Willy C. Shih
Robert & Jane Cizik Professor of Management Practice in Business Administration
Harvard Business School

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Hearing on Supply Chains
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Hearing Co-Chairs Borochoff and Goodwin, commission members, staff, and other distinguished guests, good morning, and thank you for the invitation to speak with you today.

I am on the faculty of the Harvard Business School, where I have taught for the past 15 years. Prior to that I spent almost 28 years in industry, a time that saw a dramatic expansion of the tradable sector, and the rise of China from an impoverished nation to a formidable manufacturing powerhouse. I spent a lot of time in China from the late 1990s onward, and I watched its rise. The first decade of the 21st century was a period of spectacular growth for China, as well as one of the hollowing out of substantial parts of the manufacturing infrastructure of the United States. Some of you may know that a lot of my thinking on the impact on the U.S. was laid out in a paper published in the *Harvard Business Review* in July–August 2009 on "Restoring American Competitiveness" and a subsequent book.

Let me start by addressing your questions.

1. **Describe how China has utilized process innovation to develop and occupy a leading role in global production networks. What makes China's position in global supply chains unique? How durable is China's position on this score?**

China was late to industrialize, relative to the U.S., Europe, and other East Asian countries. In that regard it had what some authors call the "late comers' advantage." When it built its electric grid, its communications network, and a fair amount of its manufacturing capacity, it didn't have a lot of existing (and older) infrastructure that was already paid for and fully depreciated, or maybe State-owned Enterprises (SOE) didn't have to worry about concepts like depreciation schedules. In either case, since it was looking to catch up, it could start fresh with the newest technologies, and this was a huge advantage. Some of the old Mao era manufacturing legacy was pretty archaic, but firms weren't afraid to invest in a lot of new capacity. They planned for vast growth with the domestic market and increasing access to global markets.

Let me illustrate this point. I used to teach with the late Clayton Christensen, who was famous for his model of disruptive innovation – and how the steel minimills caused havoc for the domestic integrated steel producers. I asked him once, "Clay, the question you really should ask is how did American steel manufacturers get in trouble in the first place?"

At the end of World War Two, American steel manufacturers were the king of the hill. U.S. Steel, Bethlehem, Jones & Laughlin, others. I remember those names from when I was young. Their competitors in Germany and Japan lay in ruins. But when those countries rebuilt, they were the first to use newer technologies like the basic oxygen process, they were the first to use continuous casting, they weren't hobbled by older open hearth furnaces that were less efficient but fully paid for and depreciated. American firms were fearful of the financial costs of excess capacity, so why add more even if it made better product at lower cost? In the late 1910s, American firms were also late adopters of electric motors distributed in factories for the same reason. The old centralized power was already paid for. I can extend this example to numerous other industries: castings, LCD display panels, vehicle assembly lines, the telephone network. As I'm sure you know, China largely skipped fixed wireline and went right to wireless.

In China during the 1990s and 2000s, a period of rapid industrialization, both Chinese and foreign invested companies imported a great deal of production equipment. Some of this was the result of "lift and shift" strategies in which production equipment was moved from the U.S. or Europe, but there were also many instances where the latest production technologies and equipment were purchased, largely from abroad. The equipment generally comes with training, as it is in the interest of the toolmakers to provide it. They therefore received a lot of know-how embedded in those production tools. I have written about this phenomena in the *MIT Sloan Management Review*, and I am incorporating that article by reference.[1] That is something everybody in every country does, but if you are a latecomer, it helps when you don't have to go through a lot of learning that is abstracted and presented to you.

Let me add that China historically engaged in a unique combination of centralized planning with experimentation. In addition to its five year plans, it engages in longer term programs as well. I would like to highlight in particular the National High-tech R&D Program, also known as the "863 Program" named for the year and month (March, 1986) when four scholars proposed a plan to accelerate the country's high tech development. It sought to boost innovation capacity in named strategic sectors like information technologies and infrastructure, biological and pharmaceutical technologies, nanomaterials and other materials, among others. I have to admit the first time I saw this program, I was impressed by its ambition and well delineated scope.

China also has a fierce form of market competition, and it is driven by policy makers in provinces and cities who take plans handed down from Beijing and implement them with their own means and methods, competing fiercely with each other. For those leaders who are successful, this is a path to promotion within the Chinese Communist Party. Sometimes Beijing tries to tone down this hyper-competition and rationalize markets, deeming it a waste of resources. But it's an interesting and powerful model that had delivered results.

China's position in global supply chains is much more pervasive than many people realize. It has combined what seemed like (until a few years ago) a virtually unlimited low-cost workforce that

[1] Shih, Willy. "Why high-tech commoditization is accelerating." *MIT Sloan Management Review* 59, no. 4 (2018): 53-58

had both the discipline and the ambition to get ahead. Workers there were willing to do things that American workers were not, and they did it for a tenth the cost or sometimes even less. While many people focus on the high profile products like lithium ion batteries, computers, communications equipment, or pharmaceuticals, we actually have broad dependencies that run much deeper than most Americans realize. Do you shop at the big box home improvement stores or retailers? All you have to do is look at who the largest importers from China are. In the midst of the supply chain crisis that we have been living through for the past two years, imports from China have posted records month after month, because we don't have anywhere else to go to for a lot of manufacturing capacity. The pandemic revealed a lot of surprise dependencies, and I guarantee there are many more.

