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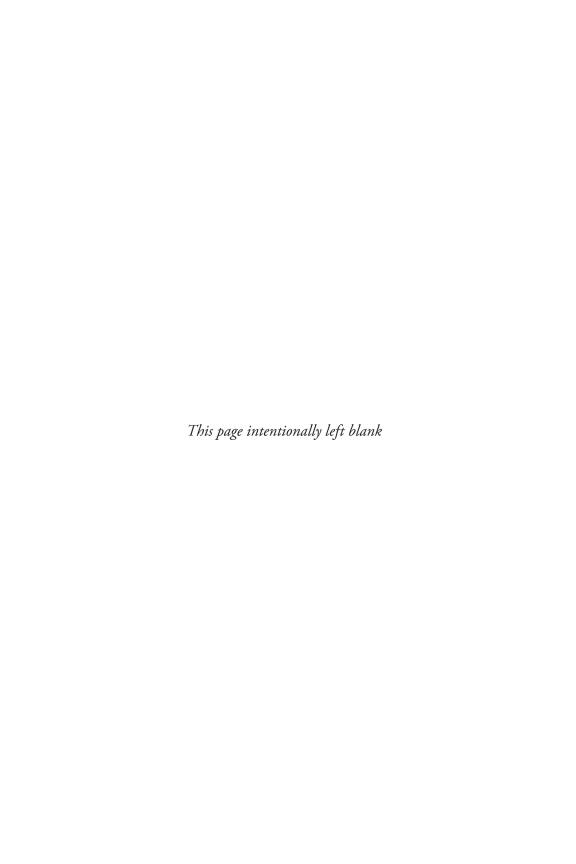
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# Interconnected Worlds

GLOBAL ELECTRONICS AND PRODUCTION NETWORKS IN EAST ASIA

Henry Wai-chung Yeung

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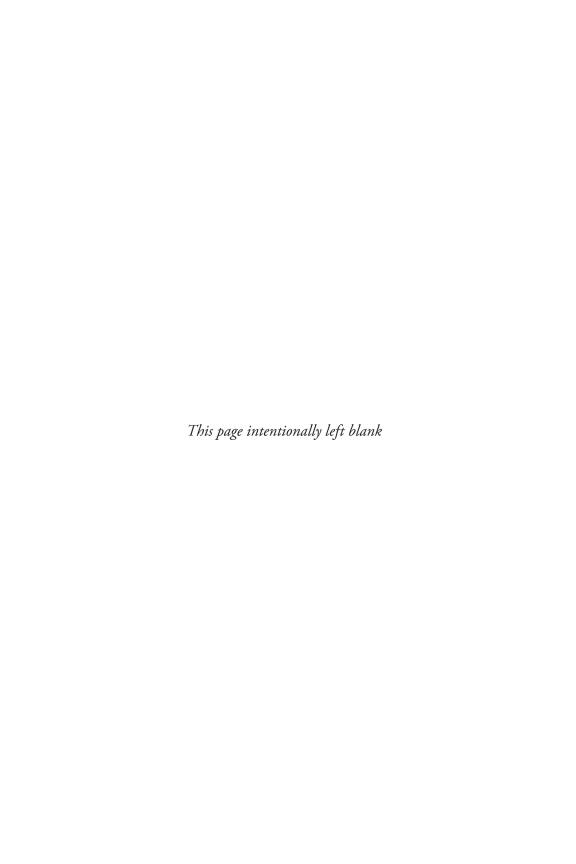
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For Yeung Ching Kwong, my late father and Peter Dicken, my mentor and fatherly figure



## Contents

	List of Illustrations	XI
	Preface	xvii
	Acknowledgments	xxiii
	Abbreviations	xxix
1	Worlds of Electronics: From National Innovations to Global Production	1
2	Changing Fortunes in Global Electronics: A Brief History	36
3	Global Production Networks: ATheory of Interconnected Worlds	83
4	Geographical Configurations of Global Electronics Centered in East Asia	123
5	Firm Strategies and Organizational Innovations in Production Networks	173
6	Explaining Production Networks: Causal Drivers and Competitive Dynamics	221

#### x CONTENTS

7	Whither (De-)Globalized Electronics Production	
	in the 2020s? Current Trajectories and Future Agendas	273
	Appendix A: IHS Markit/Informa Tech Custom Dataset, 2015 and 2018	307
	Appendix B: Methodology of the Study, 2016 –2021	309
	Appendix C: Full Tables	317
	Notes	333
	References	383
	Index	421

