FOUR

# Taking Industry Global

## *China as Rising Industrial Powerhouse Versus China as Capitalist Enabler*

### China's Growth Story as Commonly Understood

As discussed in the previous chapter, China, in an almost desperate bid for national salvation, embraced the global economy in the 1990s. What has emerged in the fifteen years hence, however, looks anything but like a nation in despair. We are all familiar with the broad outlines of the story. During the opening years of reform in the 1980s, China grew steadily but primarily on the basis of domestic changes that permitted the system to regain ground lost during the era of command planning. Areas that had long been suppressed—household farming in the countryside, small-scale rural industry, service-related business in the cities—were all to varying degrees opened up. Citizens, especially in the countryside, responded enthusiastically and with great entrepreneurial spirit. In the most forward-thinking locales—the southern province of Guangdong, for example—the goal was to make up for lost time and catch up with the higher status industrialized heartlands of China's North and Northeast.[1] For the country as a whole, the period was about growth in response to newly unleashed domestic demand, which had previously been suppressed under command planning. At least in the countryside, it was also about basic institutional change: the elimination of collective farms and the opening up of household agriculture. Such changes allowed China's most important assets, its people, to be deployed in economically far more productive ways. Equally significant, rural citizens were deployed in a manner of their own choosing rather than the state's, a change that upped the incentives for productive economic behavior.

Yet, for all these exciting developments in rural areas, change in urban areas was tentative and inconsistent at best. For most city dwellers, change was hardly evident at all in their daily lives. The impact of Chinese reform was also minimal for everybody else in the world. China was a good public interest story—a hermit kingdom creeping out of its shell—but hardly something that affected our own day-to-day existence.

How different things would look by the 1990s and 2000s. What had been steady growth in the 1980s became torrid growth in the 2000s. And now, rather than just meeting newly unleashed domestic demand, the Chinese economy was being fueled by global demand. Trade and foreign direct investment absolutely soared. Way back at the height of the Maoist era in 1960, total trade (imports plus exports) amounted to only 8 percent of China's gross domestic output. By 2008, that figure had soared to 59 percent.[2] Real exports grew by roughly 500 percent between 1993 and 2008 alone, thus making China the world's third largest exporter, ahead of Japan and behind only the United States and Germany.[3] In early 2010, China in fact surged forward to the top slot, becoming the world's single largest exporter. On a global scale, China effectively became a market maker.

By the early 2000s, China's growth story became one not just of total trade but of substantial net exports. Trade surpluses began showing up consistently in the Chinese economy in the mid-1990s but really ballooned in the mid-2000s. By Beijing's official accounts, the nation's total trade surplus in 2008 amounted to 7 percent of annual gross domestic output. One-third of America's total trade deficit that year was attributable to goods coming from China.[4] China in all appearances had become a nation supercharged by the consumerist desires of people abroad, especially Americans.

In the midst of all this trading, China was receiving massive infusions of investment from abroad. It wasn't investments in stocks and bonds that were pouring in, the sort of hot money that can enter and exit a market at a moment's notice. Rather, what was pouring in was foreign *direct* investment (FDI), purchases by outsiders of substantial ownership stakes in China-based factories.[5] People from overseas were investing in existing Chinese factories or building entirely new ones of their own. Presumably by doing so, they were bringing with them technology and expertise, benefits that stick. Foreign direct investment at the start of reform had been negligible. In 1983, by Chinese official accounts, it amounted to only US$1.73 billion spread over 470 projects. By the 2000s, FDI was everywhere in China. In 2006 alone, US$193 billion of overseas money found its way to 27,514 projects. Between 1993 and 2006, approximately US$1.34 trillion worth of accumulated foreign direct investment had flowed into Chinese factories.[6]

Equally striking, the Chinese economy over the course of this period experienced what to the naked eye appeared to be incredible upgrading. Not only was China exporting, but its exports were growing ever more sophisticated. In the 1980s and early 1990s, China's exports had primarily come from soft industries like apparel, textiles, footwear, and toys, sectors presumably driven less by know-how and innovation than the availability of low-cost, low-skill labor. Through the mid-2000s, though, Chinese exports moved rapidly up into electronics, telecommunications equipment, office machines, and appliances, sophisticated items presumably requiring considerable expertise to produce.[7] No longer about just cheap labor, the story now seemed to be one of technology-intensive, skill-intensive, state-of-the-art production, the sort of thing we would expect of nations far richer than China.[8] Somehow, this nation seems to have emerged from nowhere to become a global industrial powerhouse.

At least in terms of how it is educating its population, this powerhouse now appears poised to become a global leader in innovation as well. Since the late 1990s, the Chinese educational system has dramatically expanded its training of science and technology (S&T) personnel, the kinds of engineers, scientists, and technicians needed to push the frontiers of innovation. As Denis Simon and Cong Cao document in their definitive work on Chinese S&T training, while the country between 1991 and 2006 experienced a nearly 20 percent increase in its total workforce, it realized a more than 200 percent increase in the number of scientists and engineers involved in S&T activities.[9] Beginning in 1999 and continuing over the course of the next decade, Chinese universities expanded the size of their incoming classes by well over 20 percent per annum.[10]

It is easy to become swept up in the enormity of such numbers, and one should remain cautiously skeptical about both the quality of the S&T training provided and the skill level of the graduates produced. However, even the soberest assessments of China's expansion efforts



in education are mind-boggling. The country today is training vast amounts of human talent, an obviously critical ingredient for industrial upgrading and economic growth.

All in all then, the outlines of the story appear clear. A concerted embrace of the global economy permitted China to shift to an externally focused, trade-based mode of growth. Inflows of foreign investment and knowledge then interacted with a massive training of domestic talent to move the country swiftly up the ladder of industrial sophistication. As a result, its portfolio of global exports shifted from low-value, labor-intensive products in areas like apparel and footwear to high-value, knowledge-intensive products in sectors like computers and electronics. The move into higher value, higher productivity industries thus led to an even greater acceleration of growth and an even more rapid accumulation of resources. In the resulting virtuous circle, resources could then be devoted to more training and upgrading, more influence on the global stage, and so on down the road.

## Appearances and the Assumptions We Make about Them

Is the story just described really that clear? How exactly does it all connect up? The narrative, after all, hangs on a series of vague phenomena: some sort of "opening" on the policy front; goods moving around as "trade"; money flowing in as "investment"; people going to school and getting "trained"; and somehow, a national economy, represented by a "basket" of exports, skipping forward from one industry to the next. Such abstractions are fine in a way, but what actually do they mean, and what really do they look like on the ground?

More often than not, it is left to our imaginations to decide. That is, we hear a story bound together by abstractions, and then we make assumptions—often intuitively—about what is behind those abstractions in reality. Making assumptions is fine, but we have to be sure to check on them from time to time. After all, they frequently determine the overall conclusions we draw. Surging levels of trade in a given country, for example, can mean many things. They can mean the country is rising as a self-contained economic giant, a veritable high-tech powerhouse. They could also mean, though, that the country is simply hanging on as a low-end way station in global production, a glorified sweatshop where imported components get slapped together and sent abroad as finished products. The devil is in the details.

Chinese growth is not about abstract movements of money and goods. Those are just data points existing out in the ether. Actual growth is about how those dots are connected. It is about real people doing real things on the ground: bending metal, stamping parts, molding plastics, writing software code, manipulating digital designs, and so on. Our feelings toward China are largely driven by how we believe those dots are connected up. In other words, the conclusions we draw about China (i.e., whether it is a friend or foe, a threat or an opportunity, a rival or a protégé) are driven not by the facts of rising growth numbers or shifting baskets of exports—those, after all, can mean many different things—but rather by what we assume those numbers indicate about the nature of the activities on the ground.

The remainder of this chapter explores what those activities really look like and how they jibe with the assumptions we make about them. What has China's embrace of the global economic order really meant? Does it make sense to associate China with descriptors like "rising economic giant," "shop floor of the world," or "industrial powerhouse"? Terms like these involve a particular way of connecting the dots. Is that the right way? If not, how should the dots be connected? Such questions lie at the heart of not only our understanding of China but also our fundamental beliefs about economics. This chapter examines both.

The chapter's basic message is threefold. First, what we are witnessing in China today is neither a repeat of Japan's rise in the twentieth century nor Germany's in the nineteenth. It is not about an ascendant superpower scaling the heights of technological sophistication and unseating incumbents like us in the process.

Second, it is not the opposite either. China's export economy amounts to far more than trivial, Mickey Mouse assembly operations. That economy is indeed highly dependent on export processing, but export processing in today's globalized world involves far more than just screwing together imported components, stamping a "made in China" label on the resulting product, and then shipping it overseas for sale. This is not about just some kind of massive global-scale sweatshop. Export-oriented manufacturing assembly involves meeting extraordinary managerial challenges at the firm level and equally extraordinary institutional challenges at the systemic level. That China has been able to do all this, and do it better than virtually any other nation in the world, amounts to something worth explaining. Producing cell phones or laptop computers—or even Disney toys—in today's world is anything but a Mickey Mouse endeavor.



Third, the sort of globally focused production that takes place in China, while unquestionably allowing the nation to realize substantial growth and domestic skill upgrading, has induced equally astounding upgrading abroad. China's integration into the global economy has unleashed extraordinary innovative capacity, most conspicuously in the United States and in American companies.

## The Mystique of Manufacturing

Let's consider for a moment what worries us about China's meteoric rise into high-tech production and what lies behind our concerns when we see the "made in China" label on cutting-edge products. Let's also examine why so many of us feel jobs in manufacturing are important and why we worry when they seem to disappear from our own country. What is it about manufacturing? Why should jobs in this area be considered more important, more vital, and more strategic than jobs in services (i.e., health care, education, business consulting, finance, etc.)?

Answers to these questions are often as strongly felt as they are conflicted. In many ways, the confusion mirrors decades-old or even centuries-old divisions among economists over what fundamentally drives growth. Within the economics discipline, all manner of creative thinking and sophisticated research methods have been thrown at the problem. Yet, despite the generation of so much new knowledge and insight, economic growth in many ways remains a mystery.[11] We still cannot say for sure what catalyzes it, what sustains it, and what causes it to cease. There are so many variables involved—technology, social institutions, governmental policies, cultural factors—almost all of which change over time and vary from place to place. What appears to work in one place often fails in another, and what seems applicable under certain historical or technological circumstances often appears irrelevant under others.

To some extent in the broader public discourse, though, especially in the United States, one explanatory perspective—that of market liberalism—has dominated in recent decades. Americans, not entirely without reason, generally accept the idea that what drives growth more than anything else is markets. And we have certainly been inclined as a nation to urge other countries, especially poorer developing ones, to open their markets up to achieve prosperity. The underlying logic is that as long as markets are permitted to function—that is, as long as prices are freed up to reflect supply and demand, and goods are permitted to move in response—then basic laws of comparative advantage can kick into gear. Impoverished nations, flush with cheap labor, can specialize in low-end, labor-intensive manufacturing, exporting the output to the rich countries that need it but could never produce it as inexpensively. Rich nations, in turn, blessed with technology and skilled labor, can specialize in high-end, knowledge-intensive manufacturing, the kind of production that exists at the frontiers of innovation. The rich, then, can export their highly specialized output to one another and to the poor nations that need it but could never hope to produce it. Everybody would presumably benefit and grow in the process.

The added bonus, at least theoretically, is that if everything is done properly, the poor should be expected to grow more rapidly than the rich. The poor, in other words, should benefit disproportionately. This should be true as long as conditions on the ground worldwide actually reflect diminishing returns to scale, a situation in which the gains realized from an additional input of investment decline as more and more investment is made. Diminishing returns to scale is not hard to imagine conceptually. Consider for a moment the case of a very simple factory with just a handful of employees. The addition of another worker might conceivably increase output, and such increases could be expected to go on for a while as a few more workers are added. Relatively soon, though, things would start to get crowded as each new entering worker began butting up against and reducing the productivity of the people already there. Adding more workers, then, would ultimate cease to increase output. That, basically, is diminishing returns to scale. If you keep adding inputs, eventually, you are no longer going to realize any increase in outputs. In fact, you will ultimately start suffering decreases as the system bogs down.

