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BOOK REVIEW

Conflict and cooperation in the semiconductor industry: the global evolution of chip production Interconnected worlds: global electronics and production networks in East Asia, by Henry Wai-chung Yeung, Stanford, California, USA, Stanford University Press, Innovation and Technology in the World Economy Series, 2022, 480 pp., $90.00 (hardcover), ISBN 978-1503615298; $32.00 (paperback), ISBN 9781503632226; $31.99 (ebook), ISBN 9781503632233

Chip war: the fight for the world's most critical technology, by Chris Miller, New York, USA, Scribner, 2022, 464 pp., $30.00 (hardcover), ISBN 978-1982172008; $14.99 (eBook), ISBN13 9781982172022

Semiconductors, or what are commonly referred to as "chips", have become a central feature of global geopolitical concerns and tensions over the last few years. Their widespread use in a range of goods such as cars, consumer electronics, communication devices, and military equipment means that they are vital to many important human activities and endeavors. In addition, the perceived shortage in semiconductor supply during the Covid-19 pandemic has focused the minds of governments and companies alike in terms of their ability to source chips from faraway parts of the globe. The fragility of global supply chains has also been exacerbated by ongoing tensions in the relationship between the United States and China; tensions that have spilled over to other nations and their firms. It is, therefore, very timely that 2022 sees the publication of two books that shed detailed light on the changing nature of the global chip industry.

The first is "Interconnected Worlds: Global Electronics and Production Networks in East Asia" by Henry Wai-chung Yeung, and the second is "Chip War: The Fight for the World's Most Critical Technology" by Chris Miller. At the outset, it should be said that both are outstanding contributions and significantly advance our understanding of the huge complexities and challenges that exist within the global production networks and global political economy of contemporary high technology-based industries. Both authors have been able to craft an accessible narrative around what is undoubtedly a complex area of technology based on an intricate set of relationships and networks.

Yeung is an economic geographer and bases his book on a forensic analysis of the supply networks of the global electronics industry with a focus on the rapidly growing East Asian industry. Miller is a historian with a focus on technology and geopolitics and "Chip War" explores the global evolution of the semiconductor industry. In contrast to Yeung, Miller's perspective is the semiconductor industry in the United States, its evolution, and recent challenges. Both books are comprehensive, each having more than 400 pages. Yeung's book excels in analyzing a huge range of both quantitative and qualitative data that maps the various sectors that make up the electronics industry, while Miller pulls together archival data along with data from interviews with some of the industry's most important players in order to plot the decisions that led to today's global composition.

In "Interconnected Worlds" Yeung provides a co-evolutionary analysis of changes in the location and complexity of electronics production and associated networks. Across seven

meaty chapters the book applies the theoretical framework of Global Production Networks (GPNs), which Yeung has previously developed with his long time collaborator Neil Coe. This framework provides a lens through which to address both the inter-firm and intra-firm supply chain linkages that are a crucial feature of the electronics industries. Through the expert use of a large amount of unique data the book robustly indicates how the transformative shifts in these industries have been coupled with the rise of East Asian firms, especially in South Korea, Taiwan, and China.

In order to unpack the electronics sector as a whole, Yeung breaks it down into what he considers to be the major industry segments: semiconductors; personal computers; mobile handsets; and consumer electronics/TVs. He sees semiconductors as the logical starting point to examine the production process given that they form a key component of the products from the other three segments. As well as the wealth of quantitative data Yeung has gathered, he also draws on more than 60 interviews across 44 firms.