# **Detail Chapter contents** (my insertion)

1. Worlds of electronics: from national innovations to global production	1
A global shift in electronics?	3
Main arguments: coevolution from multinational worlds	13
to interconnected worlds of global electronics	
Multinational worlds of innovation and production till the late 1980s	13
Emerging worlds of interconnections: the 1990s and the 2000s	17
Interconnected worlds: the 2010s and beyond	26
Contributions and organization	29
2. Changing fortunes in global electronics: a brief history	36
Semiconductors	41
Personal computers	60
Mobile handsets	73
Towards the interconnected worlds of global electronics	80
3. Global production networks: a theory of interconnected worlds	83
Production networks: connecting multiple worlds through geographical configurations	86
Causal drivers: competitive dynamics and risk environments	93
Optimizing cost-capability ratios	94
Sustaining market development	98
Working with financial discipline	101
Managing risks	103
Firm strategies and organizational innovations	107
Intrafirm coordination	110
Interfirm control	112
Interfirm partnership	116
Extrafirm bargaining	118
Conclusion	121
4. Geographical configurations of global electronics centered in East Asia	123
Industrial-organizational geography of production networks	127
Semiconductors: all applications	128
Personal computers: notebooks and desktops	140
Mobile handsets: smartphones	149
Consumer electronics: televisions	153
Firm-level geographical configurations of global production networks	160
Corporate control: headquarters and regional headquarters	160
Manufacturing facilities	163
R&D, product development, and sales and marketing operations	168
Conclusion	171
5. Firm strategies and organizational innovations in production networks	173
Intrafirm coordination: internalization and outsourcing by lead firms	175
Insourcing vs. outsourcing in different product segments	176
Strategic considerations in firm-specific sourcing	191
"Customer is king": interfirm control and partnership relationships	196
Developing long-term relationships in industrial markets	197
Sharing risks with customers in semiconductors	202

Optimizing total cost of ownership through supply chain control	210
Serving as strategic partners through customization and dedicated facilities	213
Conclusion	217
6. Explaining production networks: causal drivers and competitive dynamics	221
Cost-capability ratios	224
Market imperative	233
Financial discipline	247
Risk mitigation	259
Conclusion	267
7. Whither (de)globalized electronics production in the 2020s? Current	273
trajectories and future agendas	
Key observations on globalized electronics production by the late 2010s	276
Implications for business and public policy in the postpandemic and post-Trump 2020s	281
Business strategy in the 2020s	282
Public policy in the 2020s	290
Future research agendas	298

# Illustrations

## **Tables**

1.1	World's top 10 lead firms in semiconductors, personal computers, mobile handsets, and televisions by revenue/shipment and market share, 2010, 2018, and 2020	6
1.2	Evolving national and institutional contexts of industry development in selected East Asian economies, 1980–2021	24
2.1	Changing fortunes in global electronics: Key trends and drivers, 1959–2021	42
2.2	World's top 15 semiconductor firms by revenue and market share, 1972–2020	46
2.3	World's top fabless semiconductor firms by revenue and market share, 2000–2020	52
2.4	World's top 10 semiconductor foundry providers by revenue and market share, 1992–2021	54
2.5	World's total semiconductor market revenue by product categories and industrial applications, 2008–2021	59
2.6	World's top OEM firms in computer systems by market share, 1971–1995	62
2.7	World's top 10 PC OEM firms by shipment and market share. 2001–2018	66

