2E01 Sectoral Innovation System in Software in Asian Countries

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The article compares sectoral systems of innovation (SSI) related to software in the selected Asian countries: China, India, Japan, Korea, Singapore and Taiwan, focusing on industry-academia relations. It attempts to answer a question about the relevance of scientific research in each of the countries for local software companies, using tech mining research method. The analysis focuses on relevant scientific output of individual countries: publications from Compendex database in a 5-years time frame (2000-2004). The paper characterizes the involvement of private sector in scientific research, identifying the leading regional science-based software firms as well as key foreign vendors, conducting software research in Asia. It subsequently analyzes the balance between basic and applied research by clustering applied research topics and verifying contributions to dominant software domains. The analysis helps identify potential inefficiencies and strategic threats in the software sectors of the concerned countries.

1. Introduction

Industry sectors are traditional objects of analysis for economists and technology management scholars (Malerba 2002, Carlsson et al. 2002). Sectoral system of innovation and production (SSI) is defined as a set of products and agents, carrying out market- and non-market interactions in order to create, produce and sell these products (Malerba 2002).

SSI analyses attach particular importance to institutional linkages (especially relations with non-firm organizations such as public research institutes, government bodies or interest groups) and to specific knowledge generation and learning processes, occurring within interorganizational networks (Malerba 2002). A useful method of structuring and interpreting the roles and linkages within a sector is provided by the framework of techno-economic network (Bell, Callon 1994), introducing a distinction between financial, market, regulatory and science poles (for an example of practical applications of the framework to selected industries, see the case of robotics by Kumaresan and Miyazaki (1999)). The present research focuses on the science pole, where publications are regarded as viable output indicators. Scientific aspects of technologies are important not merely because they help progress our knowledge and stimulate new discoveries. Activities in the area of basic research are believed to extend absorptive capabilities of companies, preparing them to better understand and utilize the technologies (Cohen, Levinthal 1990).

2. The Asian software systems of innovation

Analyses of software sector present methodological challenges, related to the peculiar nature of software, its development and diffusion processes – many of indicators, suggested by innovation systems researchers (Carlsson et al. 2002) are found to have only limited relevance for the software SSI (for a discussion of these methodological challenges, comp. Young 1996).

The analyzed Asian countries represent various software market development stages, economic and technological regimes, and degrees of openness to foreign technologies, while their main common denominator remains the relative geographical proximity. They account jointly for over 80% of the Asian-Pacific software market, and are main regional players in the field of software-oriented research. At the same time, the regional market is dominated by three American vendors (IBM, Microsoft and Oracle), controlling about 50% of the market (Datamonitor 2003), with relatively insignificant sales and software exports of local companies.

3. Research method

The study applies tech mining methodology (Porter, Cunningham 2005), combining bibliometrics with text mining, qualitative analyses and network mapping. The adopted method analyzes relations between actors and technologies within a given innovation system, based on input data from article or patent databases (for similar approach, comp. Kumaresan, Miyazaki 1999).

The research was based on an article set extracted from Compendex database, one of the most representative collections of peer-reviewed technical articles. Data were collected by querying Compendex with a combination of the target country (in the field of author's affiliation), 5-years time frame (2000-2004), and specialized article groups related to software (so-called Engineering Index classification codes: 723 and sub-groups). The results were imported to tech mining software VantagePoint for further analysis.

4. Cross-country comparisons

The presentation of research findings will start with general cross-country comparisons, and move towards analyzes of private sector involvement, relations between basic and applied research, as well as the relative importance of emerging software technologies for researchers in the Asian countries.

