AUTOMATING THE "WORKSHOP OF THE WORLD": EXPLAINING THE PROCESS OF INDUSTRIAL UPGRADING IN DONGGUAN, CHINA

by

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Abstract: The city of Dongguan in the Pearl River Delta region of southern China lies squarely in the region known as the "workshop of the world." In 2014, Dongguan's government launched its "Replacing Humans with Robots" policy, calling for manufacturers to upgrade their industrial production equipment. The policy implies a belief in 'technological determinism,' insofar as it champions the role of technology in helping firms better manage rising labor costs. This transformation of the manufacturing process from humans to robots is made possible, however, only if manufacturers are given sufficient incentives to engage in the transformation. This paper reveals manufacturers' reasons for industrial upgrading as they seek to achieve competitive advantage through improved productivity, enhanced product quality, and achieving greater brand recognition.

Keywords: Industrial Upgrading, Automation, Workshop of the World, China

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Introduction

In 2015, the launch of a 'workerless factory' in Dongguan made headlines in China's major newspapers.[1] On the shop floor of a mobile phone module manufacturer, conveyor belts were staffed not by dispirited and sweating workers, but by robots executing repetitive pre-programmed tasks. This 'futuristic' scenario, part of the Dongguan government's "Replacing Humans with Robots" policy,[2] showed that a single robotic arm could replace up to eight workers while reducing the product defect rate by more than 20%. The idea of the 'workerless factory' warrants academic attention because it represents an attempt on the part of China to improve its status in the global economy through industrial upgrading.

Over the last decade, business conditions in southern China have gradually become tougher. Since mid-2007, manufacturers in Guangdong have found themselves under increased pressure as a result of the combined effects of unfavorable central government policies that have penalized low-end, low-cost manufacturing: a regulation requiring exporters to pay a deposit equivalent to half the amount spent on importing almost two thousand raw materials;[3] cancellation or reduction of tax refunds on goods such as metals, plastics, textiles, and furniture;[4] a stronger Yuan; escalating prices for energy and raw materials; stringent pollution control requirements in Guangdong; the introduction of welfare benefits for employees; and the introduction of a labor law stipulating the benefits and

[1] Xinhua Net, "The Joy and Concerns Regarding the 'Replacing Humans with Robots': Investigation on the First 'Workerless Factory' in Dongguan, Guangdong." *Xinhua Net,* July 31, 2005, accessed March 19, 2017, http://news.xinhuanet.com/fortune/2015-07/13/c_1115909116.htm.

[2] The literal translation of this policy should be "Replacing Humans with Machines" (*jiqi huanren*), but we adopt the translation "Replacing Humans with Robots" because the installation of machines alone does not make a firm eligible for the Dongguan government subsidy. Rather, the firm has to demonstrate a degree of automation to qualify as a recipient of the subsidy.

[3] Ministry of Commerce of the People's Republic of China, "Public notice 22," April 5, 2008, accessed 10 December 2017, http://www.mofcom.gov.cn/aarticle/b/c/200804/20080405462357.html.

[4] Ministry of Commerce of the People's Republic of China, "Circular No.139," June 19, 2007, accessed December 10, 2017, http://www.mofcom.gov.cn/aarticle/b/e/200706/20070604800599.html&173433629=2827746338.

responsibilities of employers and employees, insurance coverage, and overtime pay.[5] The most damaging of these policies for manufacturers has been the introduction of a minimum wage, a policy applicable to the whole of Guangdong Province, where the minimum wage has risen by an average of 18.6% since March 1, 2011. To be sure, within Guangdong Province, minimum wages have been raised differentially. Shenzhen, for example, raised minimum pay by 20% to 1,320 Yuan as of April 1, 2011, and Dongguan raised the minimum wage by 19.6% to 1,100 Yuan as of March 1, 2011 (the second increase in 10 months).[6] As if these difficulties were not enough, as a result of the global financial crisis precipitated in Western economies, the period from 2008 onwards also witnessed a downturn in overseas export orders for goods manufactured in China, exerting still more pressure on Chinese manufacturers. Combined, these challenges have squeezed thousands of firms operating in Dongguan.

Against this backdrop of multidimensional challenges, the Dongguan government introduced its "Replacing Humans with Robots" (*jiqi huanren*) policy as a means of counteracting the effects of the toughening province-wide business conditions. Such a move was in line with the "Made in China 2025" plan announced in 2015 by China's Premier Li Keqiang to promote automated manufacturing. When introducing the "Made in China 2025" plan, Premier Li vowed that the government would address the desire to move up the innovation value-added chain within a decade through the deployment of 'intelligent manufacturing' backed by automated factories and big data to develop innovation-driven

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[5] China Labor Contract Law"China Legal Publicity," accessed December 21, 2015, http://www.legalinfo.gov.cn/misc/2007-07/02/content_650514.htm. See in particular Chapter 2, Clause 14 (on types of 'appropriate' contracts to be given to employees), Clauses 16 and 17 (on transparency of information between employers and employees), Clause 19 (on limits to probationary periods), Chapter 4, Clauses 46 and 47 (on employee severance pay), Chapter 6, Clauses 59 and 74 (6) (on commitment to social security benefit payments) and Clause 68 (on limits to working hours).

[6] See People's Government of Guangdong Province, "Notice on Adjustment of the Minimum Wage in our Province," accessed March 16, 2017, http://www.gd.lss.gov.cn/gdlss/zcfg/zxzcfg/t20110119_123706.htm and http://www.gd.lss.gov.cn/gdlss/zcfg/zxzcfg/t20100318_116025.htm.

growth to boost China's already rapidly expanding economy.[7] In this context, "intelligent manufacturing" is defined as the integration of communication technology and advanced manufacturing across product design, production, management, and service.[8]

This paper examines the rationale for industrial upgrading and the process by which the upgrading takes place. We seek to explore the following questions: Why do manufacturers choose to engage in industrial upgrading? How do they reconcile their rationales with their overall business goals? What are the implications of industrial upgrading for manufacturers?

In the remainder of this paper we first review the literature that has informed this research and to which this study contributes. Next, we briefly describe the study's methodology. The subsequent section investigates the context in which we conducted our research—Dongguan—and explains the Dongguan government's policy of "Replacing Humans with Robots." We then describe our findings in depth and analyze features of those findings. Finally, we conclude by discussing future research prospects.

Technological Change and Industrial Upgrading

Pioneers in the political economy of technology have revealed how advanced machinery has, rather than liberating workers, only further subjugated them. Harry Braverman in particular documented how the de-skilling of labor culminated in the 1960s as automation reinforced the hierarchical relationship between management and workers.

[7] Xinhua Net, "Joy and Concerns."
[8] For a full definition of 'intelligent manufacturing,' please refer to Ministry of Industry and Information Technology (MIIT), "Intelligent Manufacturing Development Plan (2016–2020)," accessed on November 4, 2017, http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757018/c5406111/content.html). China's manufacturing sector is however characterized by diverse sectors with varying production models, so there is no one-size-fits-all path to "intelligent manufacturing." See Boy Lüthje, Siqi Luo, and Hao Zhang, *Beyond the Iron Rice Bowl: Regimes of Production and Industrial Relations in China* (Frankfurt am Main and New York: Campus) for a study that finds that large SOEs and joint ventures typically add robots to existing advanced systems deployed in lean or modular production processes, while companies in labor-intensive, low-tech industries focus largely on using robots to conduct single operations.