Chapter 1 sets the scene for the rest of the book and broadly argues that from the dawn of Silicon Valley until the 1980s the electronics industry was broadly structured and organized within "national worlds". Following this, the growth of East Asian firms cemented the fragmentation and dispersion of production across the globe, with the earlier national worlds morphing and re-configuring themselves within production networks that have become increasingly globalized. As an economic geographer, Yeung recognizes the fact that within this global network a small number of locations have become the major production sites and technological clusters, and in particular points to: Silicon Valley and Texas in North America; Cambridge, Eindhoven, and Munich in Europe; and Beijing, Shenzhen, Seoul, Suwon, Singapore, Taipei-Hsinchu, and Tokyo-Kyoto-Osaka in East Asia. In general, these tend to be the location for tech "giants" such as Apple, Samsung, TSMC as well as other larger companies involved in semiconductor production.

Although Yeung makes clear that he is not seeking to provide a detailed and full history of the electronics industry, Chapter 2 presents an excellent summary of the sector's growth, starting with the rise of Silicon Valley in California. It analyses the rise and fall of the major corporate players across the global electronics industry and relates these changes to both industrial transformations and shifts in the global political economy. Chapter 3 presents the book's underlying theoretical framework comprising an exploration of the GPN concept. Yeung uses this framework in later chapters to structure his reasoning for the growth that has occurred in East Asia. In Chapter 4 Yeung turns his focus to the empirics and maps out the geography of global production networks from both the perspective of the key electronic segments and in relation to the main corporate functions of particular locations. Chapter 5 extends this analysis to consider the range of business strategies adopted by various firms and the organizational innovations related to these strategies, with the findings indicating significant variety across the particular industrial segments.

Chapter 6 is the book's key one as Yeung seeks to interpret his findings in light of the GPN framework. At the heart of his argument is that the success of East Asian electronics firms is due to astute organizational innovations that have allowed them to gain a significant competitive advantage. His analysis suggests that there are four principal drivers associated with the nature of GPNs. The first is what he terms "optimizing cost-capability ratios" with East Asian firms, especially since the 2010s, improving their capability substantially while managing to retain cost competitiveness. Alongside cost issues, Yeung proposes a second driver whereby a continuous "capitalizing on the market imperative" developed the capability of firms to retain competitiveness through the massive growth in the end market for semiconductors.

The third driver is "managing financial discipline" with Yeung indicating that as lead companies have become listed on major stock markets there has been a necessity for

improved corporate governance and considerations of shareholder value. As part of the more earnest approach to financial discipline, outsourcing has become increasingly prevalent. This has again resulted in advantages for the East Asian market. The final driver is termed "mitigating risks" which concerns the growing requirement to adapt to more pronounced global environmental and regulatory constraints. In this case, Yeung indicates that the most organizationally innovative firms have mitigated the risks arising from these constraints by ensuring good governance within the production networks they participate.

Chapter 7 addresses challenges for both the corporate and public policy worlds as well as considering knowledge gaps that scholars may wish to address in the future. When reading the book it is noticeable that while much is said about organizational innovation, there is little mention of the dynamics through which the technological innovation occurs. In this final chapter, Yeung makes a full acknowledgment of this and it raises a number of questions in relation as to how global production networks may act as a conduit for technological innovation. More broadly, it brings to mind questions as to the nature of channels for open innovation within an industry where intellectual property has been considered to be of paramount importance.

In terms of the implications stemming from the book, Yeung's thoughts are balanced and measured. For the corporate world he suggests that firms must more fully grasp the fact that East Asia will only grow as a major end market, particularly China. He argues that success for all will rely on developing the capability of supply ecosystems and the forging of strategic partnerships at a global level. Finally, his public policy recommendations mainly reflect the way in which governments can help address the business implications he outlines. These consist of nurturing competitive advantage within key geographical locations, and taking an open pro-ecosystem approach rather protectionism or a return to what he considers to be doomed "national worlds".

Miller's structural approach in "Chip War" is more bite-sized than Yeung, outlining his analysis across 54 chapters. This results in a thoroughly readable and riveting account of the fortunes of the semiconductor industry from its postwar creation through to its growth phase and subsequent maturity. The book not only conveys the nature of the technology in an accessible way but also presents its development in an understandable way for nonspecialist readers. Through interviews with key actors, delving through a wealth of archival material, and coupling this with media coverage of the sector, Miller has delivered a clear narrative of the historical trajectory of the industry.