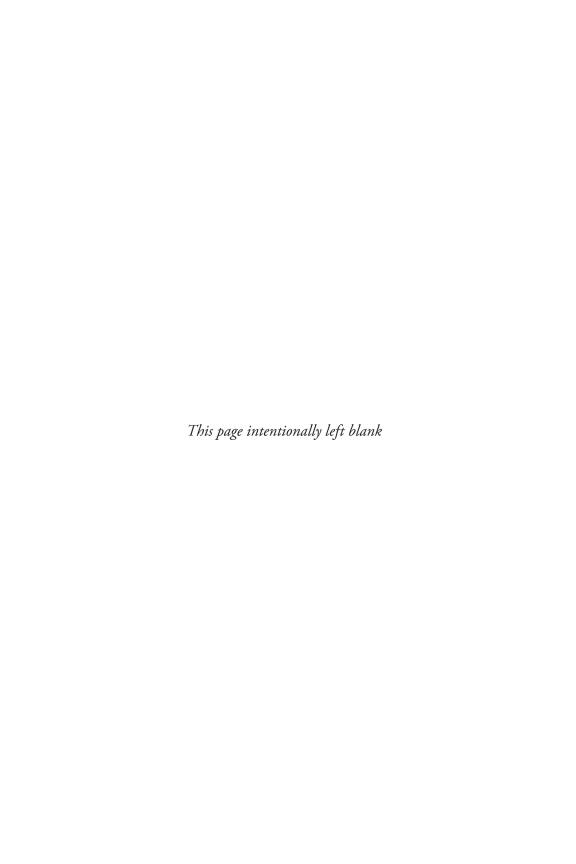
2.8	World's top 6 notebook ODMs from laiwan by	70
	shipment and market share, 1999–2018	70
2.9	World's top mobile handset OEM firms by shipment, market share, and outsourcing, 2008–2021	74
3.1	A matrix of cost-capability ratios in global production networks	96
3.2	Different risk forms in global production networks, 2010–2021	104
3.3	A typology of firms in global production networks	108
3.4	Firm-specific strategies and organizational innovations in global production networks	111
4.1	World's total semiconductor manufacturers by fab location, product applications, and capacity, 2000, 2010, and 2018	130
4.2	World's top 7 manufacturers of semiconductors for ICT products by fab location, process technology, customers, and capacity, 2015–2022	137
4.3	World's top 6 notebook PC OEM firms by shipments and location of final assembly, 2015 and 2018	144
4.4	World's top 6 desktop PC OEM firms by shipments and location of final assembly, 2015 and 2018	146
4.5	World's top 7 smartphone OEM firms by shipments and location of final assembly, 2015 and 2018	151
4.6	World's top 7TV OEM firms by shipments and location of final assembly, 2015 and 2018	155
4.7	World's top flat panel display manufacturers by fab location and area capacity, 2010, 2015, and 2018	157
4.8	Geographical configurations of production in key segments of global electronics during the 2010s	161
5.1	World's top 6 notebook PC OEM firms by procurement unit share of key component suppliers, 2015 and 2018	182
5.2	World's top 6 desktop PC OEM firms by procurement unit share of key component suppliers, 2015 and 2018	184

323

market share, and outsourcing, 2008–2021

C5	World's top manufacturers of semiconductors for ICT devices by fab location, process technology, customers, and capacity, 2015–2022	325
C6	World's top 6 notebook PC OEM firms by shipments and location of final assembly, 2015 and 2018	328
<b>C7</b>	World's top 7 smartphone OEM firms by shipments and location of final assembly, 2015 and 2018	330
Figu	ires	
2.1	Historical evolution of semiconductors and related electronics products, 1950–2020s	37
2.2	World GDP and merchandise exports of ICT hardware, 1989–2018	38
2.3	Global electronics revenues by major segments, 2018	40
3.1	Production networks: Integrating national worlds of electronics production	88
3.2	A theory of the causal mechanisms of global production networks	109
3.3	Organizational configurations of global production networks	115
4.1	World exports of ICT intermediate and final goods by major regions, 1989–2018	124
4.2	Global production networks of semiconductors and ICT end products	141
4.3	Worldwide manufacturing locations among 35 firms interviewed, 2017–18	164
4.4	Manufacturing locations in Asia among 35 firms interviewed, 2017–18	165
4.5	Worldwide R&D and sales and marketing locations among 41 firms interviewed, 2017–2018	168
5.1	Lead firms and their organization of semiconductor production networks	176
5.2	Mapping complex global production networks in semiconductors	179

5.3	OEM lead firms and their production networks in ICT end products	180
5.4	ODM 2.0: Strategic partnership with notebook PC OEM lead firms	214
6.1	Average monthly base salaries of manufacturing workers in Asia, 2010–2018	228
6.2	Capital expenditure to revenue ratios in the global semiconductor industry, 1990–2023	251



## Preface

The global electronics industry—"global electronics" in short—is certainly one of the most innovation-driven and technology-intensive sectors in the contemporary world economy. The COVID-19 pandemic in 2020 and 2021 made us all deeply aware of the critical importance of various electronic devices in supporting our remote work, learning, and daily life, and their intricate production across the world. Indeed, global electronics is characterized by organizationally fragmented and geographically dispersed production networks. Many devices and products in today's information and communications technology (ICT) sector are developed and manufactured in several macroregions and yet sold worldwide in all end markets. From semiconductor chips powering these devices to end products such as personal computers, smartphones, and televisions, complex transnational production and value-generating activities—coordinated by lead firms through their in-house facilities and/or outsourced partners around the world—have integrated diverse macroregions and national economies worldwide into what might be termed the "interconnected worlds" of global electronics.