Similarly, David Noble demonstrates how computerized numerical control (CNC) machines facilitated the programming of machine tools and allowed managers to replace unionized, skilled machinists with non-union, white-collar employees as a way to curb labor activism. [9]

This literature helps us conceptualize a critique of the notion of 'technological determinism' that assumes technological change is an autonomous and even liberating force that drives economic growth and social development.[10] Unlike Braverman, however, we do not view the technology introduced in the process of industrial upgrading as unproblematic and easily assimilated into the production process. Rather, we question the technology itself, including its meaning (as understood by those using the technology), the rationale for its introduction by managers or owners of manufacturing enterprises, and the multifaceted impacts that the technology has had on the manufacturing process. In part, we extend Morris-Suzuki's study to explore the role played by labor in accepting and using technology that is meant to replace people in the manufacturing process.[11] We also build on the work of Eduardo Sartelli and Marina Kabat to show gaps and disruptions in the uneven and messy path(s) along which industrial upgrading occurs.[12] In this way we articulate the role of users of the technology and their interactions with the newly introduced machines on factory floors.

The existing body of literature on industrial upgrading allows us to conduct a more nuanced analysis in this research to investigate manufacturers' rationale for engaging in

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[9] See Harry Braverman, *Labor and Monopoly Capital: The Degradation of Work in the Twentieth Century* (New York: Monthly Review Press,1988 [1974]); David F. Noble, "Social Choice in Machine Design: The Case of Automatically Controlled Machine Tools, and a Challenge for Labor," *Politics and Society* Vol. 8, Nos. 3–4 (1979): 313–347; and *Forces of Production: A Social History of Industrial Production* (New York: Oxford University Press 1984). See also Tessa Morris-Suzuki, *Beyond Computopia: Information, Automation and Democracy in Japan* (New York: Routledge, 1988).

[10] See Jan Cherlet, "Epistemic and Technological Determinism in Development Aid," *Science, Technology, & Human Values* 39, no. 6 (2014): 773–794; Sally Wyatt, "Technological Determinism is Dead; Long Live Technological Determinism," in *The Handbook of Science and Technology Studies*, ed. Edward J. Hackett, Olga Amsterdamska, Michael Lynch, and Judy Wajcman, 65–180 (London, England: MIT Press, 2008).

[11] See Morris-Suzuki, *Beyond Computopia*.

[12] Eduardo Sartelli and Marina Kabat, "Where did Braverman Go Wrong? A Marxist Response to the Politicist Critiques," *Cadernos EBAPE.BR* 12, no. 4 (2014): 829–50.

upgrading as well as some of the challenges they encounter during the process. Gary Gereffi defines the broader concept of industrial upgrading as "a process of improving the ability of a firm or an economy to move to more profitable and/or technologically sophisticated capital and skill-intensive economic niches."[13] Chun Yang shows how prevailing institutions that are conducive to export-oriented processing in the Pearl River Delta have evolved as obstacles to the on-going restructuring, particularly the market reorientation from export to domestic sales.[14] Stacey Frederick and Gareffi employ a global value chain approach to analyze the upgrading trajectories of leading apparel exporters.[15] They show how Chinese apparel suppliers have benefited (in terms of expanding global market share) over the course of these upgrading trajectories as a result of growing apparel demand in Asia as well as regionally integrated production networks.

In the literature on industrial upgrading, John Humphry and Hubert Schmitz's 2002 study stands out in particular insofar as it unpacks the broad and rather general notion of 'industrial upgrading' into processes of several types, and in so doing it offers us a viable theoretical framework for this study.[16] Humphrey and Schmitz inquired into the scope of local upgrading strategies wherein producers operate in global chains. Employing a global value chain approach (à la Frederick and Gereffi), they argue that the success of local-level upgrading efforts are impacted by how clusters are inserted into global value chains.

In particular, Humphrey and Schmitz differentiate four types of industrial upgrading. *Process* upgrading involves improving production or machinery by reorganizing the

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[13] Gary Gereffi, "International Trade and Industrial Upgrading in the Apparel Commodity Chain," *Journal of International Economics* 48 (1999): 51 –2.
[14] Chun Yang, "Restructuring the Export-oriented Industrialization in the Pearl River Delta, China: Institutional Evolution and Emerging Tension," *Applied Geography* 32 (2012): 143–157.
[15] Stacey Frederick and Gary Gereffi, "Upgrading and Restructuring in the Global Apparel Value Chain: Why China and Asia are Outperforming Mexico and Central America," *International Journal of Technological Learning, Innovation and Development* 4, nos. 1/2/3 (2011): 67–95.
[16] John Humphrey, and Hubert Schmitz, "How Does Insertion in Global Value Chains Affect Upgrading in Industrial Clusters?" *Regional Studies* 36, no. 9 (2002): 1017–1027. Note that some observers reserve the phrase "industrial upgrading" for the process of moving up the value chain by shifting product offerings, whereas Humphrey and Schmitz give the phrase wider application, referring also to processes that some would call *production* upgrading.

production system so as to produce a greater volume of output. Such upgrading deploys technology to enhance production efficiency (i.e., produce more with fewer inputs). *Product* upgrading involves moving into more sophisticated product lines (i.e., higher-grade products). Whether moving into more sophisticated products line is or is not successful is determined based on the unit values of the new products created through the upgrading process. *Functional* upgrading involves advances in new functions such as design, marketing, and branding.[17] Such upgrading is often associated with a move up a product's value chain such that a manufacturer captures a greater share of the overall profits brought by the product. Finally, *inter-sectoral* upgrading occurs when firms move into entirely new industrial sectors or chains (for instance, if knowledge acquired in producing televisions is used to make screens for tablets and other computer equipment). This schema is also echoed by Carlo Pietrobelli and Roberta Rabellotti, who argue that supplier firms often find it easier to accomplish process and product upgrading as compared with functional and inter-sectoral upgrading, as the latter two types of upgrading tend to threaten the hierarchical control of lead firms.[18]

As the manufacturing sector in China has only relatively recently begun making the transition from a labor-intensive model to a technology-savvy form of production, few studies on industrial automation in China have appeared in then literature. Among some of the pioneering works, Florian Butollo investigates the recent transformation of the textile and garment and LED lighting industries in the Pearl River Delta. He found that manufacturers in the LED lighting industry successfully achieved functional upgrading towards brand manufacturing, helping the industry become a 'Strategic Emerging Industry (SEI)' supported by the provincial government. Butollo's research focused mainly on understanding the

[17] Humphrey and Schmitz, "Insertion," 1020.
[18] Carlo Pietrobelli, and Roberta Rabellotti, *Upgrading to Compete: SMEs, Clusters and Value Chains in Latin America* (Cambridge, MA: Harvard University Press, 2007); and "Global Value Chains Meet Innovation Systems: Are There Learning Opportunities for Developing Countries?" *World Development* 39, no. 7 (2011): 1261–1269.

linkage between industrial upgrading and "social upgrading," a threat that undermines the rebalancing of the economy. Furthermore, the sectors he studied had made only limited use of automation and he did not prioritize seeking to understand firms' rationales for (or dilemmas faced when engaging in) industrial upgrading.[19]

Recently, Butollo and Boy Lüthje have begun exploring the automation processes utilized by Chinese manufacturers. The two cases they present are, however, flagship enterprises with successful brand names.[20] Such enterprises, as well as state-owned enterprises (SOEs), are the most common recipients of generous government subsidies as well as targets for other forms of government support of industrial upgrading.[21] This leaves unexplored the more prevalent organizational form—and arguably the form that needs more government support as well as academic study—of small and medium-sized enterprises (SMEs). As such, a similar level of attention needs to be paid to the entire landscape of firms—both large (SOEs) as well as smaller (SMEs)—to best understand the dynamics of the industrial upgrading process in China. Our study is one of a few to focus on SMEs, which have not hitherto (i.e., prior to the Dongguan government's implementation of its "Replacing Humans with Robots" policy) received as much government support in terms of investment in R&D activities. Their experience will provide a better 'litmus test' of the likelihood that Premier Li's "Made in China 2025" plan can in fact become a reality.