In contrast to Yeung, Miller's focus is very US-centric as he seeks to highlight the origins of the semiconductor industry and its subsequent growth through the prism of those at the vanguard of the technology. As such, this book also shows how the industry became increasingly globalized but does so from the perspective of the firms that created the technology and the associated geopolitical concerns of the US.

The reference to "war" in the title is particularly apt and is never far away from the action, whether it is the US military's demand for chips to operate their weapons of war or the constant battle between firms, and later nations, to compete for global dominance through innovation. As such, the book presents a broad cast list of "enemies," from the Soviet Union, with whom the US was locked into an arms race and space race in the early days of semiconductor development, to the Southeast Asian countries of Japan, Taiwan, and South Korea, who were concurrently both friends (geopolitics initially meant the US was keen to collaborate with these countries) and later rivals as their technologies threatened to overtake that of the US. Finally, there is China with which relationships are necessarily complex as it is simultaneously the biggest consumer of semiconductor chips but also is apparently hell bent on surpassing the dominance of US manufacturers by any means necessary.

As well as a broad cast of countries, Miller also focuses on the key people who enabled the development of the semiconductor as a technology and whose activities created the global supply chain that now produces these chips. Here, we see how the vision and activities of Jack Kilby (Texas Instruments), Robert Noyce (Fairchild), Gordon Moore (Fairchild/Intel), Jerry Sanders (AMD), Jack Simplot (a Utah potato farmer who invested in Micron), Akio Morita (Sony), Lee Byung-Chul (Samsung), Morris Chang (TI/TSMC), and Ren Zhengfei (Huawei) shaped the industry. While this approach leans on what historians have termed "great man theory", Miller also integrates the wider political and economic context into his narrative to explain the observed changes in the semiconductor industry.

One key strength of "Chip War" is that it provides an overview of the semiconductor triad, namely: the chips themselves; the machines utilized in their manufacture; and the products that use them. Therefore, the book focuses not only on the evolution of semiconductor technology itself but changes in the production processes and the tooling necessary to manufacture chips more reliably. Here, Miller illustrates how issues of scale drove the industry in two ways. First, the means by which to design and produce chips on an ever-larger scale in terms of numbers; and second, the process by which to produce on a smaller and smaller scale in term of their size.

In relation to chip size, Miller provides a fascinating insight into the practical implications of what became known as "Moore's Law," whereby the number of transistors on a chip doubled every two years leading to ever more powerful and efficient devices. Therefore, the production of semiconductors eventually reached a point whereby the transistors on the chips were so small that the width of a laser beam was actually too wide to manufacture them accurately. He recounts how engineers spent around a decade working out how to create lasers that utilize just one part of the spectrum, in this case ultraviolet light, in order to manufacture the latest generation of chips.

Miller's narrative also outlines how competition between many firms, and indeed countries, essentially realized Moore's Law and the creation of ever more sophisticated chips. Despite the fact that the USSR deployed a large spy network in an attempt to capture the secrets of chip manufacture, by the time any useful information was codified and understood by Soviet scientists the technology had been rendered obsolete by the relentless competition within the industry. However, Miller is careful to demonstrate that, while the evolution of the semiconductor industry could be interpreted as a triumph of competitive capitalism, the role of the US Government and universities was also of paramount importance to the development of the industry. First, the Pentagon's need for smaller devices to fit inside missiles and bombs provided funding for the development of early chips, while universities such as Stanford and MIT were instrumental in educating and training the industry's chief protagonists.

