ABSTRACT

The extant literature on technological catch-up by scholars like Nelson, Winter, Amsden, Mathews and Cho has provided lucid accounts of the critical role of institutions. However, the successful catch-up stories of latecomers like Taiwan have not been easily replicated. This study developed three analytical frameworks to examine three research questions. Firstly, the research seeks to understand how technological transitions affect latecomers' catch-up strategies, and vice versa, in a technology-intensive manufacturing industry. Second, the research seeks to examine how latecomer resource acquisition strategies vary as the industry experiences structural change. Thirdly, the study aims to understand the mechanisms of how a firm could transform from a technology follower to a technology leader, and sustain its leading technological capabilities. The study uses Taiwan's integrated circuit industry as the empirical anchor of its in-depth case studies. Critical examples are also drawn from the experience of the integrated circuit industry in other countries.

To answer the first research question, the study explains the mechanisms behind the industry's transitional process after the emergence of the world's first contract manufacturer in wafer fabrication. The study found that the relationships among technological regimes, driving forces of upstream and downstream firms in the industry, choices of organizational boundaries, and network boundaries evolve through different points in time. The dynamic forces in the industry can collectively create feedback loops to technological regime. Technological transitions provide different conditions for latecomers to catch up or to leapfrog incumbents.

In addition, the thesis provides a six-dimensional framework to analyze the dynamic value systems that latecomers face, as the industry experiences structural change. Using this framework, the analysis shows how Taiwanese foundries deployed successful

resource acquisition strategies to catch up and lead the creation of frontier technologies despite remaining as contract manufacturers. Through the incorporation of resource-based view and open innovation concept, the findings show how latecomer firms can strategize their business model to move up the value chain as they progress from one dimension to the other.

Lastly, the findings show that a firm can skip or break away from internal path dependence through coevolutionary lock-ins with the industry to launch new technological paths to sustain its technological leadership. Through a virtuous circle of vision constructions, organizational endogenous strategies, and higher intensity of research and development, firms accumulate higher absorptive capacity for learning that is carried through to subsequent phases.

This study strengthens our understanding of technological transitions, which is fundamental to analyze innovation patterns of technology-intensive industries. Understanding the complex relationships between upstream and downstream firms and the industry's innovation patterns can help policymakers to identify industry segments that can be targeted for catch-up and to identify the types of business models that can be promoted. This study posits that the catch-up process in a technology-intensive industry like the integrated circuit industry requires innovative business models and strategic resource acquisitions as the industry progresses through different phases. Finally, this study provides managerial implications of organizational learning as the study analyzes firm-level endogenous strategies and coevolutionary lock-in with industry.

ABSTRAK

Sorotan kajian pengejaran teknologi oleh ilmuan seperti Nelson, Winter, Amsden, dan Mathews dan Cho telah memberi huraian meyakinkan terhadap peranan kritis institusi. Namun, cerita pengejaran yang berjaya pendatang lama seperti Taiwan tidak dituruti dengan mudah. Tinjauan ini membentukkan tiga kerangka analitik untuk mendekati tiga persoalan penyelidikan. Pertamanya, kajian ini cuba memahami bagaimana peralihan teknologi mempengaruhi strategi pengejaran pendatang lama dan yang sebaliknya di dalam sebuah industri pembuatan teknologi tinggi. Keduanya, kajian ini cuba meninjau bagaimana strategi pemgambilalihan sumber pendatang lama berbeza ketika ianya mengalami perubahan struktur. Ketiganya, kajian ini cuba mengetahui mekanisme firma yang boleh beralih daripada pengikut teknologi kepada peneraju teknologi, dan dapat mengekalkan keupayaan teknologinya. Kajian ini mengunakan industri litar kamilan Taiwan sebagai tiang utama penelitian terperinci kes. Contoh kritis juga diperolehi daripada industri litar kamilan di negara lain.

Untuk menjawab persoalan kajian pertama, tinjauan ini menjelaskan mekanisme dibelakang proses peralihan industri ini setelah munculnya pengilang fabrikasi wafer pertama di dunia. Tinjauan ini mendapati bahawa hubungan rejim teknologi, kuasa pengerak rantaian atasan dan bawahan firma dalam industri, pilihan sempadan organisasi dan sempadan jaringan berkembang melalui titik masa yang berlainan. Kuasa dinamik industri ini boleh secara bersama menghasilkan lengkuk maklumbalas kepada rejim teknologi. Peralihan teknologi memberi syarat-syarat berlainan demi mendokong pendatang lama untuk mengejar ataupun mendahului peneraju kini.

