Technological Forecasting & Social Change xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Technological Forecasting & Social Change

# Institutional support, innovation capabilities and exports: Evidence from the semiconductor industry in Taiwan

Rajah Rasiah [a,*], Rafat Beigpoor Shahrivar [a], Xiao-Shan Yap [b]

[a] Department of Development Studies, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b] Department of Environmental Social Sciences, Swiss Federal Institute of Aquatic Science and Technology, Switzerland

ARTICLE INFO

*Article history:*
Received 4 February 2014
Received in revised form 7 January 2016
Accepted 8 May 2016
Available online xxxx

*Keywords:*
Institutional support
Innovation capabilities
Exports
Semiconductor firms
Taiwan

ABSTRACT

This paper examines the relationship between host-site institutional support, innovation capabilities and exports using data from a survey of 50 Taiwan semiconductor firms. The major questions asked in the paper are whether host-site institutional support is important in stimulating firm-level innovation capability, and whether the latter is important in firms' exports. An evolutionary perspective was used to measure innovation capabilities using knowledge embodied in machinery, training, processes and products. The statistical results show that innovation capability is correlated with institutional support. In addition, the findings also indicate that innovation capabilities (IC) enjoy a positive relationship with exports. The control variable of size had a positive effect in innovation capabilities and in exports, while human capital was critical in exports. The supply of R&D grants, R&D engineers and scientists, and support from universities and R&D labs has been viewed by firms as important in supporting innovation capability and semiconductor exports.



## 1. Introduction

The importance of institutional development in stimulating innovation was researched extensively by Veblen (1915) and Nelson (2008). Lall and Teubal (1998) and Lall (1994) had discussed the industrialization experience of East Asian nations, which highlighted the importance of coordination between research and development (R&D), training, investment and product development for improved performance. Lundvall (1992) and Nelson (2008) emphasized that the embedding organizations and institutions actively advance the role of technologies in each industry.

The most important achievements concerning the technological catch up of Taiwan are attributed to selective interventions to stimulate learning and innovation, but particularly participation in R&D activities (Amsden and Chu, 2003; Fransman, 1985; Wade, 1990). Government-support agencies, such as the Industrial and Technical Research Institute (ITRI) and the National Applied Research Laboratories (NARL) have had a significant impact in developing Taiwan's scientific and innovation base by supporting R&D activities in the private sector and exploring new technologies (China yearbook, 2012). These initiatives are a result of the policies of the Taiwan government, which laid the foundations for turning Taiwan into a global center for semiconductor foundries.

Whereas the above anecdotal and interpretative evidence on the role of the state in stimulating innovation capabilities is obvious, this paper econometrically tests for the first time the relationship between host-site institutional support and firm-level technological in semiconductor firms in Taiwan to confirm the presence of strong correlation between the two. The use of Taiwan as a case is important as past works using this approach have focused only on countries still developing (e.g. Figueiredo, 2008; Peerally and Cantwell, 2012; Rasiah, 2004). In doing so we get to examine the empirical data with firms at the globe's technology frontier. The paper analyzes empirically the data collected from a survey of 50 semiconductor firms. Former employees of the Electronics Research and Service Organization (ERSO) carried out this survey in 2013. The survey used a stratified sampling procedure based on size and functional specialization – chip implant (including R&D), chip design, wafer fabrication and assembly and test. As the firms were guaranteed confidentiality of the data set, we are not able to discuss the issues by naming the firms. We did not use ownership because of the dominance of national firms in Taiwan. The cross-sectional analysis undertaken in this paper does not allow the direction of causation to be established statistically. However, given that the government started the ITRI labs in 1974 and the early major IC firms engaged in high value added activities were started by the government, one can safely assume intuitively that host-site institutional support has caused, if any, technological upgrading in Taiwanese firms.

The rest of the paper is organized as follows. Section 2 provides the justification for the study. Section 3 discusses the theoretical considerations. Section 4 presents the methodology and data.

* Corresponding author.
*E-mail addresses:* rajah@um.edu.my (R. Rasiah), beigpours@um.edu.my (R.B. Shahrivar), xiaoshan.yap@eawag.ch (X.-S. Yap).

http://dx.doi.org/10.1016/j.techfore.2016.05.015

Section 5 discusses the results and analysis. Section 6 finishes with the conclusions.

## 2. The semiconductor industry in Taiwan

Taiwan provides an excellent laboratory for the analysis of the role of host-site institutional support on the innovation capability of firms, and the latter's influence on exports in a high technology industry because of the successful movement of national firms to the technology frontier in the semiconductor industry. Taiwan's semiconductor industry began when General Instrument Microelectronics relocated low end operations for export in 1966. However, Taiwan's success in the industry really began when ITRI was founded in 1973, which marked government efforts to transform Taiwan's manufacturing from low to high value added activities. The establishment of the Electronics Research and Service Organization (ERSO) in 1974 heralded government efforts to upgrade Taiwan's semiconductor industry, which bore its first fruit with the establishment of United Microelectronics Company (UMC) in 1980 following the acquisition of Radio Company of America.

Between 1981 and 1990 period and various companies including IC design houses, such as, Taiwan Semiconductor Manufacturing Company (TSMC), Syntek and Weltrend were established, which acted as the springboard for the emergence of a cluster of designing, masking, fabrication and assembly firms. There over 180 semiconductor firms with a significant share of the global market in 1995. By 1999, over US$5 billion worth of semiconductors were produced in Taiwan, placing it as the fourth largest global producer ahead of industrial giants such as France and the United Kingdom.