By distinguishing between types of upgrading we are able to create a useful theoretical apparatus for structuring the analysis in this paper. As we show, we find through

[19] Florian Butollo, *The End of Cheap Labour? Industrial Transformation and "Social Upgrading" in China* (Frankfurt and New York: Campus, 2014).

[20] Florian Butollo and Boy Lüthje, "'Made in China 2025': Intelligent Manufacturing and Work," in *The New Digital Workplace: How New Technologies Revolutionise Work*, eds. Kendra Briken, Shiona Chillas, Martin Krzywdzinski, and Abigail Marks, 42–61 (Houndsmills, Basingstoke, UK: Palgrave, 2017).

[21] Philipp Boeing, "The Allocation and Effectiveness of China's R&D Subsidies – Evidence from Listed Firms," *Research Policy* 45, no. 9 (2016): 1774–1789; Douglas B. Fuller, *Paper Tigers, Hidden Dragons: Firms and the Political Economy of China's Technological Development* (New York: Oxford University Press, 2016); Anthony Howell, "Picking 'Winners' in China: Do Subsidies Matter for Indigenous Innovation and Firm Productivity?" *China Economic Review* 44 (July 2017): 154–65.

our empirical research that manufacturers have engaged in three of the four types of industrial upgrading in Dongguan—product, process, and functional upgrading.

For our research question, which asks why manufacturers engage in industrial upgrading and seeks to reveal the process by which that industrial upgrading occurs, we draw analytical concepts from the extant literature that differentiate various types of upgrades, namely process, product, functional, and inter-sectoral. We use these key analytical concepts to structure our empirical research as we seek to tease out from manufacturers their motivations for engaging in industrial upgrading and for choosing a specific form of upgrading.

As the last section of the above review makes clear, while there exists a fairly longstanding stream of literature on industrial upgrading, the focus has been predominantly on empirically foregrounding labor/labor relations, or conceptually employing the global value chain approach to organize the analysis. In our research, we adopt the manufacturers' perspective to try to uncover the rationales for as well as the processes involved in industrial upgrading.

Methodology

We deployed a grounded approach in our study of the process of industrial upgrading among Chinese manufacturers. We conducted five months of intensive fieldwork between September 2015 and January 2016. During this period, we utilized participant-observation and conducted interviews with managers of eight robot-user firms (Table 1) as well as four robot-supplier firms. Each of these firms' owners is a PRC national.

The eight user-firm factories, operating in the electronics and information technology (IT), toys and stationery, furniture, and electrical machinery and equipment manufacturing industries, all adopted automation machinery. Four of the eight received Dongguan government subsidies under the “Replacing Humans with Robots” program. Although the eight firms span a diverse range of industries, they are comparable insofar as are all based in Dongguan—a city that has arguably suffered the most damage from the tougher business conditions experienced by manufacturers in the Pearl River Delta, but has also been trying the hardest among its counterparts in the PRD to extricate itself from the downward turn in manufacturing by using policy instruments to encourage manufactures to engage in industrial upgrading. To that end, our cases share a common characteristic: all face a stark decision that seems to require either embracing industrial upgrading or risking extinction from their respective industries.

In addition, we conducted 63 interviews with the following important stakeholders: policymakers and government officials in Dongguan, workers, labor-assisting non-governmental organization staff and volunteers, factory owners, *New York Times* journalists who have covered this issue,[22] managers, and academics. We also interviewed workers: some working in factories where no automation was introduced but where the owners had discussed implementing automation, some working in factories where automated machinery was introduced (after which they had kept their jobs), and some who had been laid off as a direct result of the introduction of automation by their previous employers.

We also participated in numerous informal but closely related interactions at robot-manufacturer conferences, robot-user conferences, and casual conversations with some of the interviewees outside of ‘formal’ settings (while walking home after an interview was completed, on the phone for follow-up conversations, etc.). During the participant-observation phase, we video-recorded some parts of certain manufacturing processes (where possible), and audio-recorded interviews with owners/managers.

Johan M. Kessell and Taige Jensen, “Cheaper Robots, Fewer Workers: Technology|Robotica Episode 1,” *New York* Times, April 24, 2015, accessed March 19, 2017, http://nyti.ms/1JCgraD.

The four industries (electronics and IT, toys and stationery, furniture, and electrical machinery and equipment manufacturing) were chosen as sample firms because each of these industries is part of a broader set of nine pillar industries, as classified by the Dongguan government. In particular, in the "Replacing Humans with Robots" plan, two industries, 'electronics and IT' and 'electrical machinery and equipment manufacturing,' were the two that received the largest amounts in government subsidies,[23] further reinforcing our desire to sample firms in these two industries.

Based on our overarching research question regarding why manufacturers engage in industrial upgrading and how they do so, we divided our interview questions into two broad categories. The first category was focused on exploring the necessity of or incentives for engaging in industrial upgrading. In other words, what factors persuade manufacturers to go down the path of industrial upgrading rather than maintaining the status quo (being heavily reliant on workers)? Here, we further categorized our questions according to our theoretical framework based on four broad types of upgrading: product, process, function, and cross-sectoral. We hoped to pinpoint specifically whether a manufacturer's reasons for engaging in industrial upgrading fell into one of the four types. In the second area of questioning, we attempted to probe deeper into the implications of industrial upgrading: what happens—to the production process, to the company's profitability, to the workers—once an industrial upgrade occurs?

Dongguan: Recent Historical Trajectory of Industrialization and Policies for Industrial Upgrading

[23] Interview with representative of The Economic and Information Bureau of Dongguan, January 26, 2016.

