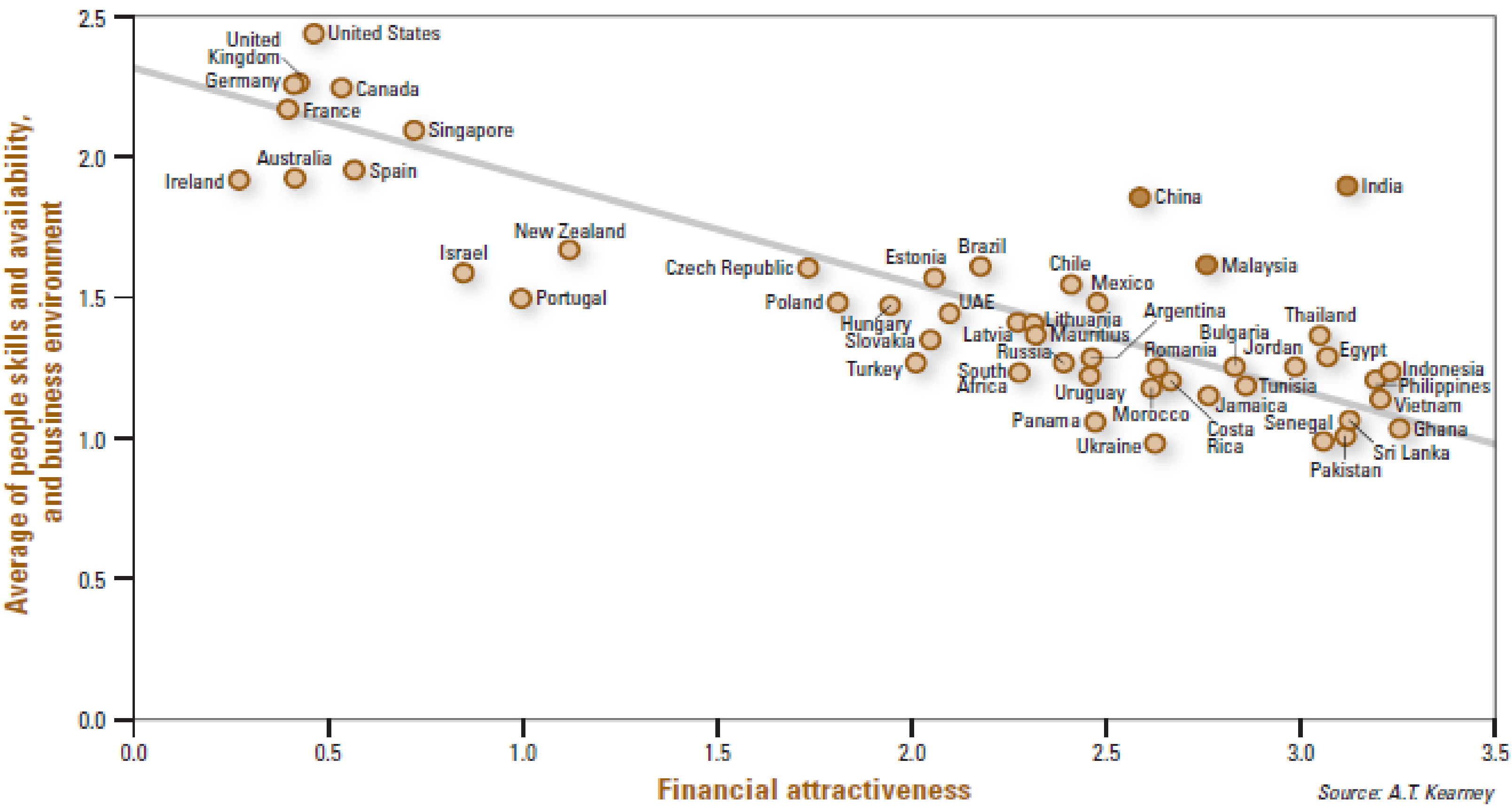
1) The New Software Exporting Nations: Success Factors, Erran Carmel, 2003
2) Human resource development policy in the context of software exports: case evidence from Costa rica, Nicholson and Shahay, 2008
3) Offshoring and employment in the developing world: The case of Costa Rica, International labour office, Geneva, 2008.

From what I read …

- ... offshoring of IT-development or IT-support to Costa Rica suffers from:
  - Higher costs than in, for example, India and China
  - Limited number of, especially experienced, software developers compared to many other countries.
  - Weak university-industry linkage (weak culture of applied research, few IT-researchers, etc.)
  - Poor English abilities
- … Costa Rica will probably never be able to compete with India and China on low price, but has to concentrate on factors such as
  - Special competence on particular domains or skills (clusters?)
  - Quality and efficiency of work (and life?)
  - Availability of well-educated, skilled software professionals
  - Less cultural difference with US/European-clients than Asian countries
  - Time zone-advantages
  - and, of course, lower price than in US/Canada/Europe

Costa Rica's outsourcing industry competitiveness is improving

- Costa Rica advanced on **Global Services Location Index 2009** from 34th place in 2007 to 22nd place in 2009 (but is still behind Mexico).