Using the motif of "worlds" to describe the predominant model(s) of organizing electronics production, I argue that the current era of interconnected worlds started in the early 1990s when electronics production moved from the multinational worlds of innovation and production

systems dominated by domestic lead firms in the US, Western Europe, and Japan toward increasingly globalized and cross-macroregional worlds of electronics manufacturing centered in East Asia—a large region comprising Northeast Asia (e.g., China, Japan, South Korea, and Taiwan) and Southeast Asia (e.g., Indonesia, Malaysia, Singapore, and Vietnam). Over time and as more electronics manufacturing shifted toward key locations in East Asia, lead firms in the US, Western Europe, and Japan remained dominant in technological innovation and product development. By the 2010s, the book's main focus, this coevolution of production network complexity and interconnectedness led to a transformative shift in global electronics through which lead firms from South Korea, Taiwan, and China emerged as key players by integrating their home macroregion—East Asia—into these interconnected worlds of global electronics production comprising predominantly the US, East Asia, and Europe.

This monograph describes and explains this coevolution of globalized electronics production centered in East Asia during the 2010s. To date, a significant body of literature has been written about the historical development of the electronics industry in specific national economies. But very few of these scholarly studies have extended their analytical coverage to the 2010s, the decade in which East Asian economies and lead firms became dominant in electronics manufacturing. In theoretical terms, this work also differs substantively from most earlier academic studies of the electronics industry, as I do not focus on individual national economies and industrial transformation within them—I have previously published a monograph taking this international political economy approach to industrial transformation in East Asia (Strategic Coupling, Cornell University Press, 2016). Contributing to cutting-edge social science debates on global production networks and global value chains, my theoretical framing in this book is premised on a *network* approach that examines intrafirm and interfirm production activities across different national economies and subnational regions. Understanding the innovative organization of these firm-specific activities in the form of global production networks, in turn, allows us to appreciate better the evolving complexity of the interconnected worlds of global electronics. This conceptual approach extends my earlier theoretical work in Global Production Networks (with Neil Coe, Oxford University Press, 2015).

In a nutshell then, this work is meant to be a theory-driven analysis of electronics global production networks. My main goal is to develop the

idea of global production networks as innovative organizational platforms that connect different and yet interdependent "worlds" of production (e.g., from technological innovation in Silicon Valley to innovation and production in East Asia) and to demonstrate how the theory of global production networks, known as "GPN 2.0" in Coe and Yeung (2015), can be productively applied to explain these organizational dynamics in global electronics. The book thus offers an industrial-organizational analysis of where, how, and why electronics global production networks operate, from a social science perspective. It is neither a detailed history of the development of any of its four major industry segments (semiconductors, personal computers, mobile handsets, and consumer electronics/TVs), nor a country-level study of these segments and national competitiveness per se. In this sense, it certainly goes beyond an industry analysis or a country study.

The book's main contribution should ideally be read as one that illustrates empirically the geographical configurations ("where"), organizational strategies ("how"), and causal drivers ("why") of electronics global production networks throughout the 2010s. This most contemporary decade can be characterized by much more complex worlds of electronics production—coordinated by lead firms from the US, East Asia, and Western Europe, underpinned by significant US-origin technologies and knowhow, and yet co-constituted by East Asia-based manufacturing facilities and firm-specific capabilities. This main focus on unpacking and explaining the organizational dynamics of electronics production networks in East Asia also means that the book has much less to say about broader economic development issues, such as labor, industrial upgrading, environment, and the state (politics and policies). But my focus on the "network box" and its underlying causal dynamics will be relevant for those development scholars interested in the unequal and contentious consequences for localities and subnational regions that are "plugged" into or strategically coupled with these production networks.