Moving from the level of the firm to the country, one could easily imagine a similar situation applying to nations competing in the global marketplace. Rich countries presumably already have lots of money and human capital (skills and knowledge), so the returns on additional investments in those areas should be relatively small. Poor countries, however, suffer scarcity in these areas, so the returns on investment should be much larger. After all, a small investment in new equipment in a barely mechanized rural factory can lead to major gains in productivity and profitability. Presumably, then, people across the world in possession of resources—whether money or their own human talent—will direct those resources to the places that can yield the highest returns. In the aggregate, we should expect to see capital and talent



flowing from rich places to poor ones. And as these resources flow, a positive growth dynamic should ensue. Infusions of money and talent should lead to industrial upgrading; industrial upgrading should permit production of higher value, higher margin exports; such production should lead to greater income; and so on. The flows from rich to poor should tail off only as the endowments of the poor—their money, their talent, their skills—equalize with those of the rich. How long that may take is anybody's guess. Nonetheless, over time, we should expect to witness an overall trend of income convergence between rich countries and poor ones.

Unfortunately, as most economists acknowledge, things have not played out this way in reality. Income convergence between rich and poor has failed to take place. Quite to the contrary, over the last 150 years the rich have tended to get richer, and the poor (at least relative to the rich) poorer. Rich nations on the whole have tended to grow faster than poor ones, and the poor have fallen progressively behind.[12]

This fact of income *divergence*, of course, neither proves nor disproves any particular theory of growth. After all, divergence could be the product of a variety of different phenomena. It could, as some have argued, be caused by markets not being opened quite enough.[13] *We didn't go far enough with marketization.* Or as others have argued, it could be caused by excessive politicization of—and state intervention in—the markets that have been opened.[14] *There is still too much governmental intervention in markets.* Alternatively, it could be caused by inadequate governmental oversight and regulation of liberalized markets, an explanation that today carries a particular air of credibility given our recent financial problems.[15] *There is not enough (of the right kind of) governmental intervention in markets.* Then again, regardless of what the government is or is not doing, maybe markets can work only if supported by the right cultural factors, norms of reciprocity or trust.[16] *Some people and cultures just are not cut out for markets.*

In an entirely different vein, our expectation that markets should generate convergence may be plain wrong. That is, we may have misconstrued the underlying conditions. What if, whether for technological or other reasons, the prevailing fact in the world is not *diminishing* returns to scale but instead *increasing* returns?[17] That is, maybe the returns on an additional increment of investment are higher in those areas already flush with the resource in question. Particularly in industries with huge start-up costs—silicon wafer fabrication, for example—the immediate returns on upgrading an existing facility might be much greater than the returns on building a new plant entirely.

Depending on the technologies involved, a large steel plant might produce more efficiently than a small one. We routinely see these sorts of things with human capital, though we often do not think about it. A trained physician is likely to earn a much higher income (i.e., realize greater returns on investment in education) in Boston than in Harare, even though doctors are far scarcer and more desperately needed in Zimbabwe than in New England. If more aspects of industry than we suspect work like this, then markets really are not the friends of the poor. Should market conditions be allowed to prevail under increasing returns to scale, resources—seeking their highest returns—would flow from regions of scarcity to regions of plenty. Income divergence would be the normal, natural outcome of markets. Indeed, for the poor to develop under such circumstances, they would have to pursue policies that somehow subvert or sidetrack market forces.[18]

Many of these issues have yet to be understood in definitive fashion. And, as often seems to be the case, just as soon as we get our finger on any one of them, the underlying conditions change. New technologies appear. New modes of organizing production arise. New ways of thinking proliferate. And new kinds of best practice developmental strategies get pushed.

Perhaps understandably, then, in our public discourse, we frequently mix and match difficult-to-reconcile views about markets. On the one hand, as noted before, most Americans are comfortable with the idea that poor nations should be advised to pursue market liberalization. We are equally comfortable with the idea that such efforts will lead to growth, presumably through the export of low-end goods. That is, we implicitly accept the story about diminishing returns to scale. In the political arena, we may complain from time to time about the proliferation of goods "made over there," and we may level accusations of dumping on overseas manufacturers, but at an intellectual level, we accept the idea that a developing country, as long as it liberalizes correctly and plays fairly, will move naturally into low-end export industries, the usual suspects of textiles, toys, shoes, and apparel. We buy those goods and do not feel existentially threatened in doing so. When nations like Sri Lanka, the Philippines, Indonesia, or Bangladesh move into textile production, we do not suddenly see them as rising powers or even serious global competitors. But why not?

Here, many of us switch over to a belief in increasing returns to scale. That is, we see low-end, low-tech production (what poor countries do) as something categorically different from high-end, high-tech production (what rich countries do). We are prepared to believe that movement into low-end production is all about diminishing returns to scale and normal global resource flows from the rich to the poor. We are ready to accept that if you are a poor nation, markets will take you where you need to go. At the same time, many of us feel implicitly that high-end production is all about increasing returns to scale. Few of us really believe that low-tech countries, simply by allowing markets to function, just upgrade naturally and seamlessly into advanced industrial production. Indeed, in the few cases in which we have seen poorer nations move up into high-tech production (i.e., South Korea and Taiwan in previous decades or China today), we have often accused them of unfairly distorting markets through trade barriers, government subsidies, or other preferential measures.

Regardless of the merits of (and politics behind) these sorts of accusations, we actually have good reason for believing that ability to engage in high-end industry stems from something more than just markets. Whether railroads and steel in the nineteenth century or automobiles and semiconductors in the twentieth, a select handful of industries at any given historical moment seemed to have separated the wealthiest, most advanced societies from everybody else. Difficult to enter and requiring huge amounts of skill to sustain, these industries stood out as a class unto themselves. The few nations in history that have successfully mastered them—Germany in the nineteenth century, Japan in the mid-twentieth century, South Korea and Taiwan in the late twentieth—also happen to be among the few that have successfully played the game of global catch up. That is, they were among the few that actually did experience income convergence with the wealthy.[19] They effectively entered the elite club of advanced industrial nations and left the rest of the developing world in the dust.

Anybody can make textiles, the thinking goes. Very few, however, can—fill in the blank for the historical period in question—make locomotives, roll steel, assemble automobiles, or fabricate semiconductors. Markets can get you naturally into apparel. They cannot, it seems, get you naturally into automobiles, aerospace, or biotech. Indeed, that is precisely why China's meteoric rise into advanced electronics, computers, and telecommunications equipment appears so unsettling. It is one thing to see "made in China" stamped on a shirt but another entirely to see it on the latest laptop or wireless device. The latter really does smack of "rising Japan" or "rising Germany."

But what exactly do we think differentiates advanced industries from their low-tech brethren? What do we imagine taking place in high-end electronics production that is different from, say, sock manufacturing?

Why should increasing returns to scale apply to the former but not the latter? How do we expect things on the ground in a rising global powerhouse (whether a Germany, Japan, or China) to look different from what goes on in an ordinary industrializer (a Bangladesh, Sri Lanka, or Philippines) that might be deeply enmeshed in global apparel production?

To arrive at an answer, we need to step back for a moment and think about something people do not normally associate with industrial production—information. Industrial production is at one level about machines and tangible products. At a different and arguably more intrinsic level, it is about information. The making of any product—high- or low-end—involves the transfer of designs (information, really) onto physical materials.[20] Hypothetically speaking, somebody coming up with a new product first sketches a design on paper. The design specifies the material to be used—say, wood, in this case—and the dimensions to which that wood needs to be cut. A craftsperson, then, looks at the designer's sketch (design information), chooses the appropriate saw (which, as a tool with a particular type of blade, has a certain amount of additional design information embedded in it), and then cuts the wood. By doing so, the craftsperson imbeds design information into a physically material, effectively transforming a chunk of wood into a part or component. As more and more components are cut, more and more design information is imparted to material. Finally, as long as the design information was reasonably accurate, the parts can all be fit together into a rough product.

Often, though, the design information is not quite complete—things get left out, pieces end up cut imprecisely, and so on—so the parts initially do not fit together perfectly. To compensate, the craftsperson then sands a bit here, recuts a bit there, and everything works out fine. In essence, the craftsperson, relying on his or her own knowledge and experience, imparts additional design information onto the material, and the final product turns out fine.

For low-end industry—sneaker or apparel manufacturing, for example—the information necessary for transforming raw materials into finished products is generally thought to be fairly straightforward. It can effectively be codified in widely available rules that describe standardized processes. The design for something like socks is simple, and the skill required to transfer that design information onto knitted material is fairly minimal, at least in theory.

These qualities amount to both a blessing and a bane. They make getting into low-end industries easy (or to put it somewhat differently, they ensure that barriers to entry are low), but precisely because so many players can jump in, competition becomes intense. Moreover, standardized production processes lead to standardized, difficult-to-differentiate products—commodities, essentially. Hence, competition can take place only over cost (as opposed to product differentiation), and cutting costs in these industries is all about cutting wages. In the end, firms compete by squeezing their workers and chipping away at their own and their competitors' margins.[21] In other words, they race one another to the bottom. Such conditions explain both why such industries crop up in poorer, marketizing countries and why the countries hosting them rarely prove able to upgrade into higher value endeavors.

Advanced high-tech industry (whether the steel and railroads of yesteryear or the autos and semiconductors of more recent times) has traditionally been understood as a totally different animal. Historically, these industries have been associated with huge upfront capital costs: expensive production facilities and lots of heavy equipment. Such equipment and tools—presses for the stamping of metals, lasers for the precision cutting of plastics, and so forth—are phenomenally costly because contained within them are extensive quantities of knowledge and design information. Just to acquire them, one has to mobilize considerable capital, a major barrier to entry in itself.

Having overcome that hurdle and jumped in, one still needs extensive knowledge and skill to carry out production. The processes involved, at least traditionally speaking, are anything but standardized. They involve huge amounts of information, more than could possibly be set down in designs or embedded in machines. Sophisticated as the designs and machines may be, even after they are brought to bear, huge amounts of know-how—information "stored" in the minds of skilled technicians—are still needed to get to a usable finished product. Put somewhat differently, participation in these industries requires titanic quantities of tacit knowledge, the kind of know-how that comes from experience and that can never quite be recorded as a recipe in a book. In these industries, you get ahead by learning, and you learn by doing. If low-tech soft industry is like a paint-by-numbers kit—you buy the kit, you fill in the colors as indicated, and you get a recognizable if uncreative painting as a result—high-tech industry is one-of-a-kind art. Rather than paint-by-numbers, it is, in a way, a Michelangelo original, something only a select few artisans can approach.

Such industries—again, at least according to the traditional understanding—are all about proprietary processes and highly differentiated products. Only a small number of firms hailing from a small number of advanced economies are ever capable of engaging in this form of production. As a result, competition tends to be oligopolistic. Only a few firms are in the game, and their profit margins tend to be large. They can then pump those profits back into innovation and new product development, thus ensuring their standing at the top. The story becomes one very much of increasing returns to scale.

And we often associate this story with a particular type of production organization: the massive, vertically integrated corporation.[22] Whether it was German steel firms in the nineteenth century or American auto giants in the twentieth, such firms for many people even today define modernity. To some degree, this makes sense given the sorts of challenges such firms were historically able to overcome. Advanced industry for well over a century was one and the same with advanced manufacturing, the coordination of multiple assembly-line steps and the fitting together of multiple highly complex components. The whole chain had to work exactly right for the final product to come out decently. Massive amounts of tacit, uncodifiable information had to be brought to bear to make this happen. Regardless of the efficacy of initial designs, final products involved so many different parts interacting in so many different ways that designers could not possibly predict performance characteristics in advance.[23] They may have known how they would like the product to perform, but realizing that goal in the initial design was almost impossible. Instead, engineers, technicians, and skilled assembly-line workers, with all their combined creativity, had to hit the shop floor, tweak parts, shift designs, reposition machines, or fine-tune processes so as to come up with a product that reflected in practice what designers had envisioned in theory.

From this perspective, then, what really makes advanced industries work—whether in the past or present—are large manufacturing-focused organizations armed with tacit knowledge. The knowledge accumulates through the act of manufacturing itself—the bending of metal, the stamping of parts, and the constant movement of engineers back and forth in the trial-and-error process of making components fit better and final products perform more effectively. Precisely because the knowledge is tacit, it must be transmitted through face-to-face interaction—conversations, meetings, and on-the-fly consultations on the shop floor. Hence, it follows logically that the various pieces of production—product definition, detailed design, design for manufacturability, component design and manufacture, subsystem assembly, and final product assembly—all



need to be located in the same place and under one corporate roof. When this process works right, all the knowledge that accumulates over years of manufacturing experience—all the trial-and-error experimentation, all the problem solving, all the refined techniques—becomes embedded in the organization. The firm, in effect, becomes a vessel for innovation, a sort of national industrial treasure.