Figure 1 presents the volumes of software-related articles,

authored in the respective countries. An additional analysis indicates that software-related research plays a significant role in all the concerned countries, accounting for 20-35% of all scientific articles (with Singapore and India positioning software as a key research area – 36.33% and 35.01% of all articles). Software article volumes were rapidly increasing in every country in parallel to the diffusion of software technologies and their growing importance for many previously unrelated academic disciplines. Interestingly, limited volumes of articles are not always related to a country's importance and share in the global software market – for example India, with the smallest number of publications among the analyzed Asian countries, has an established position in the international industry. It suggests that the scientific activities may not be related to the performance of domestic software industries and will later be discussed with reference to the corporate involvement and dominant topics of applied software research.

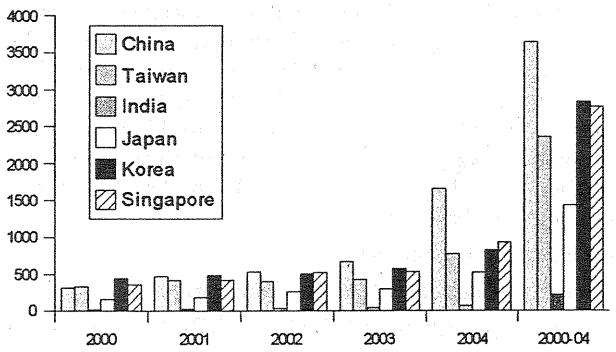

Fig. 1. Software article volumes over time

5. Private sector involvement

The software sector is based on one of the most advanced technologies, and indisputably belongs to research-based industries – however, the research is often kept within the walls of corporate laboratories and commercialized in forms of new products. This might suggest that software companies and academics co-exist in two separated worlds, not cooperating to address research problems. Table 1 outlines the involvement of private sector in software-related research of the analyzed countries. There is a substantial variance in the corporate participation – India, with the best prospering software sector in Asia, maintains an astonishingly high share of industry-sponsored scientific research (86.11%), with Japan holding the second position (18.85%), and other countries falling behind, and maintaining only minimum private investments.

Table 2 lists the most active companies conducting software-oriented research, showing all commercial organizations with at least 5 publications per country in the analyzed time frame. The revealed significant share of US-funded research corresponds to similarly high US software exports to the respective countries, and local market shares of companies such as Microsoft or IBM.

	China	Taiwan	India	Japan	Korea	Singapore
No. of articles	3,639	2,360	216	1,432	2,829	2,763
% from private sector	5.52%	3.09%	86.11%	18.85%	3.43%	1.59%

Table 1. Involvement of private sector in software research

China	India	Japan
Microsoft (62) IBM (30) Intel (14) Bell Labs (12) Nokia (9) China Aerospace Corporation (9) China Unicom (5)	IBM (75) Texas Instruments (23) GE (9) Synopsys (8) Engineers India (6) Emuzed (6) Hellosoft (6) Motorola (5) Steel Authority (5)	IBM (55) NHK (27) NTT (18) Softopia Found. (16) JVC (12) Litho Tech (10) Texas Instruments (9) JR East (8) Japan Nuclear Energy Safety Organization (7) Japan Highway (7) Japan Bio-Informatics Consortium (6) Honda (6) Nokia (5) Fuji Xerox (5)
Taiwan Taiwan Semiconductor Manufacture Corporation (60)	**Korea** Korea Telecom (42) Korea Power Engineering (15) Fairchild Korea Semiconductor (6)	
Singapore OKI (7)		

Table 2.Companies most active in software research

According to the findings, IBM remains the Asian market leader in terms of both software sales and research activities. In 2000-2004, IBM was the top software research-generating company in India and Japan, and the second largest contributor in China (after Microsoft). In Japan, the company was publishing more articles in the software area than any domestic company. Findings concerning the involvement of Japanese companies are particularly puzzling: previous studies, not specifically related to software, indicated high intensity of scientific research and paper output by the leading Japanese companies (Pechter, Kakinuma 1999). A comparison with the present research suggests that the largest Japanese companies missed the software-related opportunities, focusing on other technologies instead. The authors believe however that these results may partly be explained by the imperfections of Compendex, which fails to assign country affiliations to many articles – as a result, publications by some companies may have been omitted.