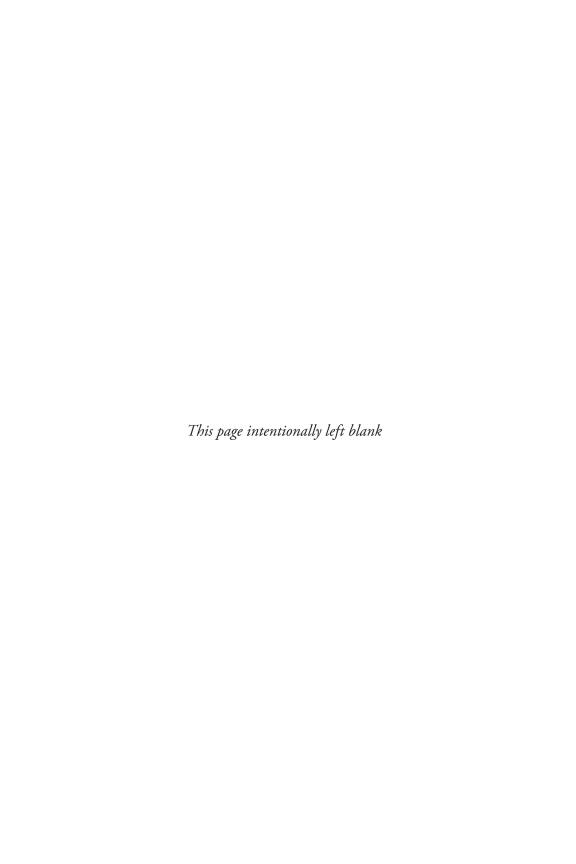
While adopting the global production networks theory, this book primarily takes on an *empirical focus* through its wide-ranging analysis of global electronics throughout the 2010s. This analysis is underpinned by substantial new empirical material based on a custom dataset and personal interviews. First, I have acquired from IHS Markit/Informa Tech comprehensive proprietary data at the firm and component levels in the four major segments of global electronics (covering up to 2019 Q3): semiconductors,

personal computers, mobile handsets, and consumer electronics (TVs). This custom material also includes highly detailed quantitative data on key electronics production networks in 2015 and 2018. Acknowledging semiconductors' distinctiveness as critical intermediate goods for ICT end products and their capital-intensive production networks, my empirical discussion in all chapters will follow the same logical order—starting with semiconductors before going into such end products as personal computers, mobile handsets, and TVs. Second, my qualitative dataset is derived from 64 interviews with senior executives of 44 lead firms in these four segments. All interviews were conducted between 2017 and 2018 in various locations in East Asia—Singapore, Taiwan, South Korea, and China. Through the in-depth analysis of this new and complementary material, the book's empirical chapters demonstrate where these electronics production networks operated throughout the 2010s, how they were organized in innovative ways, and why their pivot toward East Asia could be explained by several causal drivers and risk mitigation conceptualized in the GPN 2.0 theory.

The incredible and unexpected world events during the late 2019 to 2021 period, however, have added a major twist to my book's empirical analysis and potential use for future research, education, and policy. While I originally had the ongoing US-China trade conflicts in mind during the manuscript preparation starting in the second half of 2019, empirical events linked to the devastating COVID-19 pandemic since early 2020 have now clearly upended the world's expectations on the future of economic globalization and cross-border production networks in all industries and economic sectors. I believe there are very challenging policy implications and academic research agendas arising from these massive disruptions on a global scale during and after the pandemic. Where appropriate, I bring some of these current events and issues to the fore throughout the book and address them more fully in the concluding chapter. To some skeptical readers, though, it might be tempting to dismiss this book's empirical observations on the interconnected worlds of global electronics up to the late 2010s and their relevance for the postpandemic world economy in the 2020s. My sense is that much of the current discussion of global supply chain restructuring and national economic resilience in the public domain remains rather speculative and cursory due to the highly uncertain nature of these latest developments associated with the pandemic and ongoing geopolitical tensions (e.g., the US-China trade war since March 2018 and

its likely refashioning in the post-Trump era under the Biden administration). Solid and complete up-to-date empirical data are rare in these media reports and business analyses—they are simply very hard to collect due to the widespread travel and social restrictions in 2020 and 2021!