This national treasure, from its basis in technology- and capital-intensive manufacturing, then develops a series of complementary, knowledge-based skills.[24] It develops managerial expertise in handling large-scale operations. It develops marketing expertise as it pushes a steady stream of products into new locales and learns to respond to new customer demands. It develops financing expertise to fund its own operations and its customers' credit needs. It develops research capabilities as it seeks to place itself even further out on the frontiers of technology. All of these capabilities are understood to derive from manufacturing, and each for the company becomes an additional source of differentiation and competitive advantage.

All this knowledge, in turn, repeatedly feeds back into better and better manufacturing. Such learning can manifest itself in a variety of ways. Information might be managed more efficiently in the existing production process, thus allowing for higher product quality, fewer discards, and leaner inventories, all important issues for cost reduction. Or accumulated knowledge might permit upgrading into entirely new, innovative products. Either way, the firm effectively innovates and upgrades into activities that few if any competitors can duplicate.

To many Americans, this story should sound familiar. It is basically that of the U.S. auto industry in the first half of the twentieth century. So too is it the story of the Japanese, who supplanted the Americans by the end of the century. Large conglomerates like Toyota, often with a certain amount of governmental support, aggressively focused on learning and skill development.[25] At first, they concentrated on low-end products but almost always with an export focus. Global markets served as benchmarks for cost and quality. If the product proved uncompetitive globally, then the firm would be deemed a failure, and its practices would have to be changed. If the product proved successful, the firm would then focus on further cost cutting, further quality enhancement, and movement upward into higher value, higher margin products.[26] Time and again, this happened with Japanese firms. Later, the process would repeat itself with South Korean conglomerates. Whether for Nissan, Toyota, Komatsu, POSCO (Pohang Iron and Steel), Hyundai, or Samsung, export-oriented, globally focused manufacturing became the linchpin for catching up with leading firms from the United States and Europe. No wonder Americans worry about the apparent decline of U.S.-based manufacturing, and no wonder they are looking over their shoulder at China.

Indeed, the rarity with which nations have successfully pulled off "catch up" just adds to its mystique. Numerous countries have tried and failed. Several undoubtedly had the money and basic expertise to jump in—the Soviet Union, East Germany, and Czechoslovakia, for example, in autos, or the Chinese early in the 1970s in commercial airliner production. They bought all the right machines, and they duplicated existing, proven designs. In effect, they accessed all the codified information that was available. In some cases, they were able to turn out products—Lada sedans, the (in)famous Trabant subcompacts, Skoda hatchbacks, and in the Chinese case, a single flyable Boeing 707-like Y-10. Producing a poorly performing product, however, is different from producing a usable one. And a usable product is still different from one actually produced on a commercially competitive basis. In a way, these industrial aspirants mistakenly thought they could achieve Sistine Chapel-like products by purchasing paint-by-number kits. That they ended up with the equivalent of cheap motel room art—cars whose doors did not shut or airplanes whose excessive weight made carrying passengers or freight impossible—confirms how truly important tacit knowledge really is in these special industries and how difficult it is to capture commercially in a firm.

That, of course, makes the cases of success even more conspicuous in our minds. Virtually every great nation in modern history has been associated with storied industrial conglomerates. Some of these commercial titans remain today. Others have departed the scene. Their names, though, are recognized worldwide: Krupp, Thyssen, U.S. Steel, General Motors, Toyota, IBM, Philips, Standard Oil, Bell Labs, among others. And now from China, we seem to be witnessing the emergence of a new set of titans: Lenovo (which acquired IBM's PC business in 2005) in computers; Huawei and ZTE in telecommunications; PetroChina, SinoPec, and CNOOC in oil and gas; Haier and Galanz in appliances; Gome (Guomei) in retail; and so on. Somehow, China appears to have achieved that which has eluded so many other countries: the quantum leap from commodified, low-end production to state-of-the-art, advanced industry. Just consider what China and its leading companies were able to accomplish in the opening ceremonies of the 2008 Beijing Olympics. The event's unparalleled technological wizardry, its sheer scale, and the incredible amount of coordination



involved were breathtaking, to say the least. And now China holds the largest reserves of foreign currency in the world. It appears unstoppable. Why shouldn't it be understood as Germany and Japan redux? Why shouldn't it be seen as the latest instance of an emerging great power rising on the basis of its manufacturing-based, industrial might? And why shouldn't we be concerned?

### Shadows of Doubt: Four Puzzling Aspects of Chinese Industrial Development

Arguing that China has become a global hub for high-tech manufacturing makes a lot of sense. Arguing that it is thus duplicating the developmental trajectory of earlier risers (i.e., Germany, Japan, South Korea, etc.) makes a lot less sense. China is most definitely involved in high-tech industry but not in the way that such involvement traditionally is supposed to look. That is, the activities going on in China today bear almost no resemblance to what we saw in prior eras in Germany, Japan, or South Korea. Either China is not what we think it is, high-tech manufacturing is not what we think it is, or both.

Four factors, in particular, make China look different from previous risers. First, as mentioned, Chinese industry, particularly in export-oriented sectors, exhibits extremely high levels of foreign investment and ownership. In 2008, foreign invested enterprises accounted for 55 percent of China's total exports and 54 percent of the nation's imports.[27] In China's higher tech, higher value consumer product sectors (i.e., DVD players, TVs, high-end electronics, microwave ovens, etc.), foreign-invested firms by the mid-2000s were accounting for almost 90 percent of exports.[28] Those are incredibly high numbers, historically unprecedented for large, export-focused economies. Japan and South Korea grew with almost no FDI or foreign ownership, and even Taiwan—an island exporter once relatively reliant on multinational firms—never approached the levels of FDI dependence seen in China today.

Second, much of the advanced production going on in China today—much like in lower tech soft industries—involves export processing. Semifinished or finished components are brought in from overseas locales, usually neighboring Asian nations, assembled into finished products, stamped as "made in China," and then shipped out to markets in North America and Europe. From the early 1990s to the present, China's strongest export growth has occurred in electronics, computers, and telecommunications equipment, areas that have increasingly supplanted traditional soft exports like apparel, textiles, footwear, and toys. Yet, these higher end, high-tech areas are also the ones in which the export processing trade has grown the fastest. In 2006, for example, "electrical machinery and mechanical appliances" (i.e., televisions, MP3 players, DVD players, etc.) accounted for about 47 percent of China's total exports.[29] About 70 percent of those electrical appliance exports, though, pertained to processing trade.[30]

The Apple iPod is a typical example of the phenomenon. Accurately stamped "assembled in China," the product is for the most part composed of components brought in from beyond China's borders. As described in an extremely interesting 2007 report by researchers from the University of California, Irvine, a thirty-GB iPod in 2005 retailed in the United States for around US$299.[31] The rough cost of all the inputs—in other words, the price Apple paid for the finished iPod when it came from a Taiwanese-owned, China-based contract manufacturer—was estimated to be US$144.40. Of that US$144.40, 3 percent (US$3.70) went to the Taiwanese assembler operating in China, 51 percent went to the Japanese hard drive producer (who made that component in China, again using imported parts), 14 percent went to the Japanese display module producer (who made the display in Japan), 3 percent went to the American semiconductor designer (who, as a design house, had negligible production or overhead costs), and 2 percent went to the Korean memory chip producer (who produced those chips in Korea).[32]

One interpretation is that the advanced products being produced in China are based not only on imported components but components that embody the most sophisticated aspects of the finished product. In other words, all the things we associate with advanced industry and high-tech products—the knowledge, the innovation, the sophistication—are embedded in the components, which for the most part are made outside China by non-Chinese companies. Even when pieces are made in China—again, often with imported subcomponents—they are generally done so by non-Chinese companies. Indeed, even product assembly, an activity we rarely view as a high-tech or high-value endeavor, is done in China by foreign-owned companies.

Third, many of the ostensibly advanced, high-tech products that come out of China today—regardless of who produces them—behave on the market in ways we associate with commodities rather than in ways we associate with cutting-edge goods. Items like DVD players



and microwave ovens, all classified as high-tech exports in the statistical compilations of China's Ministry of Science and Technology, can now routinely be purchased in the United States for under US$50. They have effectively become inexpensive, undifferentiated products—commodities. Personal computers, at an obviously higher price range, have taken on this quality as well, a factor that contributed to IBM's decision to sell its PC division to China's Lenovo.[33] All but the highest end cell phones and digital cameras also now behave increasingly like commodities. They are sophisticated and high tech, but they have come down substantially in cost and are treated by consumers as undifferentiated, routine purchases. Today, buying a "made in China" MP3 player or microwave oven is for many consumers not so different from buying a "made in China" T-shirt. Products like the iPhone, gadgets people are willing to buy at a substantial premium, seem now more the exception than the norm, and even then, the value appears to be captured by the firm doing the design and branding rather than the manufacturing.

And that leads to a fourth point. Whirlwinds of innovation are taking place in advanced industry today but not primarily—or so it seems—in the companies actually doing the manufacturing. The latest innovations in wireless devices, for example, seem to involve battles between Apple, Palm, Research in Motion (the maker of the BlackBerry), and Google, companies that outsource their manufacturing to others. We do not hear much in this context about the China-based assemblers of those products, and we hear even less about indigenous Chinese firms. Furthermore, many new innovations seem to involve components rather than final products: Intel versus AMD processors, Palm-powered versus Microsoft-powered PDAs, Apple versus Windows operating systems, and so on. Nowhere really do we hear about Chinese players in the mix, though almost all the innovations we see are in one way or another embedded in products made in China.

None of these observations is definitive. Taken together, though, they describe an overall pattern. China is growing economically by deepening its involvement in export-oriented manufacturing. Yet, that manufacturing is managed in large part by foreign-owned and foreign-invested companies. In addition, that manufacturing appears in many cases to be detached from knowledge-intensive activities and products. Much of the innovation that we witness appears to be carried out by companies quite removed from the ones actually bending the metal, so to speak. And a number of the advanced products coming out of China are sold not as highly differentiated specialty items but instead as commodities.

We need to step back and figure out what this all means both with respect to China and global production more generally. Why are so many of the production activities that once had to be colocated in a single industrial conglomerate now dispersible across different firms and geographies? How and where is innovation happening now that the activities are so broken up and spread apart? Why do so many of the innovators appear not to be engaged in the physical act of manufacturing? And why is so much of the manufacturing going on in China managed by overseas firms? What does this all mean for China, and what does it mean for us?

## The Shifting Architecture of Global Production

For many people, globalization amounts to a set of new circumstances fundamentally shaping our lives—a speeding up of activities all around us, an extension of activities that were once local to the farthest reaches of the globe, and a drawing in of activities from those farthest reaches right to our own doorsteps. Everything now—from new technologies and newly rising nations to new global climatic patterns and new security threats—seems so sped up and interconnected. In many ways, this is what globalization is all about. Yet, in a deeper sense, these aspects are derivative of something else, a completely new way of organizing production. That new mode of organization, in turn, is derivative of the most fundamental new capability of all: digitization.

Digitization, the ability to represent almost anything—an object, an image, a sound, a signal—in a structured sequence of binary digits, has enabled virtually everything we associate with globalization. It has revolutionized our lives in the process. More precisely, digitization, coupled with technologies like the integrated circuit that permit the storage and handling of almost limitless quantities of binary data, has revolutionized the nature of information. Information of the type once too complex to be represented as a set of discrete steps and rules can now easily be set down as code. The codified data, in turn, can now be easily stored and recalled, as we ourselves know in our everyday use of laptops, cameras, USB drives, and other digital devices. So too can that information be easily transmitted anywhere in the world, instantaneously, and at extremely low cost, again something we take for granted in our daily downloads, uploads, and e-mails.



All of this has changed the way we as individuals live. More profoundly, it has changed the way we as a civilization produce. Human civilization, from the Bronze Age to the Computer Age, has in large part been about making stuff. And making stuff, as we noted previously, has always been largely about managing design information. Throughout history, revolutions in production—revolutions in the way we make stuff—have marched hand in hand with revolutions in information management. Digitization has ushered in the latest of these revolutionary moments.