4.3. International specialization

The domain of software is very extensive, and it is not possible to conduct research in all significant areas, maintaining up-to-date knowledge or technological lead. International specialization is evident in software sales, for example Indian companies play important roles in software services and back-end development, China with Taiwan regard embedded software as offering key synergies with consumer electronics manufacturing, while Japan and Korea have particularly well-developed gaming industries. The specialization is however less evident in academic research – figure 2 presents graphical results of cross-correlation analysis of the Asian SSIs.

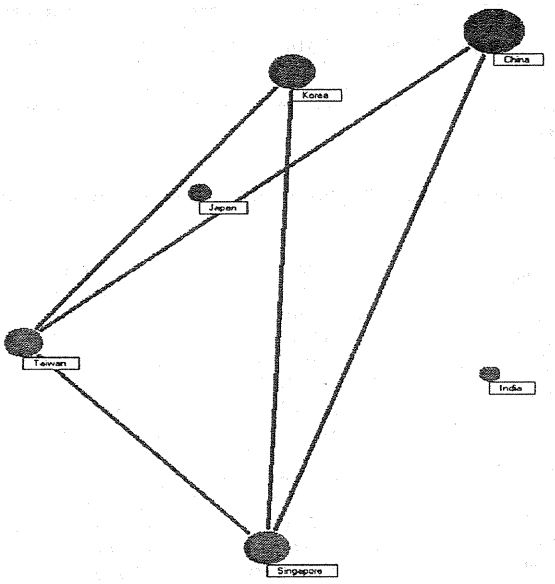

Fig. 2. Cross-correlations presenting countries' focus

Clustering and cross-correlation techniques help compare countries by measuring and visualizing the similarity of their focus. The presented map uses physical distance to symbolize the proximity or divergence of scientific focus, based on a computer-supported analysis of keywords, applied by article authors or Compendex librarians. Each article is associated with multiple keywords in Compendex, and VantagePoint identifies relevant keyword clusters to discover similarities in research interests. The size of a circle, symbolizing the respective country, indicates the overall volumes of articles written by authors with a particular national affiliation.

Lines linking specific countries symbolize statistically hypothesized relations between the analyzed objects (degrees of similarity). Tech mining methodology helps reveal hidden variables and relations in the analyzed dataset - for example, similar research interests of professors and firms from the same geographical area would not necessarily be a mere coincidence (Porter, Cunningham 2005: 156-157). This identification of hidden linkages is particularly important in the Asian context: in the domain of software-related research, there are hardly any proves of direct industry-academia cooperation, but researchers analyzing Japanese universities suggested that even though many schools do not have institutionalized cooperation programs with industrial companies, individual professors tend to work closely or to be affiliated with specific firms, and these informal cooperation patterns affect the focus of academic research, stimulating spillover-like technology transfers (Kodama, Branscomb 1999).

On the cross-correlations map, strong links between certain areas of research in Korea and Singapore suggest the existence of, or the potential for a closer cross-border research co-operation, as research teams from both countries seem to adopt similar approaches to certain problems. The co-operation could be particularly fruitful, if the research areas of both countries are relatively different (as indicated by the physical distance on the map), and therefore could complement each other thanks to the use of similar research orientations. At the same time, the lack of such a linkage between Japan and Korea, situated closely on the cross-correlations map, can be interpreted as the convergence of research interests, but the divergence of research approaches, making co-operation more difficult.

7. Applied software research

The further analysis involves the identification of specific research interests of the analyzed SSIs, with a particular focus on the applied research. There are underlying methodological problems with delineating the basic and applied research in many software-related contexts, as only some research topics could clearly be classified as basic or applied. The entire article set comprised of 39,640 specialist keywords, and Compendex does not have a standardized keyword thesaurus, so there are many overlaps between terms or even classification mistakes. Using the linkages between keywords, revealed by a PCA-based factor analysis, as well as additional literature concerning software development activities, the authors subsequently identified keywords denoting applied research and assigned them to 8 major research themes (term clusters). The selection was based on top 1767 keywords (each of them appearing in 10 or more articles), accounting altogether for 4.46% of all keywords in the dataset and referring to both basic and applied research.