While I am able to update some empirical material to 2020/2021 based on data releases up to July 2021 (finalization of manuscript), I believe the book's comprehensive analysis of global electronics production networks up to the late 2010s can serve as a definitive benchmark for future academic and policy research into the dynamic transformations in global electronics and, perhaps, other manufacturing industries. My book can also be a standard baseline reference for post-2020 empirical studies of global economic change. Some of these studies can be found in the current research on "COVID-19: what's next in the world economy?" and the "deglobalization/decoupling" literature focusing on the reshoring of manufacturing back to advanced countries and the disintegration of China-centered production networks. Future empirical research in different academic disciplines can certainly take advantage of this book's novel empirical material on intra- and interfirm networks in all major segments of global electronics that "ends" at a relatively high point in the globalization of electronics production in 2018/2019—an all-time high in both shipment and markets of semiconductors and mobile handsets, and near peak in personal computers and televisions. I believe these future comparative studies will very likely appreciate how the interconnected worlds of global electronics in the technology, production, and market domains are rather enduring and cannot be easily replaced by the politically motivated decoupling and reshoring initiatives that might seem fashionable in today's highly contentious world.



## Acknowledgments

This book would not be possible without the extremely generous US\$4 million strategic grant (R109000183646) awarded by the National University of Singapore that enabled me, as principal investigator, and my co-PI and codirector Neil Coe to establish the Global Production Networks Centre (GPN@NUS) in October 2014. I am most grateful to our founding team members from departments of Geography (Karen Lai and Godfrey Yeung), Economics (Davin Chor, Albert Hu, and Jang-Sup Shin), Political Science (Soo Yeon Kim), and Sociology (Kurtuluş Gemici and Solee Shin) for their collective wisdom and efforts in making GPN@NUS a successful intellectual hub. Under the Centre's auspices and funding support, I acquired the costly custom dataset to the tune of several hundred thousand dollars and conducted the multilocation empirical research on global electronics that underpins this book's core analysis. In particular, I thank our Centre's former research assistants, Aloysius Chia and Lydia Jiang, for their excellent research support and arrangements for interviews in Singapore and other locations throughout East Asia. Carlo Inverardi-Ferri, postdoctoral fellow in the electronics group, also provided outstanding field support and independent work. Graduate student Tan Xuan Kai conducted additional database research. Many thanks also to Dione Ng, our outstanding Centre manager, for holding us together and making the Centre's activities—both academic and social—highly enjoyable

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All these bring me to the most critical part of this book's existence and its global production—my editors, reviewers, and other professionals who collectively made it happen. First and foremost, tremendous credit and thanks should go to my two editors—Martin Kenney and Steve Catalano.

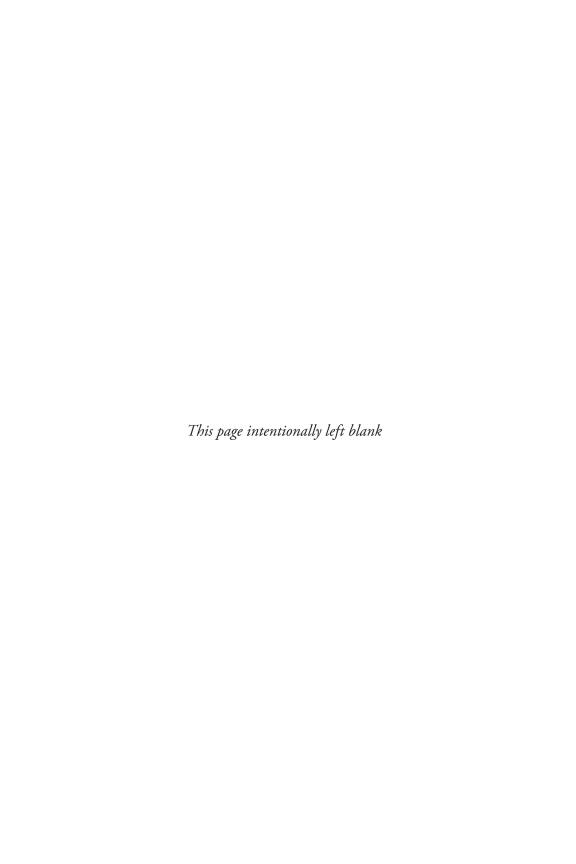
As editor of this Innovation and Technology in the World Economy Series, Martin's incredibly positive and swift response to my initial email in November 2019 made a world of difference! His continual support and insightful comments on the proposals, sample chapters, and full manuscripts throughout this project went well beyond his call of duty. At Stanford University Press, Steve was amazingly supportive and enthusiastic from day one. He was indeed an "author's editor," as I had read about him! I am very grateful for his expert advice and handling of the entire editorial process. Constructive comments and suggestions from two anonymous reviewers of my book proposal and three sample chapters and another three anonymous readers of the full manuscript in its two iterations are most appreciated. They certainly made the book much more streamlined and coherent. The usual disclaimer applies, though.