The Taiwan government built a sophisticated high technology infrastructure at the Hsinchu Science Industrial Park (HSIP), which was modelled after California's Silicon Valley in 1978 by the National Science Council and government. It is located nearby Taiwan's best technical universities, Chiaotung, Tsinghua and ITRI. HSIP was formally opened in 1980 and hosted improved facilities including medical services, R&D matching funds tax benefits, low interest loans, educational centers, investment allowances, tariff exemptions and other incentives. Most of the private firms in Hsinchu attracted Chinese-Americans from top jobs in the U.S. and encouraged “reverse brain drain” as Taiwanese professionals from the U.S. found opportunities and assisted to set up the semiconductor industry in Taiwan. This was achieved by improved incentives, such as, tariff exemptions, educational centers, investment allowances, medical services, R&D matching funds tax benefits, low interest loans and other incentives. The Central Taiwan Science Park and the Southern Taiwan were developed after Hsinchu. Each year, the Industrial Development Bureau (IDB) and the MOEA's Department of Industrial Technology provided grants to upgrade technology for conducting R&D projects by academia and industry as well as development activities of critical-planning and forward-looking industrial technologies. The importance of the high technology infrastructure developed in Taiwan became important as in addition to facilities, ERSO conducted and shared the findings of its research through R&D alliances to assist Taiwanese firms upgrade to introduce best practices.

As Amsden and Chu (2003) and Tsai and Cheng (2006) had argued, semiconductor firms in Taiwan have reached the globe's technological frontier despite the specialization of firms in non-brand holding activities. Efforts to measure the influence of host-site institutions on technological capabilities and economic performance of semiconductor firms in Taiwan would then offer the opportunity to examine the experience of a global industry leader. The Taiwan example is unique in that firms specializing in R&D-led production are able to compete technologically despite lacking in brand holding capabilities. Despite fierce competition and the need to ramp up production quickly, manufacturers have also managed to exceed the Sturgeon (2002) framework of modular production to participate in frontier R&D activities.

## 3. Theoretical considerations

Innovation capabilities form the main concept of this paper, and the key relationships that will be examined in this paper are firm-level innovation capability (IC) and host-site institutional support (HIS), and IC and exports. The influence of the control variables of age, wages and size on the dependent variables is also examined. Ownership was dropped because national firms dominated both the sample and the population of semiconductor firms in Taiwan.

### *3.1. Innovation capabilities*

Schumpeter (1934) had already demonstrated the significance of innovation in driving growth when referring to ‘creative destruction.’ More specifically, Schumpeter (1934: 166) referred to innovations by entrepreneurs to include either marrying different types of knowledge or adapting existing stocks of knowledge to generate new processes, products and organizational structures that help lower costs and delivery times and increase flexibility and quality. Although Schumpeter (1934) had captured the rationale behind path extending innovation as he referred knowledge evolved from elaborate R&D labs as essential for stimulating cycles of innovation, the neoSchumpeterians' led by Nelson and Winter (1982) carried this discussion further by differentiating explicitly minor incremental innovation from major path extending creative destruction. Evolutionary economics models added further emphasis to the understanding of innovation by advancing the concept of systems of innovation and its composition as a constellation of economic agents (firms and institutions) and the relationships between them (see Freeman, 1987, 1989; Lundvall, 1992; Nelson and Winter, 1982). Nelson (2008) showed that the functioning and change in each system is uniquely different, non-linear and heterogeneous in nature. Because the semiconductor industry is a technology creator and one of the key propellants of universal innovations, the focus in the paper is on both types of innovation activities. To the neoSchumpeterians, Mark 1 systems refer to innovation activities that rely on adapting or using existing stocks of knowledge, while Mark 11 systems refer to the utilization of R&D to produce new stocks of knowledge (Malerba and Nelson, 2012). Indeed, not only that Taiwan is dominated by a number of firms that are among the top 20 semiconductor firms, its lead firm, TSMC, is the globe's frontier firm in logic chips.

In discussing capabilities, it is important to address the dynamic management capabilities advanced by Teece (2009). Amsden (1991) had argued that managerial characteristics are important in late industrializers as they help firms adapt and adopt technologies from industrialized nations. Chandler (1990, 1977) had argued that the managerial revolution facilitated successful organizational change by means of innovation to drive greater industrial growth and performance. Also, stocks of knowledge engineers and technicians (both the non-R&D and R&D personnel), and the processes and products they create are major contributors to innovation. Teece (2009) articulated the concept of dynamic capabilities by referring to skills, processes, routines, organizational structures, and disciplines that enable firms to build, employ, and orchestrate intangible assets relevant to satisfying customer needs, and which cannot be readily replicated by competitors. Using this logic one can see the need for firms to strengthen their managerial (including the components of personnel, production, accounting, engineering, marketing and entrepreneurial) capabilities.

While this is indeed a strategic dimension of capabilities that firms acquire or develop to compete, the focus of this paper is on innovation capabilities, which refers to the capabilities that generate incremental knowledge and new stocks of knowledge. Nevertheless, the innovation potential of management capabilities are captured in embodied personnel, techniques, routines, machinery, organizational and layout restructuring embodied in process technology, and product engineering, designing and marketing embodied in product technology.

Please cite this article as: Rasiah, R., et al., Institutional support, innovation capabilities and exports: Evidence from the semiconductor industry in Taiwan, Technol. Forecast. Soc. Change (2016), http://dx.doi.org/10.1016/j.techfore.2016.05.015