How exactly, though, does digitization—the ability to specify, codify, and transfer huge amounts of data—change production? As we discussed earlier, for much of history, the defining characteristic of advanced industry—that which separated it from ordinary industry and restricted it to a select few elite players—has been informational complexity. These were the kind of industries that produced complex products through complicated multistep production processes. Vast amounts of design information had to be transferred onto physical materials. Given technologies available at the time, however, only a small portion of this information could be codified in blueprints, schematics, or production rules. The rest had to come through the accumulated experience and knowledge of people, who were then generally organized hierarchically within a single firm.

But now, digitization and computerization have erased much of that. By permitting the codification of almost all information, they have effectively eliminated what made advanced industries "advanced." Today, design information, down to the most detailed specifications, can be set down in code. Codified information, in turn, can be transmitted to a variety of different players or programmed directly into the operating software of machines that can then stamp out precisely formed components. Those components can then be fit together again through codified information—highly specific standards and formal rules of connectivity. Components no longer need to be codesigned and coproduced but instead can be made as stand-alone modules by separate highly specialized companies. Because so much design information can be codified, the production process itself can be modularized—broken apart into separate stand-alone steps that can each be done by a specialized firm.

The manufacturing know-how of a single massive conglomerate has ceased to be the "secret sauce" needed to make production work. No longer is so much tacit knowledge—so much of the shop-floor-based engineer's or machine operator's Mr. Fix-it know-how—needed in the production process to make up for the informational gaps that used to exist in formal designs. No longer do people, bound by a single firm's way of doing things and imbued with their own experience-based problem-solving skills (developed, generally, through an entire career spent in that same firm), have to continually move back and forth across the whole production process, tweaking here and refining there. In the past, especially in advanced industry, production was about complex processes glued together through the tacit knowledge of a single organization. Today, with digitization and modularity, production in all industries—from the most sophisticated to the least—is about complex processes linked by codified standards but spread across a bewildering array of individual producers.[34]

At times, it feels as if almost anything can be done anywhere by anybody. Take computer production as an example. In the 1960s, during the early days of the mainframe computer, leading innovators like IBM—all massive conglomerates—designed and produced not only the machine itself but all its key components (transistors, processors, memory chips, switches, terminals, etc.), its operating system, and its related software. For years, much of that was done in a single facility in Endicott, New York.[35]

Now, as we all know, things couldn't be more different. A typical laptop computer most likely is branded by one company, one based perhaps in California or Texas, but is assembled by another, one likely headquartered in Taiwan but doing the hands-on assembly operation in China. Design work may be shared across the engineering teams of both firms. Meanwhile, the computer's high-value "guts" are made in a variety of places by a variety of different firms. The microprocessor, a branded component in its own right ("Intel inside"), may be produced by an American company in a U.S.-based semiconductor fabrication plant ("fab") but is then assembled and tested by the same company's operation in Malaysia. The screen may be produced by a Japanese or Taiwanese company, the disc drive by an American company operating in Singapore, the operating system by another American firm operating worldwide, and so on. Thus, for the production of a single high-tech product, manufacturing activities end up spread out across North America, Europe, and Asia.

But this new architecture of production involves more than just outsourcing and offshoring, the migration of manufacturing to new people and places. It is not only—or even primarily—a story of new competitors moving up rungs of a ladder and displacing old competitors in the process. Instead, it is about organizing the ladder in an



entirely new way. The ladder has become totally transformed—bent in different directions, flipped end on end, and multiplied in a variety of different incarnations. Along all these new ladders, players from emerging and advanced economies alike are on the move and interacting. Competitors from China are scurrying upward but so too, and even more impressively, are ones from the advanced industrial world. Often, they are doing so in complementary, interrelated ways. Indeed, what is now being done in emerging markets has enabled transformative upgrading in places like the United States.

China undoubtedly now plays a central role in the new architecture of global production. Yet, this story is as much about us as them. It is as much about our own transformative upgrading as theirs. In fact, our respective experiences in rapid industrial upgrading are deeply intertwined. In the sections to follow, we examine how this is so as we march through a variety of manifestations of twenty-first-century modularized production.

## The Effect of Modular Production, Take 1: The Barriers (to Entry) Come Tumbling Down

By permitting the codification of information—and thus reducing the importance of prior experience and tacit knowledge—digitization has opened up high-tech industry to new commercial entrants. As we all know, Chinese firms have rushed in en masse. Yet, though they are now present in industries like information technology and high-end electronics, their presence is for the most part confined to the simplest, most codified activities within those industries. That is, they are in, but not in deeply. They may be producing only a small, relatively simple part of a much more complex final product. Or they may be doing final assembly of a series of components produced by others outside China. Or they may be supplying a low-end IT network that leading global providers have long since moved beyond.

The point here is that to understand what many Chinese firms are doing—indeed, what anybody today is doing—one cannot think as we once did about industries. Instead, we should think about activities. It no longer makes sense to suggest that certain industries on the whole—whether IT, computers, aerospace, or any other—are inherently complex or inordinately lucrative. Now, production processes in virtually all industries—whether advanced or ordinary—can be split up into separable, discrete steps. Some of these steps—again, both in advanced and ordinary industry—have become standardized and commodified. Relatively simple to enter, some of these steps—activities, really—behave much like our prior understanding of low-tech industry as a whole. Meanwhile, other activities today still defy codification and standardization. They remain deeply knowledge intensive, exclusive, and highly profitable. In effect, they behave like our prior understanding of advanced industry. Modularity, by breaking up production processes across the board, has lowered barriers to entry in virtually every industry, high-tech and low. But where those barriers have really fallen is not in any single industry as a whole but rather only in particular kinds of activities across many industries. Now, therefore, whether we are thinking about apparel or aerospace, we need to think about low-value versus high-value activities within each and every one of those industries. A company today can jump into aerospace but end up doing nothing more exclusive than what it had been doing previously in basic electronics assembly. Conversely, a company can be in apparel today but doing highly specialized, difficult-to-replicate, high-value activities.

In the Chinese case, we have seen producers rush into newly opened industries but largely in the low-value end of the activity spectrum. What appears as upgrading from soft industries to high-tech ones, then, often involves very little upgrading at all, at least in the way many of us understand the term.

A survey of Chinese firms that I conducted in 2001 in cooperation with the World Bank illustrates the point.[36] The survey focused on high-tech industries—sectors like electronics, IT, and automotives where one would expect to find more sophisticated commercial activities. Several things became immediately apparent. First, the Chinese companies that participated in the survey—1,500 enterprises spread across five major cities—were unquestionably engaged in global production. Almost all were either producing components whose designs and specifications were set by foreign firms or doing export processing and final assembly for foreign-branded products. Second, the survey respondents were generally operating at much smaller scale and with much narrower profit margins than global counterparts in the same overall industry. Third, the Chinese firms, though engaged in high-tech industries and integrated into global production chains, clustered around the most standardized and nondifferentiated activities in those chains. Only a small portion of the firms surveyed, roughly 15 percent, reported doing any design work for foreign customers.



An even smaller portion, 7 percent, reported doing any R&D work or any provision of specialized, proprietary services to customers. In fact, deeper relationships with other players up and down the supply chain—let alone with consumers of the final completed product—seemed to elude these firms entirely. Most just moved their output through trading companies, effectively "throwing their products over the wall" instead dealing directly with actual end users.

All in all, these firms were rule takers rather than rule makers in the game of globalized production. They had rapidly moved into activities thrown open by modular production and digitization. Once in, though, they were having a difficult time moving up. As survey respondents themselves reported, they were struggling just to survive in an intensely cost-competitive environment. Pump money into R&D and upgrading? Where were such funds supposed to come from? Where was the time to devote to research going to come from? Rather than squirreling away profits for investment in upgrading, these firms were doing the opposite—cutting their margins in a bid for survival.

Chinese firms, though, do have to make substantial investments just to stay in the basic manufacturing game. In this sense, it is not quite accurate to say that jumping into standardized manufacturing is a trivial matter. It is also not completely accurate to suggest no upgrading takes place in these new participants in global production. Just to participate in supply-chain-oriented work, firms have to substantially upgrade their capital equipment and their managerial capabilities. Complex supply chains, though they involve many different firms, are frequently driven by the demands of a few dominant players such as Boeing, Coca-Cola, Siemans, Johnson Controls, Nike, or Wal-Mart. Such firms set the standards, define the products, issue the designs, and push the delivery schedules. Although neither omnipotent nor immune from hold-up problems by partners in the supply chain, these firms are extraordinarily powerful, particularly relative to those performing truly commodified activities like basic product assembly or basic component fabrication. Those firms at the bottom of the food chain have to meet exacting specifications, quality standards, and schedules, all passed down from above. Moreover, they need to respond to frequent changes along all these dimensions. If they cannot respond, particularly if they are performing a basic assembly function, supply-chain leaders will take the business elsewhere.

So what is the product assembler to do? How can it firm up its position in the chain? One thing it tries to do is invest in the latest capital equipment—state-of-the-art knitting machines, advanced metal stamping machines, precision machine tools, or whatever else is required for the activity in question. By purchasing machines that are embedded with complex design information—the kind of information that previously could be conveyed only through the tacit knowledge of a skilled technician—the assembler can more easily meet the quality and flexibility standards demanded by supply-chain leaders. Most of these tools are imported from abroad.

This story unquestionably has positive aspects. After all, on an aggregate level, purchases of such infusions of technology have driven economic growth in China. Much of the country's growth story has been about productivity gains achieved through movement from low-technology conditions—minimally mechanized agriculture and basic industry—to higher technology ones. That is, by purchasing foreign technologies—know-how embedded in machines—China's industrial economy has been able to realize higher output per worker, greater returns, and all the attendant effects of wealth generation.

This story also has positive aspects for those outside China. China may be a massive exporter today, but it is also a massive importer both of knowledge-intensive components used in export processing and of capital equipment necessary for modern manufacturing. In 2008, U.S. exports to China amounted to US$71.5 billion, about 5.5 percent of all American exports that year and an increase of nearly 10 percent from the previous year's exports to China.[37] China today is the third largest purchaser of U.S. goods globally, trailing only Canada and Mexico. What kinds of things have American companies been selling to Chinese customers? Electrical machinery and equipment (i.e., computers, computer-aided design systems, etc.), medical equipment (CT scanners, MRI machines, etc.), power generation equipment, heavy transport equipment (construction vehicles, excavators, cranes, etc.), and of course, aircraft.[38] The story is similar but even more pronounced in Germany's trade with China. China is Germany's second largest export market outside the European Union, trailing the United States but ahead of Japan.[39] And what are Chinese companies buying from the Germans? Again, plant machinery, electrical equipment, optics, transportation equipment, and so on. When a semiconductor fab (fabrication plant) goes up in China, more likely than not it is using hundreds of millions of dollars of nanomanufacturing equipment from the likes of Lam Research, Applied Materials, and KLA-Tencor in the United States or ASML in the Netherlands.

When Chinese companies purchase such equipment, they are, in a sense, upgrading from low-technology conditions to higher level ones.



What they are not really doing, however, is upgrading to higher value activities. In other words, they are purchasing know-how that has been codified and embedded in machines. Those expensive machines, then, permit a Chinese factory with a low- or semiskilled workforce to manufacture a high-quality component consistently, flexibly, and rapidly—performance characteristics absolutely essential for playing in the global supply-chain game. Worth remembering is that all this has to be done just to participate in the basic manufacturing—the straightforward assembly—of fairly simple commodity products. Consider, then, how much more is needed to move into higher value activities like R&D, product design, branding, or customer service.