Dongguan, located in the Pearl River Delta, hosts over 80,000 manufacturers in a 2,460 km^2 area.[24] In 2014, the city (a former county) had a population of 8.3 million, divided between 1.9 million permanent residents with urban *hukou* (household registrations) and 6.4 million rural migrants, most of whom were employed in factories.[25]

In Dongguan, the electronics and IT industry (including communication equipment) boomed from the mid-1990s onwards when Taiwanese contract manufacturing companies relocated their production clusters to Dongguan in response to rising labor costs in Taiwan and dwindling orders from the U.S. market. The electronics and communication equipment manufacturing industry became the largest industrial segment, registering a production value of 23.8 billion yuan for a 40% share, employing the largest portion of the labor force, comprising a fifth of the total labor force.[26] Although the city had already become China's largest personal computer (PC) production base by 2004, core components still needed to be imported.[27]

The prevailing production model, which involved producing parts and equipment that might be marketed by other, usually branded, manufacturers (also known as original equipment manufacturers, or OEMs), might have helped factory owners in Dongguan accrue profits quickly and easily, but it was also a volatile model, rendering firms highly sensitive to changes in global demand and the whims of the brand names that control the ultimate sales and marketing of products. The imposition of tougher business conditions from 2007 onwards ruthlessly exposed this fragility and wreaked havoc on the local economy, resulting

[24] Neil Gouch, "China's Fading Factories Weigh on an Already Slowing Economy," *New York Times*, January 19, 2016, accessed March 19, 2017, https://www.nytimes.com/2016/01/20/business/international/china-economy-slowdown.html?_r=0.
[25] Dongguan Statistical Bureau, "Dongguan Statistical Yearbook," (n.d.), accessed March 19, 2017, http://tjj.dg.gov.cn/website/web2/art_list.jsp?columnId=10000.
[26] Y. Wang, Y. Ma, and X. Yan, 2002. "Dongguan hangye tezheng fenxi yu zhanwang (An Analysis of and Outlook on the Industry Features of Dongguan)," *Tropical Geography* 22, no. 3 (2002): 199–203.
[27] M. Wang and W. Li, "Discussion on Sustainable Development for the Electronics and Information Industry in the Pearl River Delta," *Nanfang Economy* 1 (2004): 71–74.

in negative GDP growth in the first quarter of 2008 (the first quarter of negative growth in Dongguan's most recent 30-year history of industrialization).

It was against this backdrop that the Dongguan government rushed to implement its "Replacing Humans with Robots" policy, outlining the government's determination to salvage its economy by turning the workshop of the world into a base of intelligent manufacturing through industrial upgrading. The resolution, entitled "Promotion Plan for 'Replacing Humans with Robots' for Dongguan Enterprises 2014–2016)" (*Dongguan shi tuidong qiye 'jiqi huanren' xingdong jihua* 2014–2016), was passed in August 2014. The policy emphasized the importance of "pushing forwarding technological dividend in place of demographic dividend" (*tuidong jishu hongli tidai renkou hongli*).[28] In three years' time, the plan stated, the government would allocate an annual fund of 200 million yuan to reimburse firms that invested over 1 million yuan in industrial upgrading for 10–15 percent of the equipment procurement expenses.[29] The vice-mayor of Dongguan vowed to increase Dongguan's robot intensity (i.e. the number of robots as a ratio over the number of workers) by 2020 and even boost the city's own robot and automation equipment manufacturing industry.[30]

The "Replacing Humans with Robots" policy comprises two parts: the application of automatic machinery (*jiqi*) and the replacement of human labor (*huanren*). To address the first issue, an applicant is required to describe the technical specificities of the equipment involved, including the source of the technology, the technical principles, the method of application, and the state of the art. In our interviews with the government official

[28] Dongguan Municipal Government, "Announcement on Circulating the 'Promotion Plan on "Replacing Humans with Robots" for Dongguan Enterprises (2014–2016),'" August 4, 2014, accessed March 19, 2017, http://wnd.dg.gov.cn/publicfiles//business/htmlfiles/wnd/s42345/201507/902878.htm.
[29] Dongguan Municipal Government, "Administrative Measures on 'Replacing Humans with Robots' Specialized Funds," August 14, 2014, accessed March 19, 2017, http://www.dg.gov.cn/007330010/0202/201610/3a81940f182b450a91089f9dea0e5e1e.shtml.
[30] C. Pang and Y. Zheng, "Dongguan shishi 'jiqiren zhizao' jihua (The Plan for 'Intelligent Manufacturing Driven by Robots' Is Implemented in Dongguan)," *Economic Daily*, January 29, 2016, 10, accessed March 19, 2017, http://paper.ce.cn/jjrb/html/2016-01/29/content_290864.htm.

responsible for administering this scheme, he told us that the funding recipients for the year 2014 were divided between 95% (semi-) automatic equipment users and 5% industrial robot appliers. Simple mechanization by itself does not, however, make a factory eligible for the subsidy. Rather, there must be a clear demonstration of compliance with the second part of the policy, "replacing humans."

The application form requires information on the working steps and production procedures involved in the automation process, asking for information on "direct displacement" of workers before and after automation or "indirect displacement," estimated labor savings for new firms. Since the overall goal of the plan encompassed "workforce reduction, productivity increase, quality improvement, and work safety protection (*jianyuan, zengxiao, tizhi, bao anquan*)," firms were also required to report other relevant performance data.[31]

By January 2017, more than two years after its implementation, it was reported that the policy plan had already subsidized 2,303 manufacturers for 66,711 sets of equipment with total firm investment amounting to 33.5 billion yuan. This helped increase average productivity by 2.1 times and raised the product pass rate from 87.4% to 92.2%. Significantly, these investments helped reduce the workforce by 190,000 workers (already far exceeding the estimated labor shortage of 100,000 reported in 2015).[32]

Can industrial upgrading help firms overcome the tougher business conditions and, more importantly, how does the process of industrial upgrading actually occur? In seeking to answer these questions, we next consider why Dongguan manufacturers engage in industrial upgrading.

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[31] To assess the effectiveness of this subsidy program, the Dongguan government contracted an expert panel consisting of over 60 members with expertise in engineering and industrial automation as well as finance and accounting. See Dongguan Municipal Government, "Administrative Measures."
[32] *Nanfang Daily*, February 3 2017.

Manufacturers' Rationale for Engaging in Industrial Upgrading

Although industrial upgrading seems on the face of it to be inevitable and should benefit Dongguan's low-end, labor-intensive manufacturing industries, in practice firms encounter a number of issues that reflect the ambivalent role technological development plays in increasing profits.

Process Upgrade Leading to Improved Productivity and Greater Output

Five firms in the electronics and IT industry in our study identified productivity increase as the most important reason behind their drive for process upgrading.[33]

For Mr. Lin, the owner of an LED backlight module supplier (Factory L), repeated upgrading has become a necessity in the rapidly changing electronics industry. In 2013, intense competition in the PC industry forced him to enter the thriving mobile phone business. In 2015, he decided to adopt automatic die-cutting production lines. He bought three production lines from a local supplier for 700,000 yuan per line and even created a dust-free workshop. The total investment came to more than 3 million yuan.

> I switched from personal computers to cell phones due to a greater quantity of orders [for cell phones]. Look at our present orders! Our clients place orders of 1KK, million by million. In comparison, we received an order for only tens of thousands of PCs. That's a significant difference. We still have a few workshops making PC materials, which do not require a dust-free environment. However, the production value of those workshops is not high.

Factory L produced 100,000 sets of die-cut optical sheets every day, for a total of 2.6 million sets per month in a factory with only 120 workers. The high output volume was an

[33] The OECD defines productivity as a ratio between the output volume and the volume of inputs: in other words, a measure of how efficiently production inputs, such as labor and capital, are being used in an economy to produce a given level of output. See the OECD website, accessed December 3, 2017, https://www.oecd.org/std/productivity-stats/40526851.pdf.

outcome of repeated upgrading of production equipment. Since the factory was built in 2007, Mr. Lin has initiated three major upgrades of production equipment in the facility. He further explained that 'upgrading" did not mean modifying existing equipment but rather *replacing* old machines with new ones, so that the new machines would be even *less* reliant on humans.