China's position is durable, though not insurmountable, because they have both the capacity and the capabilities. If you want to assemble 10 million iPhones in preparation for a launch weekend, there is only one place where you can marshal the labor, enjoy the labor flexibility, and do it at a reasonable cost, at scale.

2. What economic advantages has China's leadership in process innovation conferred on China? To what extent can other economies realize similar advantages?

As described above, Chinese companies have been willing and able to apply the latest process innovations. They then use learning and economies of scale to cement their positions. Economies of scale and process learning as exemplified by the learning curve play a crucial role. These effects overlap of course, but let me start with scale economies.[2]

Economies of scale are cost decreases that result from expanding production. If the cost per unit of output rises more slowly than the costs of inputs in the same proportions, there are economies of scale (for example, if output doubles while the total cost of inputs less than doubles). The simplest scale economies arise when there are high setup costs and relatively low run costs per unit of output so that spreading setup over larger run volumes improves efficiency of labor and asset utilization.

Economies of scale are frequently found in industries that require large capital expenditures on plant and equipment, or the establishment of a large infrastructure prior to the ability to begin providing service. High fixed costs get apportioned across the entire product volumes, so larger production volumes mean a smaller per unit allocation.

China has been able to take advantage of the tradability of its output, and as a low cost provider combine the gigantic export market with its own growing domestic market. This is something that the United States was able to take advantage of during the 20th century, but the growth of the tradable sector enabled by low cost ocean container shipping from the late 1990s has helped China immensely. Thus its firms have been able to build extraordinary positions as low cost producers.

[2] This explanation comes from Shih, Willy, "Scale Effects, Network Effects, and Investment Strategy," HBS Case No. 611-082 (May 13, 2011)

Process learning is essential. The experience (learning) curve originated from the work of Theodore Wright, who studied aircraft production.[3] He observed that the more times a task was repeated, the less labor time was required in each subsequent iteration. Empirically this takes the form of:

$$C_x = C_1 x^{\log_2(b)}$$

where C_x is the unit cost of producing the xth unit, C_1 is the cost of producing the first unit, and b is the progress ratio. ($1 - b$) is the proportionate reduction in unit cost with each doubling of cumulative production volume. Experience curve benefits can be attributed to improvements in labor efficiency as workers' dexterity improves, standardization, specialization and work method improvements, improved use of tools and equipment, product redesigns to improve assembly efficiency and productivity, material substitutions and more efficient use of inputs, and a shared experience effect when multiple products share usage of common resources.

One of the key benefits that I have observed Chinese manufacturers have been able to exploit is a market breadth and depth that facilitates this learning. When a firm starts out making a product, it might not be as good as international competitors but it is good enough for many buyers in its local market. Thus it is able to get practice and move down the learning curve. Customers pay for this learning by buying the firm's output, and this gives the manufacturer the cash flow to keep operating and improve. I describe this as "paying my tuition" while I learn and improve. China didn't invent this idea – it is a feature of market economies. Japan and other Asian economies leveraged this earlier, as did the U.S. in the 19th and 20th centuries. But a broad tradable sector with low cost shipping facilitates it.

3. Is the international competitiveness of China-based manufacturing networks eroding, and if so, why? Is any such erosion significant enough to precipitate a meaningful shift of production outside of China?

In my opinion the competitiveness of China is eroding, and I would attribute this to several factors:

- Increasing logistics costs and transit times, essentially eroding the tradability of many goods. If you don't have sufficient value density, it makes no economic sense to produce physical products that far away from where they are sold. Since 90% of global trade moves on water-borne trade lanes, the arrival of IMO 2023 regulations on shipping suggest to me that we are not going back to the days of the first 15 years of this century.
- China's population dividend has peaked, and demographic trends are not in its favor. China's workforce is no longer seemingly limitless, and workers are demanding more pay. That die was cast with the country's one-child policy, and there is no correcting that in the near term.
- Heightened trade tensions between the U.S. and China have made manufacturing some commodities too high risk, and we have already seen the beginnings of a lot of diversification.
- China's Zero Covid policy has made business much harder to conduct, and has injected a major degree of risk uncertainty. Manufacturers really dislike uncertainty.

[3] Wright, Theodore P., "Factors affecting the cost of airplanes," Journal of Aeronautical Sciences," 3, no. 4 (1936):122-128.

- The Chinese government's willing to disruptive some of its own industries through policy and regulation have injected more uncertainty. Until the Party Congress later this year, this uncertainty is likely to continue.

Meaningful shifts in production have already, and continue to take place. Countries like Vietnam, Malaysia, and Mexico have seen gains. Having said this, I am not prepared to write off China's long term capabilities or its ability to react and respond to these shifts.

4. How should the U.S. government and industry work together to diversify sourcing and production away from China? Are there certain manufacturing processes the U.S. public and private sector should prioritize to reduce exposure to China-centric production networks? Where are the opportunities on this score?