Tambahan pula, tesis ini mengutarakan suatu kerangka berdimensi enam untuk menganalisis sistem nilai dinamik yang di hadapi oleh pendatang lama, ketika industri mengalami perubahan struktur. Kerangka ini memunkinkan analisis yang menunjukkan

bagaimana faundri Taiwan melancarkan strategi berjaya pengambilalihan sumber untuk mengejar dan menerajui ciptaan teknologi tercanggih biarpun mereka kekal sebagai pengilang kontrak. Melalui penerapan firma perkilangan rantaian bawahan, kajian ini memperlihatkan bagaimana firma pendatang lama boleh merangka strategi model perniagaannya untuk menaiki rantaian nilai apabila mereka bergerak daripada satu dimensi kepada yang lain.

Akhirkata, penemuan memperlihatkan bahawa sesebuah firma boleh melangkau ataupun bercerai keluar dari jalan pergantungan dalaman melalui penguncian coevolusi dengan industri untuk melancarkan jalan teknologi baru demi mengekalkan kepimpinan teknologinya. Menerusi satu pusingan pembinaan visi berasaskan pembinasaan, strategi organisasi dalaman, dan keamatan penyelidikan dan pembangunan yang lebih tinggi, firma mengumpul keupayaan meresap untuk belajar yang lebih tinggi yang dibawa kepada fasa seterusnya.

Kajian ini mengukuhkan pemahaman kita terhadap peralihan teknologi, yang mengasaskan analisis pola inovasi industri yang berintensif teknologi. Pemahaman hubungan kompleks antara rantaian atasan dan bawahan firma dan pola inovasi industri boleh membantu pembentuk dasar untuk mengesan lapisan industri yang boleh disasarkan untuk pengejaran dan untuk mengesan model perniagaan yang boleh digalakkan. Kajian ini menekankan bahawa proses pengambilalihan sumber dalam sistem nilai yang berubah boleh dirancang secara teratur untuk mengalakkan pengejaran yang berjaya. Akhir sekali, kajian ini memberi implikasi ke pengurusan terhadap pembelajaran organisasi kerana ianya menganalisis strategi dalaman dan penguncian coevolusi di peringkat firma.

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All errors and shortcomings remain my own.

Yap Xiao Shan

Kuala Lumpur, Malaysia

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LIST OF ABBREVIATIONS

AMD	Advanced Micro Devices
ASE	Advanced Semiconductor Engineering
CEO	Chief Executive Officer
CoWoS	Chip-on-Wafer-on-Substrate
CMOS	Complementary metal–oxide–semiconductor
CNSE	College for Nanoscale and Science Engineering
CREST	Collaborative Research in Engineering, Science and Technology Center
EDA	Electronic Design Automation
EUV	Extreme Ultraviolet
ERSO	Electronics Research and Service Organization
GVC	Global Value Chain
IBM	International Business Machines
IC	Integrated Circuit
IDM	Integrated Device Manufacturer
IEK	Industrial Economics and Knowledge Center
IP	Intellectual Property
ITIS	Industrial Technology Information Services
ITRI	Industrial Technology Research Institute
ITRS	International Technology Roadmap for Semiconductors
JV	Joint Venture
LSI	Large Scale Integration
MIDA	Malaysian Investment Development Authority
MIMOS	Malaysian Institute of Microelectronic Systems
mm	Millimetre
MNC	Multinational Corporation
NEAC	National Economic Advisory Council
NCIA	Northern Corridor Implementation Authority
NCTU	National Chiao Tung University
nm	Nanometre
NMOS	N-type metal-oxide-semiconductor
OBM	Original Brand Manufacturer
OEM	Original Equipment Manufacturer
ODM	Original Design Manufacturer
OSAT	Outsourced Semiconductor Assembly and Test
PMOS	P-type metal-oxide-semiconductor
RCA	Radio Corporation of America
R&D	Research and Development
SERI	Samsung Economic Research Institute
SMIC	Semiconductor Manufacturing International Corporation
SoC	System-on-a-chip
STPI	Science and Technology Policy Research and Information Center
TAC	Technical Advisory Committee
TSMC	Taiwan Semiconductor Manufacturing Company
UDFM	Unified Design Manufacturing
UMC	United Microelectronics Corporation
UNIDO	United Nations Industrial Development Organization
USPTO	United States Patent and Trademark Office