Previously in Factory L each die-cut machine needed one operator, who placed a piece of film on a machine, punched a key, and cut the sheet into a specific shape. Now, an automated system punches a roll of film continuously, improving efficiency more than 10 times compared with the previous rate. The urge to increase productivity came from Factory L's falling profits. Moreover, the necessity to seek a boost in efficiency was more a demand than a choice. Mr. Lin said:

> In China, the cell phone industry has always witnessed price drops. On average, we encounter a price reduction every two months, sometimes even once per month. [The industry] places very high demands on us. A new model takes only half a year from investment to production. After half a year, it's very possible that the model has already disappeared [from the market], especially for smaller brands. In this situation, the factory has to be highly adaptable. It requires you to perform mass-quantity production in a short period of time, because in half a year you will have to change to produce new models. How to produce so many units quickly in such a short period? It has to be through automation. There is no way humans can change *and* produce such large quantities so quickly.

Less than 250 such factories would produce enough mobile phone components annually for the global population of phone users. Yet, Mr. Lin estimated that the number of competitors in Dongguan alone exceeds 100. In this way, the electronics industry faced an encroaching crisis of hyper-competition in the region that Mr. Lin characterized as follows:

> As a processing factory, we don't have any bargaining power. . . . The key is that in the Pearl River Delta, there are too many factories like ours. The problem of extreme competition is very severe. The only way to make money in such a cut-throat market environment is to lower your labor costs by upgrading your production. If not, then lower prices!

In Factory L, process upgrading reduced the workforce from 20 to only three workers per line, an 85 percent replacement rate. So far, however, the replaced workers have not been laid off, with most having been transferred to the quality control department, as this department still relies on manual labor to inspect products under bright lights. However, there is no guarantee that the quality control department will not be automated in the future.

Whereas wages for laborers have steadily increased in Dongguan over the last decade, the price of automated production machinery, while still high, has been steadily decreasing over the same period reducing the average payback period to only two years. Combined, these two factors make it an economically sensible proposition for a factory owner like Mr. Lin to lower his reliance on laborers in favor of greater reliance on process upgrading—not just to reduce costs but also, significantly, because the machines that replace laborers are able to produce at speeds—while changing their production schedules according to new models—at far swifter rates than laborers can.

According to Humphrey and Schmitz's 2002 taxonomy, the industrial upgrading Mr. Lin has chosen to pursue falls into the category of process upgrading because his firm is adopting automation to directly reorganize the production system, with a greater reliance on machines and a concomitantly reduced reliance on workers. Such a transformation allows Mr. Lin to produce a greater volume of output with fewer capital inputs: technology's primary and central role is to enhance production efficiency, a goal that Mr. Lin successfully achieves.

Product Upgrade for Enhanced Product Quality

Unlike Mr. Lin, who repeatedly upgraded his factory's production machinery to achieve higher productivity, Mr. Zhou was well aware that process upgrading increased the productivity of all firms that engaged in such an upgrading process—one's *own* firm, but also one's competitors' firms (provided competitors also upgraded their production machinery). For this reason, Mr. Zhou, a manufacturer of high-end parts for optical-fiber communication equipment, chose the path of product upgrades to achieve *quality* increases, not just quantity increases.

Mr. Zhou established a separate unit, Factory M, in 2013 to achieve this end. Factory M is registered as a "private science and technology enterprise" (*minying keji qiye*), a legal category under a 1994 regulation designed to encourage academics and professionals to establish start-up companies. As an engineer, Mr. Zhou chose to demonstrate his competitive edge through "differentiation" (*chayi hua*) in quality: "I targeted high-end parts."

In 2013, Mr. Zhou set up Factory M when he decided to quit a business co-owned by Hong Kong partners. Factory closures in 2008 (as a result of the declining orders in response to the global financial crisis) had left much of the shop floor space vacant. After leasing a more-than-2,000 m^2 space in an industrial district in Dongguan, Mr. Zhou purchased a number of brand-new computer numerical control (CNC) machines at a cost of between 300,000 and 400,000 yuan each. Mr. Zhou noted that upgrading was effectively compulsory in the high-precision metal processing industry. The 4- and 5-axis CNC machines can process metal parts along four or more dimensions, saving the step of unloading a half-processed product from one machine and reloading it on another machine.

While high-end CNCs helps Mr. Zhou improve product quality, he does not attribute his competitiveness to the machines alone:

> There are more advanced machines that sell at 1 million to 2 million yuan each. I can't afford them. Machinery is something everybody can buy, but a good production process (*gongyi liucheng*) needs to be designed. One component is hardware and the other is *software*.

These remarks reflect the need to train skilled workers who can participate in designing the production process. This reflects an implicit recognition of the limits of technology. Mr. Zhou understood that technology is important—hence he is willing to spend money on it—yet at the same time he recognized that the true value of the machines could be harnessed only if the technology was combined with the relevant and appropriate human-embedded skills.

Approximately 50 employees were working at Factory M. The manufacturing department is the largest, with more than 40 people, among whom about 30 are CNC operators who are divided into two groups working two shifts (each group working one shift), overseeing the factory's 30 CNC machines.[34] Depending on cycle time—the time required to load and unload each product—one operator is assigned to control between three and five CNCs. One supervisor is assigned for each shift, comprising workers from various ranks (see Table 2).

Mr. Zhou established an apprentice track to train skilled workers who can handle tasks such as changing fixtures and jigs, adjusting CNCs for new tasks, and eventually participating in designing the production process. Before a new employee signs an employment contract, he or she has to choose between the operator track and the apprentice track. Operators are paid nearly 3,000 yuan a month. In contrast, an apprentice will receive an entry-level monthly salary of only 2,000 yuan, which rises to 2,500 yuan in three months, 3,000 yuan in six months, and so on. However, an operator has virtually no upward

[34] When Mr. Zhou's Factory M was established in 2013, it had already installed CNC machines. Therefore, we cannot compare how many workers would have been replaced by the CNC machines.

occupational mobility, whereas an apprentice can be promoted all the way to 'Technician I.' By saving on labor costs, Mr. Zhou was able to recoup his investment by engaging in product upgrading in only one year.

The in-house apprenticeship training program that Mr. Zhou established represents an exceptional case among China's SMEs, which for decades have been content with labor-intensive, low-value-added production on behalf of other, better-recognized brands, which discourages the development of a skilled labor force.[35] Mr. Zhou's innovative apprentice program derives from his long experience working at a *danwei* (from 1979 to 1997), at both a state-owned mining research institute and at its affiliated coal-mining machinery factory.[36]

In Mr. Zhou's case (Factory M), the trigger to engage in product upgrading stemmed from a focus on improving quality. This focus was not just the catalyst for product upgrading but it had a backward-vertical integration impact on Mr. Zhou's factory, stretching from machines to workers. Backward-vertical integration reflects Mr. Zhou's need to ensure with certainty that the relatively costly machines that he had purchased to improve his product quality were *coupled* with suitably trained workers. In this respect, Mr. Zhou's Factory M differs from Mr. Lin's Factory L.