The 8 analyzed research themes were:

- business intelligence (data and text mining),
- enterprise applications (ERP, CRM, SCM and transaction systems),
- application development,
- multimedia (video, image and sound processing),
- Internet & mobile (content development and publishing),
- embedded systems (software for electronic appliances),
- security,
- network services (telecommunications and corporate).

Applied software research comprises also of numerous other themes - the article subsets cannot be used to measure overall shares of the applied research in SSIs of target countries, and the following analysis only helps identify the relative importance of selected research themes. Figure 3 demonstrates the varying importance of individual applied research topics in specific countries.

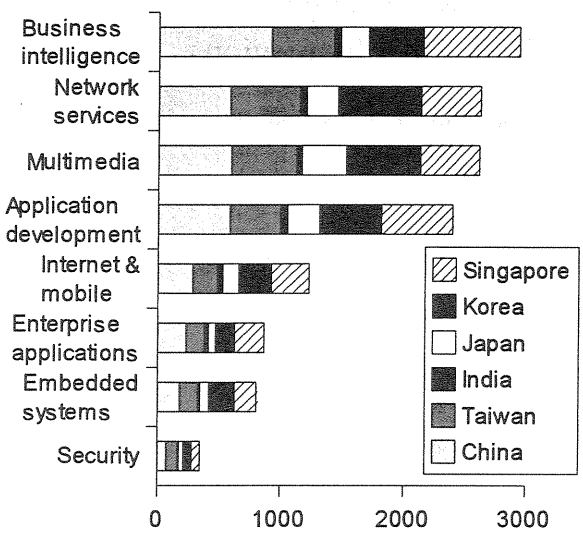

Fig. 3. Domains of applied software research

8. Conclusions

The research shows that software is regarded as an important research topics in all of the analyzed Asian countries, accounting for 20-35% of all technical articles. At the same time, the investigated science pole of the techno-economic network in the software industry does not seem directly related to commercial efforts of domestic companies. Even though software industry is science-based, important research findings remain usually confidential, not released to the public, but used by companies in internal product development processes.

Asian software firms have low shares in domestic markets, and similarly limited involvement in public research – as opposed to several international flagship companies, especially IBM and Microsoft. IBM remains the most scientifically active software company in Asia. Asian private sector is in general not interested in scientific research, accounting for up to approximately 5% of software articles in most countries, except for Japan (18.95%) and India (86.11%).

The research reveals also diverging research profiles of individual countries. The analyses indicate a predominance of basic research topics, such as generic algorithms, optimization or simulation techniques. The identified interests of specific countries in individual applied research themes do not necessarily correspond to the actual commercial specialization of domestic firms.

Most domestic software SSIs would probably not be able to become self-sufficient – the high-tech industry is already globalized, with multiple cross-border interdependencies and international specialization. Asian countries are actively involved in the global division of labor in the industry, with Taiwan's strength in semiconductors, China being a popular location for hardware manufacturing, and India emerging as the global leader in IT services. At the same time, local high-tech industries would benefit from more balanced structures, particularly from investments in software-related capabilities, which are flexible enough to not be endangered by the changes in exchange rates or demise of physical technologies.

The upcoming disruptive market changes in the following years may again turn the page in favor of Asian countries. The growing popularity of offshore software development, provision of software as a service, centralized Internet-based data processing and ubiquitous networking may lead to ground-breaking changes of the entire software market. The future move towards content, digital entertainment and multimedia is likely to change the market structure, linking the strategic advantage in software to content and electronic businesses, and opening up new global opportunities for the Asian market players.

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