In sum, "Chip War" makes a clear contribution to the extant literature on semiconductors, complementing a wealth of other work in this field such as John Markoff's (2006) "What the Dormouse Said: How the Sixties Counterculture Shaped the Personal Computer Industry", Martin Kenney's (2000) edited volume "Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region" and Daniel Nenni and Paul McLellan's (2014) "Fabless: The Transformation of the Semiconductor Industry". Consequently, "Chip War" represents an important and complementary analysis and account of the evolution of the semiconductor sector.

In conclusion, both Miller and Yeung have made a significant contribution to our understanding of how the globe's most important technology-based industries are evolving. Semiconductors are at the center of the evolution as they represent the fundamental components that allow innovation to be undertaken. "Interconnected Worlds" is very much based on a firm-level examination, with the book clearly indicating the changes in corporate power and distribution in profit that have occurred across the world. In contrast to Yeung,

Miller takes a more human agency based approach highlighting the role of the key entrepreneurs and politicians that have most significantly impacted upon industrial change.

While Miller details the geopolitical issues, particularly perceived security problems, Yeung is more concerned with understanding the strategies that the most successful corporations have employed to improve or maintain their global competitive advantage. Of course, the key difference between the two books, which is apparent in their titles, is that while Yeung sees this competition being embedded within connectivity and interdependence, Miller is more concerned with competition, be it fair or foul, in relation to technological independence and sovereignty. Therefore, while reading only one of the books will provide considerable insights into global competition within high-technology industries, reading both books will provide a much wider canvass and perspective to consider what needs to be done if the world as a whole is to have access to the technologies that foster development, prosperity and well-being.

A clear message from the books is that while corporate strategies may generate jobs and profits, they may work against desired national outcomes. This is illustrated through the actions of China, Japan, and South Korea by investing heavily in semiconductor technology to attract more and more production to these locations, allowing device and consumer good manufacturers in North America and Europe to take advantage of lower manufacturing costs. However, the outcome of this has been the empowerment of these firms in Asian countries in their bid to compete with US firms. This has allowed them to capture larger market shares and positions in a global supply chain that may be efficient but has proved vulnerable to unforeseen events.

Policymakers and politicians in both the United States and Europe have recently reacted to the drift to the east by agreeing to provide their semiconductor industries with significant state investment to improve their own semiconductor manufacturing bases and supply chains. The implementation of so-called "CHIPS" acts in the both the US and Europe is based on an ethos of improving the sovereignty of production within each jurisdiction. However, Miller's and Yeung's analysis suggests that this may be far from straightforward. They both highlight that these supply chains are hugely complex both technologically and geographically, with high levels of interdependence existing across key corporations. It will be no easy task to untwine these relationships and, as Yeung alludes to, the benefits from such a decoupling are far from assured and potentially destructive. Furthermore, Miller illustrates the potential wastage of investment that appears to occur in an industry whereby billions of dollars have been sunk into new plants that have proved unsustainable. The moral of the story, therefore, is that policymakers intent on using taxpayers' money should take account of these tales.

Our own takeaway from both books is that the semiconductor industry is of such strategic importance to all parts of the world, and operates at such a high speed of change, there needs to be some form of global governance involving all stakeholders from the business and political worlds to build more trust-based relationships across relevant groups. Both Miller and Yeung point to elements of good practice that can be built upon, but the elephant in the room is that, at present, China and the United States are very unlikely to enter such relations if the other is at the table. Without such an agreement, the increasingly volatile environment that we are living in is likely to lead to a global high-technology industry with interconnections that may become increasingly more adversarial than the trust-based ones the industry requires.

References

Kenney, M., ed. 2000. *Understanding Silicon Valley: The Anatomy of an Entrepreneurial Region*. Stanford: Stanford University Press.

Markoff, J. 2006. *What the Dormouse Said: How the Sixties Counterculture Shaped the Personal Computer Industry*. New York: Penguin Books.

Nenni, D., and P. McLellan. 2014. *Fabless: The Transformation of the Semiconductor Industry*. A Semiwiki. com Project. https://semiwiki.com/books/Fabless%202019%20Version%20PDF.pdf.