Challenges with the University-Industry Collaboration

- From Nicholson & Sahay, 2008:
  - “.. we do not have the fund to support long-term research” [companies]
  - “The linkage (university-private sector) does not exist. While the public universities are the best, they are very difficult to link up with …” [companies]
  - “The university policy of theoretical work takes precedence over applied also contributed to widening the divide between the university and the public sector, and as a result no effective interface existed for firms on which to approach universities to deal with their research inquiries.”
  - A senior researcher told: “There is a lack of **culture** (in the universities) in research and development … We also have to make the research more applied and work more closely with the software firms”
  - Another researcher told: “The problem is that historically the public universities have very **little resources**, and because of that we cannot do research.”

Evidence-Based Software Engineering An opportunity for Education, Research and IT-industry in Costa Rica?

- I'v visited many outsourcing companies in Asia and Europe..
  - Many companies are concerned about processes and certification, e.g., CMM in India, Scrum and ISO 9000 in Europe, but none of them are ”evidence-based”!
  - Many universities are concerned about evidence in support of various method and technologies, but few of them are good at transferring this knowledge to the industry.
  - The current software engineering curriculum is not very much evidence-based and directed towards the needs of a software engineer/project manager.
- The first country (companies) to advance from opinion and fashion-based to evidence-based software engineering may have advantages:
  - Medicine and many engineering disciplines did this step towards evidence-based practice years ago. Why are we still fashion and opinion-based?

How to Collaborate on Evidence-Based Software Engineering

- Create a collaboration between the industry, university education, researchers and government (providing the funding) in Costa Rica under the ”umbrella” of **evidence-based software engineering (EBSE) for the offshoring industry.**

- The role of the IT-researchers/universities in this collaboration would be to.
  - Produce, collect and summarizing evidence leading to higher quality of offshoring work (leading to competitive advantages compared to other exporting nations)
    - **NB**: Evidence creation should of course be related to problems of the type ”basic, applied research”, i.e., a role different to consultancy work.
  - Translate evidence and knowledge into practice in collaboration with the industry (improved processes, tools and methods).
  - Educate the IT-industry (and the students) in use of EBSE.

Evidence-Based Software Engineering (EBSE)

- Tore Dybå, Barbara Kitchenham and Magne Jørgensen, *Evidence-based Software Engineering for Practitioners*, IEEE Software, Vol. 22, No. 1, Jan-Feb 2005.

- *The general steps of EBSE are as follows:*
  - *Convert a relevant problem or need for information into an answerable question.*
  - *Search the literature and* ***practice-based experience*** *for the best available evidence to answer the question and/or conduct own studies to generate the evidence (create new knowledge).*
  - *Critically appraise the evidence for its validity, impact, and applicability.*
  - *Integrate the appraised evidence with practical experience and the client's values and circumstances to make decisions about practice.*
  - *Evaluate performance in comparison with previous performance and seek ways to improve it.*

- Simple steps, but difficult to follow! Little training in this as part of the education.

The role of public funding in EBSE …

- My experience is that software companies are very interested in EBSE to improve their processes and products, but:
  - Do not have the resources or the competence to collect evidence, to experiment or to analyze the effect of process changes.
  - Do not have the time for developing process and tool innovations.
- Examples of possible uses of funding to support the IT-industry (and the IT-research) in EBSE-related topics:
  - The funding covers the extra costs of the companies for experimenting, collecting data and reporting results.
  - The funding covers the cost of a researcher with industry experience to do research in a software company. ”Industry PhD scholarship” is an example of doing this, is getting more and more common in Norway.
  - The funding covers the development of tools and other products based on the research. Sometimes, this will lead to the funding of a new company.

Main Messages

- Public funding of IT-research is, **on average**, worthwhile.
- Conditions for higher likelihood of benefit from public funding on IT-research seem to be:
  - Strong collaboration with industry on basic, applied problems
  - Long-term focus with dedicated researchers (talents)
- Some of the elements that separate Simula Research Laboratory from the universities are likely to have been important for its success.
  - **Perhaps the Simula-model could be an inspiration for similar initiatives in Costa Rica?**
- Research under the "umbrella" of Evidence-based software engineering may be an efficient means to create collaboration between industry and academia.
  - **Evidence-based software engineering should be part of the university curriculum, to make the next generation of software engineers able to collect and synthesize evidence on how to improve their work.**