Whereas in Factory L laborers are viewed as a liability to be jettisoned through product upgrading, in Factory M laborers are thought to be as critical as the machines (if not even more critical) to the manufacturing process. Granted that Mr. Zhou's Factory M needed fewer workers as a result of upgrading his production process (as was the case in Mr. Lin's Factory L) as a result of his adoption of multi-axis CNC machines, but the resultant laborers

[35] Elena Klorer and Matthias Stepan, "Off Target: China's Vocational Education and Training System Threatens the Country's Rise to Industrial Superpower Status," *Mercator Institute for China Studies (MERICS)* 24 (October 2, 2015), accessed March 19, 2017, http://www.merics.org/fileadmin/templates/download/china-monitor/China_Monitor_No_24_EN.pdf

[36] *Danwei* (work unit) refers to socialist workplaces whose employees are guaranteed economic benefits such as secure jobs, affordable housing, and generous retirement pensions. See Xiabo Lu and Elizabeth Perry, "Introduction: The Changing Chinese Workplace in Historical and Comparative Perspective," in *Danwei: The Changing Chinese Workplace in Historical and Comparative Perspective*, eds. Xiabo Lü and Elizabeth Perry, 3–20 (Armonk, NY: M. E. Sharpe, 1997).

who remained played a more central role and were also more highly skilled than those whose jobs had been replaced by machines. In fact, the skill level of these laborers was so consequential that it induced Mr. Zhou to establish an apprentice track—backward-vertical integration—to train suitably skilled workers. On this view, workers do not straightforwardly or independently represent costs or liabilities in the production process. Rather, the worker is an important asset and *part* of the production process, an asset that is to be cultivated through training and apprenticeship. Without either the machine *or* the worker, the production process with its strong emphasis on quality is rendered useless. Such a view contrasts with the traditional technology-as-taken-for granted conception where technology is seen in binary terms as a panacea (or not) in terms of improving productivity and quality without symmetrical attention given to the usage of the technology.

The case of Mr. Zhou's factory illustrates the second type of industrial upgrading distinguished by Humphry and Schmitz's 2002 taxonomy: product upgrading. This form of industrial upgrading, as the above case illustrates, involves the manufacture of a higher-quality product, one that can command a higher selling price. The central emphasis, unlike in the first case of Mr. Lin, is not primarily on increasing production output; rather the driver of the process of automation is a desire to improve overall product quality through the combined use of automated machinery and skilled workers.

Functional Upgrading from Original Equipment Manufacturing (OEM) to Own Brand Manufacturing (OBM)

When we conducted our research in late 2015, Mr. Zhou's company was running well if measured by profitability. Due to the gradually decreasing demand for high-precision parts, though, he was nevertheless worried about maintaining a healthy order book over the longer term. Despite his background in engineering, he has not been able to manufacture his products under an indigenously created brand name. Rather, he is still confined to manufacturing components and parts (which he sells to others to use under their brands). This lacuna represents a type of transition that functional upgrading can help achieve—that is, ascending the value chain through brand development (rather than focusing narrowly on increasing output or quality).

Recently, in both Chinese media and academic discussions of industrial upgrading and the "Made in China 2025" plan, the term "smile curve" has gained popularity.[37] The concept of the smile curve implies that, along the value chain of the personal computer industry, upstream R&D as well as downstream brand-based marketing can yield more added value as compared with mid-stream assembly and processing activities (activities with which Mr. Lin's Factory L and Mr. Zhou's Factory M are entirely occupied).[38]

Other scholars propose an OEM–ODM (original design and manufacturing)–OBM (own brand manufacturing) developmental trajectory and argue that latecomers should follow this path of 'technological learning' by developing processing capabilities first, followed by product design capabilities, and finally their own product branding capacities.[39] The "smile curve" thesis espouses the benefits of foreign direct investment in facilitating spillover of innovation and helping to achieve productivity growth. However, the "smile curve" thesis fails entirely when facing challenges created by the inequality of the international division of

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[37] See X. Wang, "*Xin gongye Beijing xia de 'zhongguo zhizao 2025* ('Made in China 2025' in the Backdrop of the New Economy)," *China Development Observation* 7 (2015): 17–20; Y. Mao and Q. Zheng Q, "*Jiyu weixiao quxian de qiye shengji lujing xuanze moxing: Lilun kuangjia de goujian yu anli yanjiu* (A Model on Firms'Choice on Upgrade Trajectory Based on the 'Smile Curve': Development of Theoretical Framework and Case Studies)," *Journal of Sun Yat-Sen University (Social Science Edition)* 3 (2013): 162–174.

[38] See figure 1 in Y. H. Wei, Jian Li Dennis, and Yuemin Ning, "Corporate Networks, Value Chains, and Spatial Organization: A Study of the Computer Industry in China," *Urban Geography* 31, no. 8 (2010): 1118–1140.

[39] Compare Michael Hobday, "East Versus Southeast Asia Innovation Systems: Comparing OEM- and TNC-led Growth in Electronics," in *Technology, Learning, and Innovation: Experiences of Newly Industrializing Economies*, eds. Linsu Kim and Richard R. Nelson, 129–169 (Cambridge, UK: Cambridge University Press, 2000); and Fung Hsu Liu, Heng-Yi Liu, and Ting-Ling Lin, "The Competence and Constraints of Brand Building for Contract Manufacturers," *Brand Management* 15, no. 6 (2008): 412–432.

labor that started in the 1980s when multinational corporations outsourced their production lines overseas and utilized cheap sources of manufacturing labor in developing countries.[40]

Several manufacturers whom we interviewed complained about the low profit margins experienced by OEM factories such as theirs, irrespective of whether they operate as components suppliers or engage in assembly operations. Mr. Guan of Factory H, for example, told us that while his company sold a motorcycle helmet for the US$25 ex-factory price, the retail price would typically be six times higher, meaning that the majority of the product's profits were captured by another entity in the value chain. Similarly, Mr. Wang of Factory C, which has tried very hard to develop its own brands, hazarded his estimate that OEM accounted for only 30 percent of product value, while 70 percent of that value is captured by brand owners for design, development, and marketing.

With a net profit rate of only 3–4 percent, Factory H is now engaging in functional upgrading to develop its own-brand bicycle helmet for the domestic (Chinese) market. By undertaking functional upgrading, Factory H has in fact has elevated to ODM and developed a strong R&D department. The vice-manager explained to us the incompatibility between OEM/ODM and OBM:

> Some of the top brands in sports helmets have asked us to produce their helmets. If I create my own brand, they won't be willing to give orders to me as I'll be their competitor. If you were the top brand, would you give me an order? Obviously not! Why? Because how does the top brand manufacturer know that I won't copy him? To be safe, they won't give me any orders, so as not to share knowhow with me. And when that happens, we receive orders only from second- and third-tier brands who want to make use of me, utilize my R&D capacity to create better products for themselves. I have invested in

[40] Xue, Hong, and Anita Chan. 2013. "The Global Value Chain: Value for Whom? The Soccer Ball Industry in China and Pakistan*." Critical Asian Studies* 45 (1): 55–77.

industrial upgrading, so that won't work as a long-term solution for *my* company's operations.

The 'knowhow' involved with helmet design pertains to understanding safety protection, selecting appropriate light-weight materials, identifying where in the helmet to maximize safety, and creating a fashionable appearance. He explained that for the own-brand helmet that they targeted for the domestic Chinese market, they cannot use any of the 'knowhow' that their clients possess. Moreover, they also need to clearly report the 'knowhow' involved in the new design of their domestic brand to their clients and obtain their approval.