Moreover, all of this technology adoption and operational flexibility must be managed, which is a tall task in its own right. Some kinds of know-how can be purchased as embedded information in machines. Other kinds—managerial know-how—while not available in machines, can still be purchased in a sense. It is purchased as foreign direct investment (FDI). When a Chinese corporate entity sells a piece of itself—an ownership share—to an outsider, a two-way transaction is taking place. The foreigner is acquiring an ownership stake in the Chinese firm (often a majority one), which carries with it a substantial amount of managerial control and a claim to future revenue streams. What does the Chinese entity get in return? Some scholars, including my friend and brilliant colleague at MIT, Yasheng Huang, have suggested that they don't get much, save for decent treatment in a poorly designed, politically misguided Chinese regulatory environment that affords foreign-owned entities better treatment than domestic private firms.[40] According to this perspective, the Chinese entrepreneur, simply to get a fair shake in his or her own country, must sell out to the foreigner. Huang is undoubtedly correct that private entrepreneurs have suffered considerable discrimination at the hands of the state in China. Nonetheless, I would argue that such discrimination is not the only, or even primary, reason for the prevalence of foreign ownership. Instead, what drives demand for FDI—the willingness of Chinese industrial entities to sell shares to outsiders—are the managerial challenges associated with operating in global supply chains. By selling off stakes in themselves, Chinese firms are effectively purchasing managerial know-how not unlike how they purchase know-how in imported manufacturing tools. And just as know-how embedded in a machine often remains in the machine (the machine is not easily reverse engineered), so too does managerial know-how often remain embedded in the foreign manager. That is, the knowledge is slow to transfer over to

Chinese managers. Hence, we see persistent patterns in China of high levels of sophisticated technology purchases and high levels of foreign ownership of domestic industry.

This need not be viewed either positively or negatively. It should by no means be taken as a slight to the Chinese system. That China has been able to purchase the machines, welcome in the foreign owners, and build the supporting market institutions, and do it better than virtually every other developing world locale, is a credit to the nation and its population. At the same time, what the Chinese experience indicates is that for low- and middle-income nations, the era of modular production has brought anything but a flat world. Many have fallen behind. China, the greatest success story among them, can claim the signal achievement of having kept pace, playing its part in a global production system effectively controlled by—and often convulsed by—foreign commercial entities.

Because the focus for Chinese industry is now so much on basic manufacturing assembly, outcomes in high-tech sectors look much as they do in ostensibly lower end areas like apparel. The relationship between Wal-Mart and Chinese suppliers in the knitwear industry is fairly typical.[41] Wal-Mart since the early 2000s has operated a major sourcing network in China. By the mid-2000s, the company was annually sourcing from China roughly US$18 billion in goods—mostly clothing, home decor items, and toys.[42] The exact figure is hard to determine because Wal-Mart reports only direct purchases by its China-based sourcing operation, leaving unstated the purchases done through China-based agents with whom it works closely. By splitting the figures in this way, a practice dating from 2005, Wal-Mart can distance itself from some of the political headaches that come from racking up high levels of Chinese imports, not to mention the public relations headaches that come from reports of substandard conditions in China-based suppliers.

Regardless, for many Chinese suppliers, particularly in areas like knitwear, Wal-Mart is far and away the largest customer. The Boshan Linar Garments Company in China's Shandong Province is typical. In 2006, roughly 80 percent of the company's output went to Wal-Mart.[43] Similar numbers obtained for the "king of the sock industry" (*waye dawang*), China's Langsha Knitting Company. Suppliers like Langsha, Boshan, or the Jiaxing Yishangmai Fashion Company, a major sweater exporter in eastern China, generally operate in one-industry towns surrounded by hundreds or even thousands of similar firms producing similar kinds of goods. Yiwu City, an apparel manufacturing hub in China's Zhejiang Province and home to Langsha, has more than 14,000 enterprises spread across everything from hosiery to zippers and accessories.[44] To distinguish themselves from the crowd and attract the business of major buyers like Wal-Mart, suppliers, as discussed earlier, often must import expensive capital equipment—knitting machines, embroidering equipment, cutting machines, and so forth. Such equipment is necessary for achieving the tighter weaves, higher quality standards, and more varied production runs expected by overseas customers. The financial and managerial demands of these teched-up operations then push producers to demand FDI—that is, enter joint ventures or other co-ownership arrangements with foreign manufacturers, whether from Europe, North America, or Australia, thus adding claimants to already narrow profit margins.

Having done all this just to enter the supply chain, producers still get squeezed by rising production costs and increasing competition. By 2007, Chinese garment producers, as in so many other manufacturing sectors, were facing rapidly escalating wage bills, energy prices, and raw material costs. At the same time, new competitors from places like Indonesia and Vietnam were nipping at their heels, luring away North American retailers and their purchasing agents.[45] In 2007, Langsha, insisting it could not survive on the profit margins offered by Wal-Mart, severed the relationship for a period of time. That same year, Jiaxing and Boshan also lost all or some of their Wal-Mart orders. Meanwhile, these suppliers were stuck with the capital equipment and attendant financial obligations they amassed simply to participate in global production in the first place.[46] It is an awfully tough, unforgiving game to play.

### *The Smile Curve*

One way to conceptualize the phenomenon is through what Stan Shih, the founder of the Taiwanese computer company Acer, terms his "smile curve" for value creation.[47] The curve, derived from Shih's observations of the IT industry, attempts to compare the relative profit margins of all the different activities needed to produce a finished product—a computer, say—in a high-tech knowledge industry. In many respects, though, it can be applied to any industry today. As indicated by figure 4.1, the high-value portions of the curve appear at the extreme edges—upstream in knowledge-intensive and highly proprietary R&D, product definition, and design and downstream in equally knowledge-intensive branding, marketing, distribution, and customer service. The activities surrounding the invention of new technology,

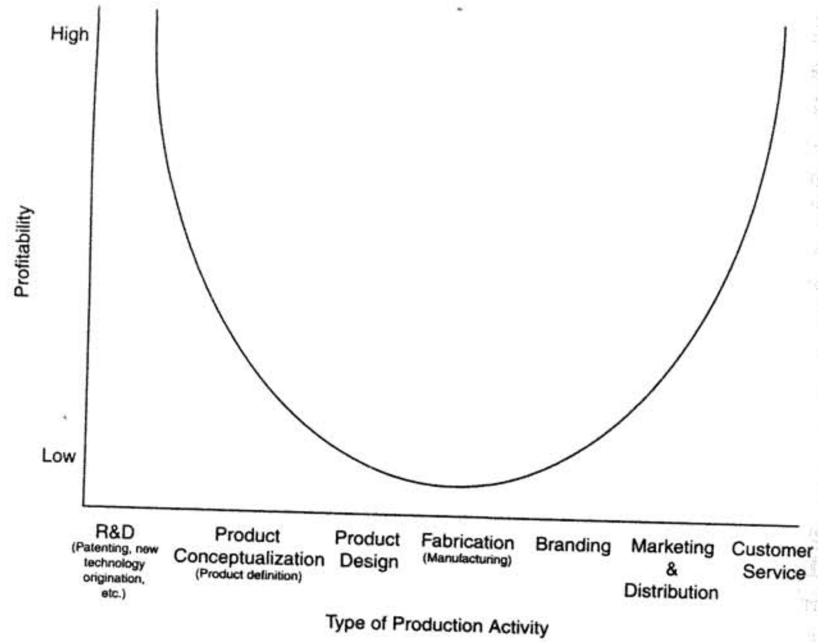


FIGURE 4.1 Stan Shih's Smile Curve

like those involving actual engagement with end users, involve firm- and person-specific know-how rather than standardized, codified routines. Hence, such activities remain proprietary and high value.

Manufacturing, however—or more precisely, product assembly—ends up as a standardized, low-value affair. As long as you buy the right machines and, for slightly more sophisticated manufacturing activities, relatively easy-to-obtain foreign managerial expertise, you are in. But so too is everybody else who does the same. The lesson is clear. If you want to survive over the long run, and especially if you want to make money, you have to get out of the smile's trough and up into its dimples.

If the curve were applied to China, one could argue—somewhat accurately—that producers there are stuck almost exclusively in the trough. They are suffering the plight of developing country manufacturers worldwide. The very thing that granted them entry into manufacturing—codification of information—now haunts their existence as they struggle for dwindling profits in completely standardized operations. The only difference in China is that producers there have struggled better than counterparts elsewhere. Thus, while their entry into commodified production may have displaced workers in comparable activities in the United States—whether in footwear, apparel,



furniture, or similar industries—most of those activities departed American shores decades ago. Instead, the workers who have really been unseated by the Chinese are those in other developing world locales: Southeast Asia, South Asia, Mexico, and much of the rest of Latin America. As indicated by the Langsha example, though, some of these locales—Vietnam, the Philippines, Indonesia—are fighting back, thus inducing further cost cutting by the Chinese and a more rapid "race to the bottom" for producers everywhere.

## The Effect of Modular Production, Take 2: Upgrading by Foreign Contract Manufacturers in China

Despite all the challenges just discussed, there is nothing about modular production that absolutely precludes movement up the smile curve. Indeed, within China, there are several noteworthy examples of manufacturing-centered upgrading. Where they have occurred, though, are primarily in overseas-owned, especially Taiwanese-owned, firms. Such companies, while maintaining a substantial presence in China, are actually multinational manufacturing specialists that have been able to integrate China-based operations into a broader set of activities. In so doing, they have become potent global players. Some of the best examples are companies like Quanta, Foxconn, Delta, and ASUS, Taiwanese-owned multinationals that now perform vital roles in global electronics and IT production.[48]

These firms share a set of basic characteristics. First, they all started as contract manufacturers, specialists in the fabrication of all manner of electronics products and componentry. No matter what the component—motherboards, graphics cards, cables, power supplies, and so on—they could produce it inexpensively as long as its design was fairly well established. Their expertise lay neither in product definition (the initial conceptualization of a product), product design, branding, nor marketing. They simply knew how to build stuff cheaply and almost always for somebody else—whether IBM, Dell, Hewlett-Packard, or any other brand leader—whose name ended up on the product and who garnered the bulk of the profits.

Second, over time, in large part through huge manufacturing campuses that they located across the Taiwan Straits in mainland China, these firms have grown to tremendous scale. Foxconn today, in its main manufacturing site in Shenzhen, China, employs upwards of 300,000 people and manufactures virtually every laptop computer and printer sold by Dell and HP.[49] Taipei-headquartered ASUS, with manufacturing sites in Suzhou and Shanghai, by 2008 was producing more than 24 million motherboards (40 percent of the global market) and hundreds of thousands of notebook computers annually.[50] Quanta, arguably the largest laptop manufacturer in the world, makes in its China-based facilities, among other things, virtually all of Apple's solid body laptop computers, high-end machines like the MacBook Pro and MacBook Air, not to mention Apple iPhones. Delta, in addition to the many other things it does, produces the power supply "bricks" for most of the branded laptops sold worldwide.

The pattern fits Timothy Sturgeon's characterization of electronics-related contract manufacturing more generally.[51] The outsourcing of manufacturing by brand leaders has not led to an explosion of small-scale contract manufacturers operating in every corner of the globe. This isn't the flat world of limitless opportunity for the little guy. Instead, even in ostensibly commodified manufacturing assembly, the piece of the supply chain with the lowest barriers to entry, we witness a world composed of a small number of scaled-up, highly specialized conglomerates operating in a select few global locales, China paramount among them.[52] These large contract manufacturers compensate for razor-thin margins by achieving tremendous manufacturing volume. Equally important, they develop managerial expertise that enables further cost cutting, more rapid turnaround times, and deeper, longer term relationships with brand leaders. By attaching tacit knowledge, managerial know-how, to an otherwise standardized activity—that is, by coupling basic assembly with the ability to achieve especially high yields, especially rapid turnaround times, or especially flexible small-batch production—they elevate the activity to something special and something difficult to replicate by potential competitors. Assemblers that have upgraded in this way still face narrow margins, a reality, perhaps, of their power relative to other players up and down the supply chain. However, within their own sphere of activity—assembly—these firms drive out less skilled competitors, amass tremendous production volume, and achieve a certain position of dominance.

That leads to a third point. Taiwanese-owned contract manufacturers have over time moved from doing only manufacturing assembly to coupling assembly with the provision of design services. That is, they are not just assembling products for brand leaders but are now doing much of the design work for those products as well. The whole evolution has a sort of push–pull feel to it. Brand leaders, on the one



hand, have pushed design work, especially the detailed design work needed to ensure a product's manufacturability, down onto contract manufacturers. The brand leaders, naturally, want this work done for free. The more successful contract manufacturers, on the other hand, have sought such work, for by developing proprietary design capabilities, they can lock in relationships with brand leaders and even move toward establishing their own brands. Once a company like Delta not only assembles but also designs the power supply brick for a MacBook—and when Delta proves faster than anybody else in miniaturizing successive generations of those power bricks with ever-smaller versions of the MacBook—it becomes difficult for Apple to turn on a dime and have its products produced by somebody else. In a sense, by taking on design work, the contract manufacturer, though still squeezed by tight margins, insulates itself from the race to the bottom, dog eat dog conditions of purely commodified manufacturing assembly. After all, taking on design work entails the development of capabilities (i.e., building and running R&D centers, recruiting and retaining trained engineers, etc.) that elude many firms worldwide, including most in mainland China.