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Henry Wai-chung Yeung home, Singapore July 2021



## **Abbreviations**

APT—assembly, packaging, and testing

ASEAN—Association of Southeast Asian Nations

ASIC—application-specific integrated circuits

ASP—average selling price

AVAP—assigned vendor assigned price

Capex—capital expenditure

CMOS—complementary metal-oxide-semiconductor

CPU—central processing unit

DARPA—Defense Advanced Research Projects Agency

DRAM—dynamic random access memory

EDA—electronic design automation

EEC—European Economic Community

EMEA—Europe, the Middle East, and Africa

EMS—electronics manufacturing services

EPS—earnings per share

ERSO—Electronic Research Service Organization, Taiwan

ESPRIT—European Strategic Programme for Research and Development in Information Technology

ETRI-Electronic Technology Research Institute, South Korea

EUV—extreme ultraviolet lithography

FDI—foreign direct investment

GPN—global production network

GPU—graphics processing unit

GVC—global value chain

IC—integrated circuit

ICT—information and communications technology

IDM—integrated device manufacturing

ITRI—Industrial Technology Research Institute, Taiwan

JETRO—Japan External Trade Organization

JV—joint ventures

KIST—Korea Institute of Science and Technology

LCD—liquid crystal display

LED—light-emitting diode

M&A—mergers and acquisitions

MITI—Ministry of International Trade and Industry

NAICS—North American Industry Classification System

NAND—non-volatile memory

NIEs—newly industrialized economies

ODM—original design manufacturing

OEM—original equipment manufacturing

PC—personal computer

QLED—quantum light-emitting diode

R&D—research and development

RCEP—Regional Comprehensive Economic Partnership

ROE—return on equity

ROIC—return on invested capital

SCM—supply chain management

SEMATECH—Semiconductor Manufacturing Technology, US

SEMI—Semiconductor Equipment and Materials International

SIC—Standard Industrial Classification

SMIC—Semiconductor Manufacturing International Corporation

SoC—system-on-a-chip

TFT-LCD—thin film transistor-liquid crystal display

TNC—transnational corporation

Triad—East Asia, Western Europe, and North America

TSMC—Taiwan Semiconductor Manufacturing Company

UMC—United Microelectronics Corporation

USPTO—United States Patent and Trademark Office

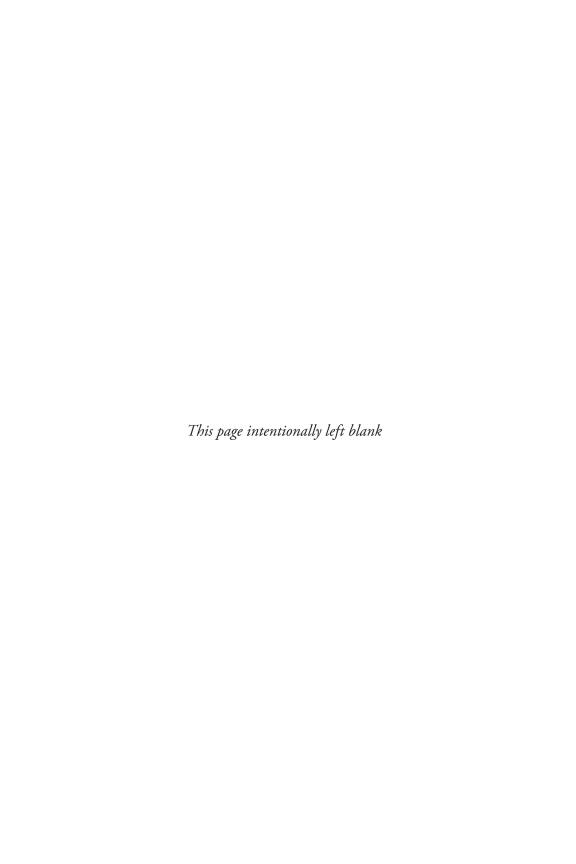
VAT—value added tax

VCR—video-cassette recorder

VMI—vendor managed inventories

WLAN—wireless local area network

WTO—World Trade Organization



# INTERCONNECTED WORLDS