Factory H produced the entire helmet from scratch. Despite that, they know very well that their clients are able to keep the essence of their own technology a secret. Some scholars argue that the global division of labor will reduce global inequality in technological development when advanced multinationals consider technology spillovers to developing countries that are gradually catching up in their competencies. Over time, firms that carry out low-value-added functions seek to move up the value chain by developing their own brands rather than merely being suppliers.[41]

In recent years, however, critics have shown that the benefits of such spillovers are far from straightforward and are unlikely to be realized through a linear evolutionary process. Rather, the benefit to developing countries is either limited or at best uneven, depending on the sector in question.[42] Our research has shown how OEM status—irrespective of investments in industrial upgrading—actually limits a firm's brand development capacity.

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[41] See Ram Mudambi, "Location, Control and Innovation in Knowledge-Intensive Industries," *Journal of Economic Geography* 8, no. 5 (2008): 699–725.

[42] See Dani Rodrik, *The New Global Economy and Developing Countries: Making Openness Work* (Washington, DC: Overseas Development Council, 1999); and X. Xu and Y. Sheng, "Productivity Spillovers from Foreign Direct Investment: Firm-Level Evidence from China," *World Development* 40, no. 1 (2012): 62–74.

Although it seems unlikely that technological change itself can help Factory H overcome this OBM barrier, the management team still feels an urgent need to engage in functional upgrading. The factory was established in 2011 and began functional upgrading in 2014 by adopting automated painting, CNCs, and robotized bicycle helmet vent-hole cutting as well as installing other automated equipment. Over the 2014 to 2016 period, the factory invested 4.5 million yuan in upgrading production and reduced the workforce from 93 to only 36 workers, while production more than doubled and the product qualification ratio also improved.

In this case, one catalyst for functional upgrading derives from difficulties in recruiting younger workers who are willing to endure the noisy, dusty, injury-prone environment of the shop floor where helmet vent holes are cut and the often-toxic conditions that characterize helmet painting. From this perspective, functional upgrading benefits the employer by allowing the company to scale the value chain through creating its own brand of product, but it has a mixed impact on workers. On the one hand, it improves occupational health and safety. However, on the other hand, functional upgrading leads to deskilling, reducing the training period from six months to three days, which translates into a change from a piece rate to a time rate as well as a reduction in monthly salary from 5,000 yuan to less than 4,000 yuan.

This final case of factory H corresponds to the third form of industrial upgrading distinguished in Humphrey and Schmitz's taxonomy: functional upgrading. One significant implication of functional upgrading is that new functions such as design, marketing, and branding are taken on board by the manufacturer, who had previously not performed such tasks (and was content with merely supplying other firms who took on the responsibilities of designing, marketing, and branding). Factory H is an example of automation employed for the purpose of allowing a manufacturer to scale the value chain so as to capture a greater share of the overall profits from the final sale of an item (in this case a helmet) to the final customer.

Discussion and Conclusions

An issue that runs throughout this research but is crystalized most aptly by the case of the helmet manufacturer warrants expanded discussion: what do these moves towards industrial upgrading mean for workers in particular and for the overall Chinese workforce in general—especially low-end production workers? Or, put another way, what are the implications of these moves towards industrial upgrading for the individual worker and the broader Chinese workforce? While this issue might not be a serious problem immediately insofar as the general climate that prevails still features a shortage of labor, the sustainability of the policy of "Replacing Humans with Robots" will surely be questioned much more deeply as it takes off on a large scale. From the perspective of workers, there are two standout themes that merit discussion here.

First, the path towards industrial upgrading, while filled with various necessities and incentives (from the perspective of the manufacturing plant owner/manager), has serious implications for the livelihoods of individual workers. What happens to the workers who are laid off? Their choices can vary along a spectrum from reskilling (retraining) to upskilling (through education) to simply moving to another factory that has yet to embrace the wave of industrial upgrading that the government is trying to promote.

What mechanisms are used by employers to lay workers off? Employers may not need to be perceived as being cruel or cold-hearted when laying off workers through the process of upgrading production. They can simply shift the basis of a worker's pay away from an attractive piece rate (based on quantity of output) to a less attractive model based on a time rate (based on the number of hours worked). When automated machinery is responsible for producing the majority of pieces of output, workers are inevitably forced to accept a time-rate remuneration scheme, a scheme that circumvents the need for the employer to directly lay the worker off, but still saves the employer money. Given the unattractive remuneration of a time-rate scheme, ultimately it achieves the same result for the employer of eliminating the employee from the factory's payroll (assuming the worker is not immediately laid off by the employer the moment at which production is upgraded through automation).

Second, on a macro scale, it is easy to see that this trend towards industrial upgrading will, sooner or later—ultimately depending on the strength of the necessities forcing employers to change, the attractiveness of the incentives given to them, and the take-up rate of those incentives on the part of manufacturers—force a broad swathe of the previously employed workforce into either unemployment or underemployment. At an aggregate societal level what, if any, are the mechanisms in place to re-integrate these workers into the labor force? Are the newly laid-off expected to fend for themselves, or are there government incentives for laid-off workers—as there are for manufacturers—to receive government funding or other kinds of support to help them either reskill, upskill, or otherwise return to their hometowns and seek gainful employment? This is an issue that neither the "Made in China 2025" plan nor employers in general are comfortable addressing in any depth. This neglect can only be interpreted as delaying the inevitable given the building momentum of the push towards industrial upgrading that is occurring throughout southern China in particular.

From the perspective of employers, this issue has serious implications. Although much analysis in economics simplistically assumes that employers make rational economic decisions that ultimately improve their companies' profitability, one of our cases (that of Mr. Zhou in Factory M) in particular shows that such a linear conceptual narrative is at best naïve. Even after industrial upgrading occurs, firms need workers. To be sure, they need *fewer* workers, but these remaining workers are more highly skilled and better trained than were their counterparts. Industrial upgrading therefore does not relieve employers entirely of their reliance on workers. Rather, the nature and character of that reliance changes.

As China embarks on its program of industrial upgrading, or the 'robotic revolution,' the mainstream media and many scholars tout the potential of industrial upgrading to enable China to transform itself from the 'workshop of the world' to a hub for 'intelligent manufacturing.' Building on the idea of technological determinism, they champion the role of technology in helping the manufacturing sector manage the toughening business conditions that have been gradually enveloping southern China over the past decade. Rather than assuming a Whiggish perception of technology as 'progress,' however, we might need to adopt a dialectical approach when analyzing the contradictions that industrial upgrading entails.

We say this first because the real issues discussed above relating to employees should the industrial upgrading become more widespread and pick up its pace should not be dismissed. Second, if we look back at the West for precedents and possible implications of the process of industrial upgrading as it unfolded there, we find that the process took off largely in the 1960s and 1970s, with mixed outcomes. Beginning half a century earlier, Fordist production and later welfare-state protection enabled workers to enjoy mass consumption through mass production. However, further automation has led to unemployment and deskilling, and the former labor aristocracy saw its unionized power gradually weakened as global capital took advantage of the globalization of the value chain and contract manufacturing to outsource production to countries where wages were lower. Are we, in effect, seeing the effects of this process again unfolding in China?