And that raises a fourth point. The Taiwanese that prove capable of doing this are multinationals who can bring together operations across a variety of geographical locales and functional areas. These firms, in terms of where their greatest number of employees reside, are China-based product assemblers. But they are actually much more than that. They are Taiwanese-headquartered managerial operations, pan-Asian (Taiwan, Hong Kong, China, South Korea, etc.) R&D centers and in some cases global marketing operations. Moreover, at the managerial and engineering level, they are populated by individuals with extensive international experience, often in global technology centers like California's Silicon Valley. Such individuals—"Argonauts," as the scholar AnnaLee Saxenian terms them—move smoothly to and fro between Taipei, Shanghai, and Silicon Valley. As they weave together complex activities and relationships among leading firms, research centers, and universities, they become key bearers of cutting-edge knowledge.[53] Their employers, then—the more elite, Taiwanese-owned contract manufacturers—end up operating at the frontiers of innovation.

Fifth and related, these firms are now upgrading into new product development and branding. This, of course, involves a delicate dance because it suggests possible competition in the future with the contact manufacturer's current customers. One of the solutions involves inventing entirely new product categories rather than competing in areas already occupied by brand leaders.

The recent case of netbooks is a great example. In 2007, ASUS, in part motivated by work being done by rival Quanta, began marketing an ultrasimple, ultralow-cost machine based on a novel combination of established technologies—a seven-inch LCD screen, flash memory, and a Linux operating system.[54] The stripped-down netbook, easily transportable and useful primarily for Web surfing and checking e-mail, became an instant sensation at its roughly US$400 price point. Marketing the product as the Eee, ASUS sold out its complete 350,000-unit inventory well before the close of the year.[55] By the end of 2008, ASUS had sold roughly 5 million netbooks. Other companies, witnessing the appeal of the category, rushed in with their own versions and sold another 10 million units. Within a year of their introduction, netbook sales came to represent almost 10 percent of the entire global market for laptops.[56]

The development is interesting because it says something about the nature of innovation and upgrading in modular production. Taiwanese contract manufacturers moved up the smile curve by building a combination of manufacturing and design capabilities, thus deepening their relationship with brand leaders. On the down side, they could not continue moving up the smile curve—to the extent that curve is understood as applying to a single product like a standard laptop computer—for doing so would put them in direct competition with their main customers. On the plus side, because they were modular producers, their ultimate fate was not tied to any single product, any single smile curve, in other words. They could use the knowledge garnered from manufacturing an existing product—say, a high-end Dell laptop—to jump to an entirely different product like a netbook. In effect, they could employ the knowledge accumulated on one smile curve—knowledge about componentry, knowledge about designs, knowledge about user preferences—to jump over to and simultaneously operate on a different smile curve. The basic point is that in a world of modular production, upgrading may very well involve not so much moving up the smile curve but instead operating simultaneously on a variety of curves, all of which intersect at the given firm's activity of specialization.

The other interesting point about the netbook innovation is that although it amounts in some respects to just the cobbling together of off-the-shelf parts, it also reflects a very different way of thinking about how computing devices are structured and used. For well over a decade, debate has existed in the industry between "thin" and "thick" client architectures. In thick client setups, computers are built with maximal processing power to allow them to run virtually any kind of software and conduct virtually any kind of operation internally, relying on servers only to store information and communicate with the outside world. In thin client setups, computers are built with minimal capabilities—often inexpensively—and then most of the processing activities are carried out on the servers they connect with. High-end laptops, with the fastest processors and most robust software, reflect the thick client approach. The netbook, in contrast, very much fits a thin client model.[57]

In pushing something like the netbook, a modular producer like ASUS is not just introducing a new low-end product. Rather, that producer is catalyzing the development of a whole series of technologies, products, and commercial activities associated with thin client computing—more powerful servers, software designed to be run from them and accessed remotely, services for remote data storage, better wireless networks, and so forth. Concomitantly, other kinds of technologies associated with thick computing—smaller and smaller disc drives, longer lasting batteries, and better heat management systems, just to name a few—could potentially be de-emphasized. The point here is that the modular innovator, by popularizing something like the netbook, ends up shifting barriers to entry across a variety of different industries and technologies. New kinds of businesses become enabled, and others are forced into obsolescence.

So, what does this story of Taiwanese contract manufacturers tell us about upgrading in China? It tells us that upgrading is going on there and that innovation can still percolate up from manufacturing. At the same time, at least at present, much of that upgrading and innovation is happening not in indigenous Chinese firms, but instead in the Taiwanese and other multinational firms with China-based operations. Moreover, they are achieving this upgrading not by focusing exclusively on activities within China but instead by linking their China-based operations with people and capabilities located elsewhere. Thus, this is not a story of *China* upgrading per se. Instead, it is a story of China and Chinese-based operations at once enabling and being pulled into broader patterns of global upgrading. Global is used in two senses here: global in that the companies doing it tend to be multinationals, and global in that it is happening through networks of operations across multiple countries. China is playing a key, but not autonomous, role. And its participation does not, at least up to this point, suggest rise at somebody else's expense. It is still too early to say exactly what this model is. What it clearly is not, however, is traditional mercantilism or even traditional state-led development à la Japan or South Korea.

### The Effect of Modular Production, Take 3: "Upward Commodification" by Chinese Producers

What about all those emergent indigenous Chinese producers we keep hearing about, automakers like Chery and Geely, appliance makers like Haier and Galanz, telecommunications systems providers like Huawei, or a computer maker like Lenovo? They have obviously moved into some very sophisticated business activities, branded their own products, and in many cases, introduced those products into overseas markets. How should we understand this? Does it signify upgrading? Why or why not? How does it differ from the upgrading efforts of the foreign-owned contract manufacturers described previously?

What so distinguished the best of the Taiwanese subcontractors was their ability to scale up, dominate globally their respective segments of the value chain, and build a set of unique managerial capabilities in the process. In so doing, they fit themselves into a global division of labor with a number of other scaled-up, leading firms. At the same time, while remaining primarily within their specialized activity of manufacturing assembly and design, they situated themselves across a variety of products and industries: computers, cell phones, automotive electronics, among many others. In other words, they positioned themselves on several smile curves at once.

A small subset of Chinese indigenous firms—the few that the Chinese government has tried to build into traditional conglomerates—has attempted something different and much more timeworn. They have sought not to deverticalize and specialize but instead to integrate across the supply chain. That is, they have sought to stay on a single smile curve but add activities on the upward curving ends to those they already perform down in the trough. In doing so, they have sought to build themselves—often with considerable governmental support—into "national champions," the sort of conglomerates that were dominant worldwide prior to the era of modular production, and that were hallmarks particularly of the East Asian model of state-led development. Their very existence is interesting because it suggests that even as the Chinese system as a whole plunges headlong into deverticalized, globally integrated production, elements of traditional industrial policy still linger in Chinese governmental and commercial circles.

Firms like Haier, Huawei, and others—all with expertise in low-cost manufacturing—have in many cases successfully marched up the learning curve. Huawei is now selling telecommunications networking systems and equipment in Europe and North America. Lenovo, as many people know, purchased IBM's PC division and now owns the Thinkpad brand worldwide. Haier today is the world's fourth largest white goods (home appliances) manufacturer. Chery has ambitions of soon selling vehicles in the United States.

Nonetheless, the march up the curve has not always delivered on its promise of enhanced profitability and control. Lenovo, for example, even after the IBM acquisition, has struggled to build global market share. In terms of worldwide personal computer sales in 2008, Lenovo, with 7.5 percent of the market, substantially lagged global leaders HP, Dell, and surprisingly, the Taiwanese multinational Acer. Indeed, whereas Lenovo experienced a 5 percent decline in market share between 2007 and 2008, Acer was up a whopping 25 percent.[58] The industry inevitably exhibits volatility from year to year, but if anybody was rising in 2008, it was Acer and Apple, not Lenovo. Meanwhile, nipping on Lenovo's heels were contract manufacturers like ASUS who were at once producing the PCs for leaders like HP and Dell and introducing the next generation of products that could supplant PCs.

In telecom network provision, Huawei has clearly situated itself as a low-cost provider, but it substantially lags global leaders like Cisco, Ericsson, Alcatel-Lucent, and Nokia-Siemens Networks in terms of technology, value-added service provision, and overall revenues. That is not to say Huawei lacks either dynamism or innovative zeal. By early 2008, it had emerged as the global corporate world's fourth largest patent applicant (with 1,365 patent applications in 2007), trailing only Matsushita, Philips, and Siemens. Where a firm like this will be in several years is difficult to say. Yet, its overall development arguably fits a pattern that obtains across many of China's most advanced indigenous firms. Each time the Chinese champion moves up into a more sophisticated activity, the activity seems to commodify, while leading global competitors race forward into something yet more sophisticated and more difficult to replicate. In other words, as the indigenous firms race up the smile curve, as indicated in figure 4.2, the curve seems to drop downward right under their feet.

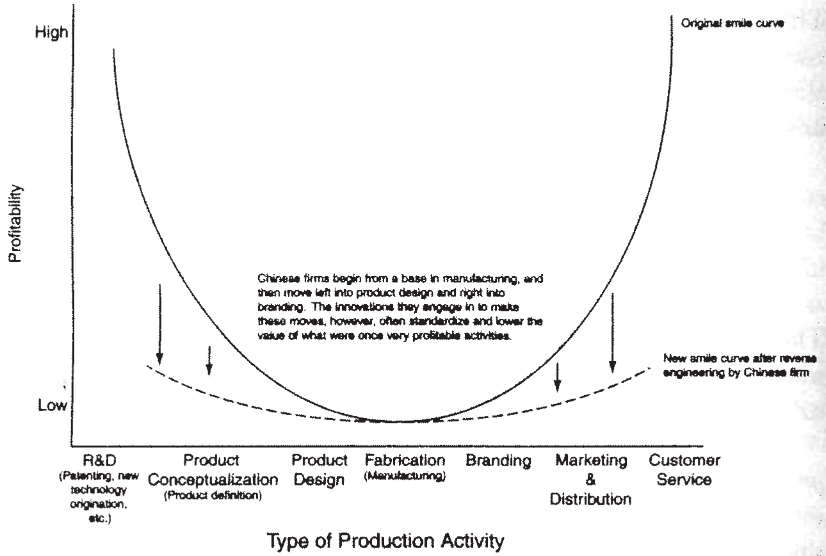


FIGURE 4.2 Upward Commodification by Chinese Firms

This drop is not coincidental. Rather, it has to do with the particular kind of innovation and upgrading the Chinese firms are engaged in. In essence, what they have specialized in is a kind of innovative reverse engineering. They find completely novel ways to standardize the previously uncodified, proprietary activities of industry leaders. Products and production processes that had once been uncodified and extremely difficult to replicate end up fully opened and standardized. This is not to say that Chinese firms are necessarily stealing existing designs or violating competitors' intellectual property. Those are issues for legal experts to decide.[59] In purely production terms, these firms are devising new ways of dealing with design information that dramatically lower the cost of producing a product.

A good example comes from the Chinese motorcycle industry.[60] During the 1980s and 1990s, globally dominant Japanese motorcycle assemblers like Honda, Yamaha, Kawasaki, and Suzuki had ambitions to enter the China market. Their entry strategy, in part dictated by Chinese governmental regulations, usually involved the establishment of joint-venture manufacturing operations with a Chinese partner. There were many to choose from, for like much of Chinese industry—both then and now—the motorcycle sector was characterized by extreme fragmentation. Many players existed, but few if any operated at commercially viable economies of scale. Even today in a typical motorcycle manufacturing hub like Chongqing, one can still find a bewildering array of both state-owned and private assemblers, companies like Jianshe, Jialing, Lifan, Zongshen, Shineray, Hi-Bird, and many others.[61]

When some of the older state-owned players like Jianshe and Jialing entered these initial joint ventures, they were exposed to a particular variety of Japanese-style production. That style, as the scholars Dongsheng Ge and Takahiro Fujimoto have observed, involved an assembler-led, design-focused system that placed great emphasis on new product development.[62] Lead Japanese assemblers would come up with detailed designs for the product as a whole and for every component. Maintaining full control over those designs, they would then divvy up production tasks among a series of essentially captive suppliers. The assembler set all the parameters beforehand and then managed a closed production network that supplied parts precisely tailored to specific motorcycle models. In contrast to so many of the modularized, deverticalized supply chains that we see today, this was an almost organically interconnected, stand-alone entity under the proprietary design control of the lead assembler. This resulted in high-quality, high-performance motorbikes. What it did not result in, though, was very inexpensive bikes. And it did not provide opportunities for Chinese participants in the network to break out and market their own bikes.