This research has shown that the three overarching reasons that explain why manufacturers choose to engage in industrial upgrading are increasing quantity of output, increasing the quality of the manufactured product, and scaling up the value-added chain (so as to be able to reap a greater share of the profits associated with the product sales). These reasons map onto the theoretical framework of multiple types of upgrading that we identified from the extensive extant literature on industrial upgrading. While our cases cover three of the four types of upgrading in Humphrey and Schmitz's taxonomy, we were unable to find SMEs in our sample that engaged in inter-sectoral upgrading (involving moving into entirely new sectors or chains). In some ways, this is to be expected given that our sample comprised SMEs rather than large firms or SOEs—enterprises much more likely to command the organizational slack and ample (spare) resources required to engage in inter-sectoral upgrading. To this extent, our findings echo those of Pietrobelli and Rabellotti, who show that supplier firms (such as the subjects of our research) find it easier to accomplish process and product upgrading as compared with functional and inter-sectoral upgrading.[43] That said, our final case does demonstrate a scenario in which an SME attempts to threaten the hierarchical control of lead firms by engaging in functional upgrading.

One theme that ties these three rationales together is profitability. Perhaps understandably, the happiness, livelihood, or welfare of the workers who are impacted by industrial upgrading are at best minimally important and at worst almost nowhere to be seen. Given the extent to which industrial upgrading is occurring in Dongguan and likely spreading across other manufacturing regions in the Pearl River Delta, if employers are not sufficiently incentivized to defend or promote the workers' interests, the state remains the only entity with the resources needed to assume such a role. The question then remains: When will the state meaningfully acknowledge the workers, at least in a way that is commensurate with the attention and resources they are piling into the industrial upgrading process (as part of "Made in China 2025" plan)?

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[43] Pietrobelli and Rabellotti, Upgrading to Compete.

A second theme is that all of our cases discuss industrial automation. Whereas earlier authors have focused on industrial upgrading especially along the global value chain (cf. Humphrey and Schmitz 2002), few have discussed the issue of upgrading in the context of industrial automation, even less so in southern China. We do so by employing a theoretical framework drawn from the global value chain literature to parse out the various forms of industrial upgrading and show how these distinct forms of upgrading act as the rationales for manufacturers to engage in upgrading activities. This framework provides the structuring apparatus for our analysis as well as key analytical concepts that our empirical research uncovers.

A third theme is that manufacturers, in responding to government incentives for industrial upgrading, have cited several rationales for undertaking such upgrading. Each of our cases shows manufacturers employing a unique set of criteria for deciding to take advantage of the government's promotion of automation—but the incentives offered by the Dongguan government are *not* the primary driver of those decisions. Rather, issues considered by the manufacturers include product upgrading, process upgrading, and functional upgrading. While helpful, the Dongguan government's subsidies and incentives fail as an explanatory factor when describing why manufacturers engage in industrial upgrading. At best, the subsidies and incentives are subsidiary or secondary explanatory factors. The three individual forms of upgrading we identify are the deeper-rooted reasons, which better explain manufacturers' industrial upgrading choices.

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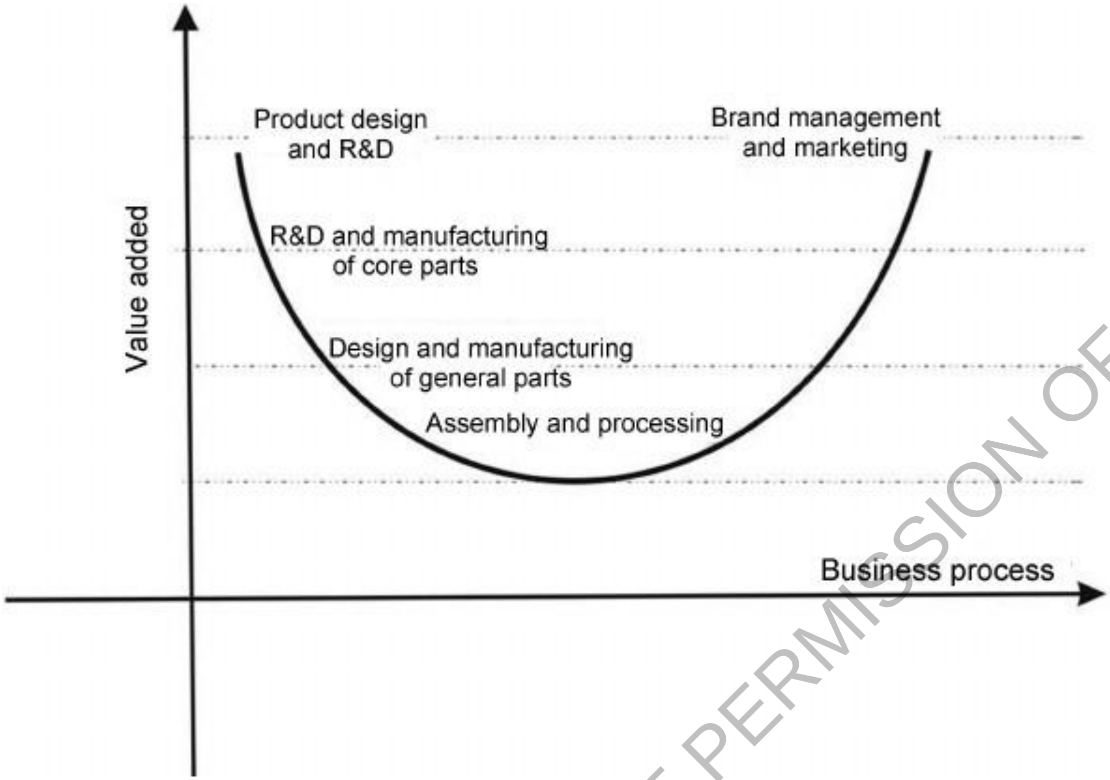
Figure 1: "Smile Curve"



Source: Wei et al., 2010

Table 1: Participant-Observation-Interview Subjects

	Code	Interviewee	Industry	Product	Automation Equipment Deployed
1	M	Mr. Zhou (owner)	Electronics	Optical fiber communication equipment parts	Computerized numerical control (CNC)
2	L	Mr. Lin (owner)	Electronics	LED die-cut modules for mobile phones	LED die-cutting automation system
3	H	Mr. Guan (vice-manager)	Toys	Bicycle helmets	Automatic painting and mold cutting
4	P	Mr. Zhang (owner)	Electronics	Transmission wheel for printers	Plastic injection molding machine
5	C	Mr. Wang (owner)	Electrical machinery and equipment	Parts for car motors	Plastic injection molding machine
6	D	Participant-observation across the factory	Furniture	Fire-proof doors	Automatic painting and wood processing
7	J	Mr. Cheng (owner)	Electronics and information technology	Mobile phone chassis	Cloud-data-controlled automation system and robots
8	K	Mr. Wong (owner/ manager)	Electronics and information technology	USB connectors	Automation systems

Table 2: Production Department Employee Title and Wages (in yuan)

Position	Operator	Appren-tice	Technician III	Technician II	Technician I	Engineer	Supervisor

Wage (Yuan)	About 2,800[44]	2,000–3,500	4,000	5,000	6,000	Over 8,000	Over 10,000

[44] The operator's salary is calculated as RMB1510 (basic salary) + overtime pay + RMB300 (performance bonus).