Those firms, though, ultimately found ways to break out, and they did so by innovating, in a sense. They learned how to take a nonmodular, highly integrated system of new product development and convert it into a highly modularized, highly deverticalized mode of production. As Ge and Fujimoto point out, Chinese assemblers and parts manufacturers alike—whether they had worked directly with the Japanese or not—selected certain Japanese motorcycles as focal models and then disassembled them. Once the focal models were broken down, the indigenous assemblers and parts makers worked in parallel to reengineer individual parts and entire models. Parts effectively had to be redesigned for manufacture. In some cases, the parts were simply copied. The problem, though, was that the parts had been originally designed to work only with specific models. In some cases, Chinese parts makers (rather than final assemblers) were now doing the reverse engineering, so they wanted to ensure that the parts could be used in the widest variety of motorcycles possible. That is, they wanted their reverse-engineered parts to be salable to a wide variety of customers. Hence, they redesigned parts in ways that made them much more standardized—modular, in effect.[63] At the same time, assemblers, who were also trying to reverse engineer entire motorcycles, did not have the design capabilities to do the whole task. Hence, they outsourced detailed design for key parts and subsystems to the components makers, thus almost by definition forcing previously integral, top-down designs to become much more modular. The Chinese assemblers, in effect, gave up the kind of design control that had been at the heart of the Japanese system.

The upshot by the late 1990s and early 2000s was an extremely dynamic and competitive manufacturing environment in places like Chongqing. Local assemblers and component manufacturers were introducing one reverse-engineered motorcycle after another. Call them what you will—"knockoffs," "pirated goods," "low-cost alternatives"—but these Chinese-produced "Yamehas," "Suzakis," and "Honeas," all essentially reverse engineered, modularized variants of Japanese models, became all the rage not just in Chinese markets but throughout much of Southeast Asia.[64] These bikes may not have been as reliable as the Japanese focal models on which they were based. They may not have performed as well or been as fun to ride. Yet, they were much less expensive to produce and, thus, much less expensive to purchase and maintain for the consumer. Plus, as the Chinese assemblers improved their techniques, the bikes became much more reliable. Even today, they still cannot compete in high-end markets with the likes of Honda or Harley-Davidson, but they have established a solid foothold at the low end of the product spectrum.

Legal issues aside, the story is unquestionably one of skill upgrading and innovation by Chinese manufacturers. After all, working from somebody else's production architecture, they created a new one of their own and, in so doing, substantially lowered production costs for a complex product. In many ways, this is similar to what Chinese producers have done in a number of other areas: home appliances, electronics, toys, telecommunications switching equipment, and so on.

The problem, however, is that by opening up and modularizing production processes that had once been closed, Chinese manufacturers end up lowering entry barriers for everybody. That is, they induce tremendous competition and undercut potential avenues for differentiation and profitability. In a way, one can think of it as the Chinese producer moving up the smile curve in a fashion that ends up wiping the smile off the curve entirely (see figure 4.2). When Taiwanese contract manufacturers have upgraded, they have tended either to move up the smile curve by deepening relationships with brand leaders—usually by providing propriety design work in addition to manufacturing assembly—or to effectively jump onto new smile curves by introducing new products. Chinese indigenous manufacturers generally have done neither. They have instead worked to standardize previously proprietary, closed products and processes.

Having done so, the Chinese manufacturers often still lag in the ability to effectively integrate activities across the supply chain. The Chongqing motorcycle manufacturers, for example, can effectively reverse engineer existing designs, but they are still unable to come up with designs of their own. As an expert from a major European design consultancy that works with these firms noted, "In China, they [the motorcycle manufacturers] make nice parts, but they still do not do designs...They have weak project management skills, and they neither see the need for, nor have the ability to control their suppliers in order to implement a project."[65] Such management skills—often involving coordination across multiple firms—are, unlike actual motorcycle designs, difficult to reverse engineer. They are the still uncodified, tacit element of production, which separates a low-end, commodified product from a high-end, high-performance one. Such skills are likely to be acquired over time, but it is going to take a lot of learning across a lot of trial-and-error experimentation. Meanwhile, Chinese manufacturers are generally relegated to the lower cost, more commodified end of the consumer products spectrum.

Although not ideal for these manufacturers, the situation is great for consumers worldwide. It makes for very inexpensive, reasonably high-quality TVs, DVD players, microwave ovens, low-end servers, computers, and other products that now behave as commodities. The Chinese producers then scramble to put their brands on these products, but as commodities, the products are no longer easy to differentiate. Do consumers care now what kind of basic microwave oven they buy? Do they care what name is on the US$40 DVD player they purchase on a whim? For many of these products—precisely because Chinese producers have figured out how to standardize them and produce them so inexpensively—brand has ceased to matter. In their admirable efforts to move up, Chinese manufacturers have in many cases undercut the profitability of doing so. Once they move in, brand leaders know it is time to move out.

That, in some sense, explains why IBM was willing in 2005 to sell its PC division—and its marquee Thinkpad brand—to Chinese computer maker Lenovo. At least in the minds of some IBM managers, the laptop had ceased to be a differentiated product. Producing and selling it had become a thankless task, a commercially suicidal endeavor in which the only way to win was to keep cutting one's profit margins.

Whether this is simply post hoc self-justification is hard to say, but more than a few senior managers at IBM felt they had dumped the computer business on Lenovo, thus freeing IBM to move onward to the next generation of proprietary, high-value activities: provision of tailored business solutions for high-end industrial customers, cutting-edge R&D, new technology development, IT network provision, and a variety of other high-margin endeavors. To the extent the example is generalizable, one can say that indigenous Chinese firms are upgrading into advanced manufacturing at precisely the time global industry leaders are upgrading out.

## The Effect of Modular Production, Take 4: Modular Innovation in Advanced Industrial Economies

The advent of modularity has brought more than Chinese-made knock-offs, low-priced gadgets, and supercharged contract manufacturers. It is about more than just rising firms, whether from China or anywhere else. Rather, in this new way of structuring production, everybody is on the move. Indeed, modularity has enabled change in North American and Europe no less impressive than what has occurred in developing locales like China. As Chinese firms move up into—and commodify—high-end manufacturing, they undoubtedly cause problems for people engaged in those same activities elsewhere. Frankly, they in some respects create problems for themselves as they drive down entry barriers for potential competitors. The broader reality, though, is that they are participating in, and even fostering, production changes that catalyze entirely new and extremely profitable commercial activities in places like the United States.

Our earlier version of the smile curve suggested that modularity has lowered profit margins in manufacturing and raised them in areas like design, branding, and tailored customer services. In some respects, that is an oversimplification. By pulling apart the production process into separable, stand-alone stages, modularity has enabled the creation of entirely new manufacturing industries. For example, when companies like IBM managed the production of all facets of a computing product, it would have been hard to imagine the rise of firms like Intel or AMD wholly devoted to the design and manufacture of a component, the semiconductor, or the rise of Microsoft on the basis of an operating system.



In its own way, modularity lowers barriers to entry not only for low-end manufacturers but also for highly skilled, highly specialized firms that previously would never have had outlets for their products. "Vertical specialization" is how a recent study from the U.S. National Academies aptly termed this.[66] In some ways, an even better term might be "deverticalized specialization." When the computer industry, for example, deverticalized (moved away from a single firm doing everything to multiple firms doing just one or two activities in the production process), it was not only Microsoft and Intel that blossomed. So too did semiconductor foundries, firms specialized in making chips but not designing them. Those operations, then, fostered the development of fabless design houses, firms, often based in places like Silicon Valley, that specialize in the creation of new semiconductor designs. New designs allowed new kinds of capabilities to be built into new kinds of products. As indicated by figure 4.3, the smile curve for a product like a personal computer has become full of high-profit peaks even as the product itself commodifies. These peaks are often dominated by companies which, though their names may not be recognizable to ordinary consumers, enable whole waves of innovation.

Indeed, a number of these companies, through innovations directed at personal computers, have made possible follow-on products like the smart phone. Because of various innovations in chip design, screen design, miniaturization, and heat management, the handheld smart phone can do today what only the desktop computer could do yesterday. Indeed, the smart phone can do more. It can also do what the film camera used to do. But that function, of course, first migrated to a semiconductor-enabled digital camera, and then to a credit-card-sized camera, and then to the phone.

And now with the smart phone, another set of activities—or industries—has been enabled as the phone has become a platform for new applications (apps) created by independent software developers. Some of those software apps—GPS-based turn-by-turn navigational programs, for example—might replace what previously had been stand-alone hardware devices. The phone also evolves hand in hand with new screen technologies—again produced by specialized firms—that permit users new ways to view (digitally delivered) media. That creates many new opportunities for media providers. In fact, savvy computer companies like Apple reinvent themselves as media companies, pushing new ways to deliver digitized entertainment to the users of their devices. Apple's iTunes software is a good example. At the same time, the traditional media providers—namely, network television and

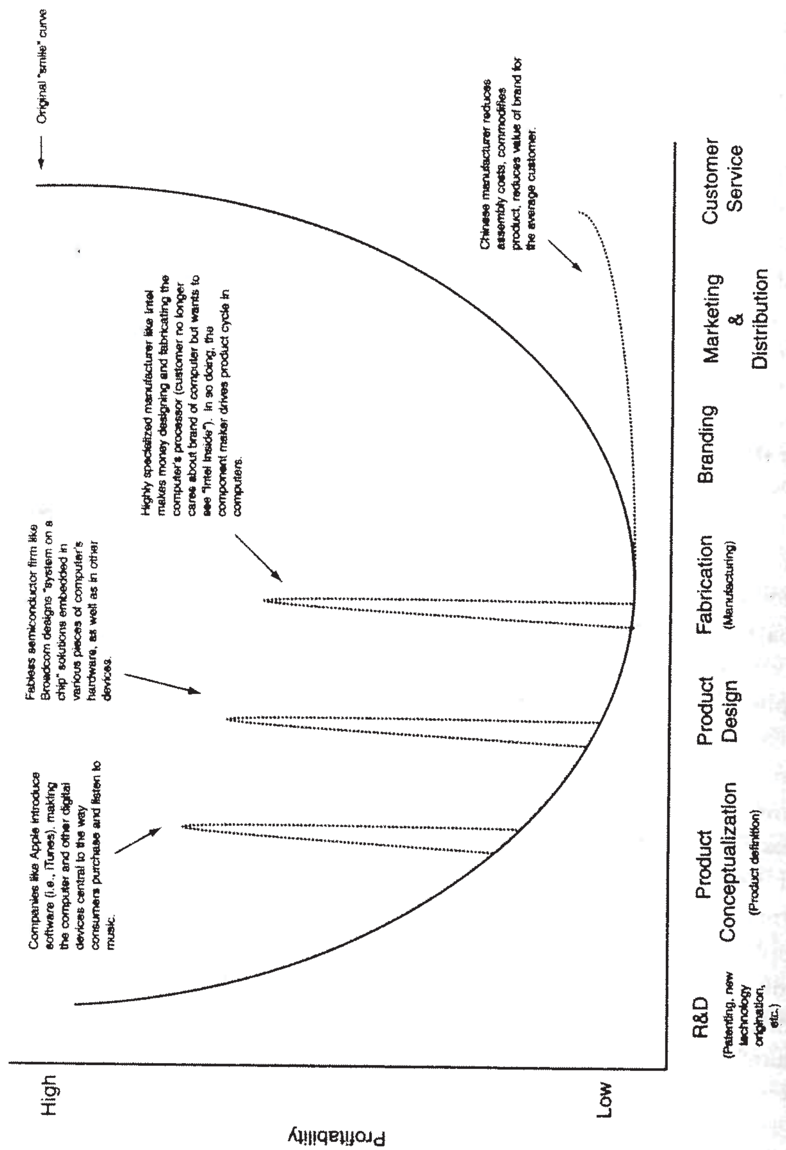


FIGURE 4-3 Modular Innovation: Creating Value in Unexpected Places



radio—face big problems as their advertising-based revenue model gets the rug pulled out from under it.

The point is that citizens in the world's wealthiest countries are not just being challenged from below by overseas competition. And they are not only being showered as consumers with a bewildering array of novel and often quite affordable products. Rather, they—we—are now as producers participating in completely new ways of value creation. Production is now no longer just about finding the right spot on a single smile curve. Nor do the points on even any one curve so simply come together as a smile. All sorts of new value opportunities are opening up along those curves. What are in some cases extremely lucrative industries today—semiconductor design, data storage and security, Internet search engine development, and so on—were not even industries at all yesterday. At the same time, once lucrative activities have in some cases become either far less profitable or utterly obsolete.

More specifically, modular production, the very kind of production both facilitated and accelerated by China's economic rise, can be understood as impacting advanced countries like the United States in the following ways. First, modularity has made it easier for small entrepreneurial start-ups to enter the market. Now, new enterprises can join the electronics, telecommunications, automotive, or virtually any other industry without having to own a single piece of capital equipment. They need nothing on the scale of a multibillion-dollar semiconductor fab or a massive auto assembly plant. They may, for example, just need a small number of computers to produce highly proprietary, industry-enabling semiconductor designs. Or perhaps they develop algorithms for the creation of new kinds of data storage devices. Possibly they design and manage networks upon which digitized medical scans can be sent for reading anywhere in the world.

Second, many of the highest value portions of production have been detached from the physical act of manufacturing. Some Americans rue the demise of U.S.-based manufacturing, partly—and understandably—because they worry about the disappearance of jobs. Partly, though, they worry more existentially that in its shift to a postindustrial economy, the United States is losing know-how, innovative capacity, autonomy, and power. This latter set of concerns for the most part misses the point. Modularity has blurred once-firm distinctions between manufacturing and services. Research and development and design-related activities in the past were inseparable from physical manufacturing. Hence, they were all previously treated as manufacturing. Today, many of these activities are carried out by highly specialized firms that do no physical manufacturing at all. The jobs appear as services, but they in fact claim the bulk of the profitability and power in the broader production chains they feed into. They often end up as the biggest repositories of know-how in the entire manufacturing process.

Thus, whether Intel, Google, Cisco, Qualcomm, EMC, Lam Research, Nvidia, Marvell, and so many other U.S.-based entities, these are firms that hold the keys to the manufacturing kingdom, for they are the ones that drive the most innovative and knowledge-intensive aspects of production. Some actually bend metal; others focus only on design. Some have branded products; others operate far upstream in the shadows, pushing R&D and innovation in componentry or network infrastructure. However, all are creating jobs, in some cases directly through their own operations, and in other cases indirectly through the wealth they generate. All, by defining the frontiers of innovation and new technology development—the most difficult-to-replicate, innovative aspects of global production—set the tempo at which everyone else in the supply chain must march.

That they do leads to a third point. Because many of the high-end producers in the United States are modular and rarely invested in the capital-intensive aspects of production, they are no longer tied to any single downstream consumer product. These firms frequently end up straddling multiple industries simultaneously. A fabless design house may one day design a chip that permits new functionality on a laptop computer, only to follow up the next day with a design enabling products that wipe out the laptop entirely. Or it may create a design that ends up having applications in automobiles, a downstream product whose value increasingly resides in its electronics and software.

Similarly, Microsoft grew originally on the basis of a computer operating system, but now it is seeking to become the dominant operating system provider in the cell phone industry. Just as it determined a key standard in the computer industry, now it is trying to do so in cell phones. Of course, in trying, it has to compete against other American companies like Google, which, like Microsoft, may not be associated with telecommunications but have managed to move into that domain from a variety of different starting points. Meanwhile, Google, with its recent announcement of the Chrome Operating System, is itself moving into Microsoft's computer operating system business. Microsoft, in turn, with the announcement of its Bing Internet search engine, is moving onto Google's home turf. Both of them, however, as they now try to dominate software standards in the smart phone business, compete with Palm, Apple, and Research in Motion (BlackBerry), all major players in this area. None looks like what we would traditionally



understand as a manufacturing firm. None, in fact, really amounts to a telecommunications company. Yet, each is trying to control the standards, the rules of connectivity, that serve as key enablers of products and key drivers of the production chain.

Why engage in physical manufacturing—product fabrication—if you can control the high-value rules and design parameters that those doing manufacturing must scramble to meet? Even if those manufacturers reverse engineer your designs—which they may be wary of doing if you are their primary customer—you will have already moved into new products or jumped across into new industries. After all, as a modular player, you have the option of operating on multiple smile curves simultaneously. You are free to do this precisely because you no longer have to invest in all the capital equipment, facilities, and infrastructure associated with product fabrication in any one industry. Somebody else—namely, China-based contract manufacturers—has done that for you.

Fourth, because their specialized activities can straddle so many different industries, American firms are freed up to pursue a particular kind of unbridled, modular innovation. When producers were vertically integrated—that is, when they had invested in all the facilities and equipment necessary to make a single complete product—their fates effectively became tied to that product. They may have been inclined to innovate, at least in the sense of improving the product to meet evolving consumer preferences, but they would have resisted new technologies or ideas that might unseat the product entirely. To use management scholar Clay Christensen's terminology, they would have engaged in "sustaining" but not "disruptive" innovation.[67] In the era of modularity, however, everything is about disruption, especially for innovation leaders in places like the United States. As noted previously, a modular producer—a design house, for example—may innovate today in ways that knock out its previous innovation from yesterday. As long as it keeps moving and stays at the cusp of value creation, it remains not just a viable business but a business effectively in the driver's seat.

Hence, we see firms like IBM and Apple continually reinventing themselves. What really is Apple today? A computer design company? A smart-phone company? A media company that is just using all those electronics devices as platforms for iTunes? And what about IBM? It very clearly and publicly has moved out of computer manufacturing and into the provision of proprietary business software and IT networks. In the process, it is trying to shape IT industry standards by pushing open-source, Linux-based computer operating systems, a move that could unseat potential competitors like Microsoft while catalyzing entirely new avenues of software development. Meanwhile, in its upstream research labs, IBM, through concepts like "racetrack memory," is pioneering new ways to store and manage digitized data that could revolutionize the computer hardware industry and the myriad devices that flow from it.[68]

Time and again, just as the competition starts busting down the door, these innovation leaders jump to new products in which they can embed their own proprietary, uncodifiable know-how. For Apple, this know-how may come in the form of software for selling and listening to digital media. For Google or Microsoft, it may be software delivered online or through a handheld device. For Cisco, it may be in software and designs embedded in routers and servers that it may have branded but subcontracted to somebody else to manufacture.[69] In moving forward into knowledge-focused activities, these companies continually leave behind other activities that have been opened up and commodified. Indeed, leading companies actively encourage the commodification of activities they seek to exit or activities that are the heart of their rivals' competitive advantage. Hence, IBM dilutes the value of brand generally in laptop manufacturing by selling the Thinkpad name to Lenovo, but presses ahead on proprietary innovation in the high-value guts of computing devices or the design of tailored IT systems for large corporate customers. Similarly, it actively encourages open-source computer operating systems, potentially undercutting products like Microsoft's Windows, and at the same moves into the provision of Linux-based IT networks or software solutions for large corporate customers. Not entirely unlike what the Chongqing motorcycle manufacturers did to the Japanese, these firms find ways to open up and commodify the activities of their competitors. Yet, they do so only because they can simultaneously take the next step by offering a proprietary, high-value product that then rides on the back of that which has just been commodified.

One way this is manifested for consumers is in the rapid product cycles that exist today across so many industries. In the past, it was only items like apparel that changed across four, five, or six seasons per year. Now, it is computers, cell phones, data storage systems, home networking systems, digital cameras, and so many other kinds of products. The gadgets come and go with incredible rapidity, with each new one bringing with it enhanced capabilities, new functionality, and in many cases, lower prices.



## Conclusion: China and The Modular Revolution

China in recent years has achieved extraordinary growth by plunging into the center of a global production revolution. Having carved out a particular place in a new global division of labor, Chinese firms now perform critical manufacturing functions in virtually every consumer product category. In some cases, their innovations have substantially lowered production costs and changed the nature of the products themselves, transforming high-end, brand-specific goods into commodities. In almost all cases, often by buying new technologies and developing better managerial techniques for employing them, these firms have realized major productivity gains. Productivity gains translate into long-term wealth creation and national growth.

At the same time, China as an industrial nation has been thrust into an extremely challenging situation. The rapid product cycles typical of modular production impose unprecedented pressures for flexibility and cost cutting on the part of those doing the physical manufacturing. Product fabricators must become adept at absorbing new designs, managing small-batch production, and responding quickly to shifting orders, all while keeping costs down and volumes up in inherently narrow-margin businesses. In essence, they must learn to operate in environments of intensely high "clockspeed."[70] Rapid turnaround times, new innovations cascading down from above, compressed product cycles, and lots of competition have all become the new normal.

A select few firms in China have proved particularly adept at meeting these challenges while remaining focused on manufacturing. They happen to be Taiwanese-owned multinationals that couple substantial operations in China with their other business units located abroad.

Indigenous Chinese producers could conceivably compete with them in the future. One problem at present, however, is that the most advanced of these indigenous companies, though impressive, appear held back by the particular manner they have pursued upgrading. Whether by choice or in response to governmental pressure, they have tended to move toward vertical integration rather than specialization. In other words, they have sought to couple the basic manufacturing they are already doing with new efforts in downstream product branding and upstream R&D, often within narrowly defined, single industry boundaries. Thus, they end up doing many things, but none particularly well, and all within the confines of a single industry. The products they brand often end up commodified. The manufacturing they engage in, while often quite good, is not managerially flexible or adept enough to compete with the Taiwanese. The fact that they are single-industry defined and single-industry branded makes them less inclined to move, as Taiwanese contract manufacturers do, across multiple product areas. Moreover, because they are often manufacturing for their own branded product lines, they get cut off from some of the interfirm partnering efforts—the sort of joint design work that goes on between Apple and Quanta, for example—that lead to skill upgrading and knowledge transfer. This is not to say that they are failing. Rather, it is to say that they are struggling to keep up, struggling to keep pace with those who seem to have responded more adroitly to the challenges of value creation and value capture in a world of modularized production.

Of course, in a world of rapid innovation, those at the top at any given time may not remain there tomorrow. Interesting to note, however, is that much of the churning that takes place today is not between incumbents from wealthy nations and new entrants from developing ones but rather among the rich country firms themselves. In computers, Dell and HP get squeezed by Apple and Acer, not China's Lenovo. In computer operating systems, Microsoft fends off challenges from Google, not indigenous Chinese software companies. Even in areas suddenly opened by disruptive technologies, wealthy-nation firms are consistently first to jump into the void and reap the gains. GPS-based navigation systems are a good example. Sales of handheld and in-car devices surged in the early and mid-2000s, only to come crashing down in 2008 with the growing availability of navigation apps for smart phones. In the process, the fortunes of companies like Garmin (founded in Taiwan but now headquartered in the Cayman Islands) rise and fall, but not at the hands of upstart Chinese device makers producing low-cost substitutes. Instead, the new competitors are U.S.-based software developers, the people coming up with the new apps for smart phones. To compete, device maker Garmin, in turn, must scramble to reinvent itself as a software company.

Examples like these and many others typify an overall trend. As illustrated in figure 4.3, modular production—a key part of which involves China-based manufacturing—is facilitating extremely rapid, almost unbounded innovation in places like the United States. American and other innovators, then, are competing fiercely among themselves, introducing new products, blowing away old ones, creating opportunities in new activities, shutting them down in others, establishing new standards, forcing the obsolescence of old ones, and so on. As a result, various new corporate entrants have been able to find their way onto



the ever-expanding competitive landscape, one far more complex and interesting than a simple smile. Few if any of the new profit peaks, however, are being claimed by Chinese domestic industry.

Who exactly owns the current architecture of production is impossible to say. It is perhaps the wrong question to ask. Yet, far more certain is that as much as the modern era is about China emerging as a global manufacturer, so too is it about the United States advancing faster than ever before as an innovation leader. Had it not been for the advent of modern modular production—globalization, in effect—neither outcome would have been possible.