The U.S. Government should engage in long term planning, *i.e.,* beyond one or two election cycles, to identify strategic capabilities that we believe we and our allies need to possess or can scale rapidly under times of duress. I believe the focus should be on *platform capabilities* upon which others rest. For example the metalcasting industry is a critical part of the U.S. manufacturing ecosystem. Highly engineered castings are used to produce 90% of all durable goods and nearly all manufacturing machinery. If you cannot make metal castings efficiently and cost effectively in the quantities you need, you will have trouble making machine tools, plumbing and fluid handling devices, oil field equipment, motor vehicles, and countless other goods. We have experienced waves of offshoring in the metalcasting business, generally sending the high volume work overseas, leaving small volumes to domestic firms, including many SMEs. Thus the overseas manufacturers have been able to buy the latest tools, and they have the scale and learning curve benefits described above.

There is a lot of anxiety about our dependence on overseas sources for high capacity batteries. But again we are dependent on those sources for the manufacturing tools as well, and many of those tools depend on platform capabilities like coatings and fine chemical manufacturing.

Some of these capabilities will take a long time to restore or develop domestic capabilities. What we should watch for are step-change innovations in manufacturing process technologies that can change the game and obsolete existing processing methods, just like basic oxygen, continuous casting, and electric arc furnaces did it to the incumbent American steel makers. I see a number of these opportunities:

- Continuous flow and on demand process technology platforms for manufacturing of fine chemicals, medicines, and sterile injectables.
- New metal processing technologies, such as hydrogen assisted magnesiothermic reduction for the production of titanium spherical powders, to replace the energy intensive Kroll process.
- Additive manufacturing technologies such as binder jet printing coupled with computer modeling applied to the production of advanced metal castings.

At the same time, I believe it as crucial that our country invest to maintain leadership in the fields that will be crucial in this century:

- Life sciences, in particular manufacturing processes to support things like synthetic biology, and gene and cell therapy.
- New energy technologies, including hydrogen and derivative forms, green transition technologies, and compact modular nuclear technology.
- Advanced tool making, metrology, and packaging technologies in support of semiconductor manufacturing.

5. The Commission is mandated to make recommendations to Congress. How should the United States restore its industrial competitiveness vis-à-vis China? What other policy recommendations would you make based on the topic of your testimony?

I have been thinking a lot about this question lately. First, we need to adopt the mindset of the challenger who is trying to climb back into the ring. What I mean here is we should stop wasting emotional energy about how we have been wronged in the past and pour it into what we are going to do to (1) strengthen where we are still strong so we don't mess it up, and (2) create strategic plans to grab the lead in areas that we decide are important, leveraging many of the ideas I have mentioned above.

Part of the first suggestion is to do an honest assessment of where our free market system is having trouble competing. I have been thinking about one of these areas a lot lately, and have been interviewing numerous experts. I am decidedly NOT a tax expert, but I want to frame the issue. The question is what makes a company attractive to investors, and what are the impacts of different tax and incentive regimes on financial metrics above and below the earnings before interest, taxes, depreciation, and amortization (EBITDA) line of a company?

Why do I think this is a problem? When investors compare companies that are in capital-intensive manufacturing industries or ones where sophisticated technology investments may take years to earn a return, they often bet instead on the sectors with shorter horizons or the prospects of closer-in earnings and cash flow. Strategically critical industrial sectors, particularly capital intensive ones like most types of manufacturing have suffered in comparison. Deductions for capital investments are spread out over time, and the tax code creates a bias that favors services firms with higher labor costs and lower capital costs compared to manufacturing firms with high capital costs and lower labor costs. Investors also dislike long horizon risks associated with investments or projects that take many years to reach fruition. This is problematic for a company that has to make a large investment to stand up a new facility that may not be able to yield product for several years and turn a profit even further out – 10 years is not uncommon in some areas.

Tax policy in the U.S. is shifting with the upcoming expiration of certain deductions such as for investments. At the same time, other countries have enacted significant incentives to attract new manufacturing capacity. Incentives range from outright cash grants, concessions on land and buildings, as well as preferential tax treatment including reduced or zero corporate income taxes and exemptions from transaction taxes and import duties.

Refundable tax credits might be one vehicle to level the field a bit. Because they are refundable regardless of tax liability, under U.S. GAAP accounting rules they are treated as a grant

equivalent, so they are above the EBITDA line. Thus it also contributes to cash flow, which means it results in a P&L benefit, *making the investment more attractive*.

Non-refundable tax credits, like the R&D tax credit require a firm to have sufficient tax liability in order to absorb the credits and the associated benefits, and therefore are treated as part of tax expense and are below the EBITDA line. France, to use one example, has a refundable R&D credit, so it is treated as an above the line reduction of R&D expense.

Investment tax credits are a similar vehicle. The Section 48 Investment Tax Credit allows project owners or investors a credit for installing designated renewable energy generation equipment placed in service during the period 2006 through 2024. This might be a tool to foster both new investment, and modernization of existing processes and technologies.

Another thing to consider is the treatment of R&D expense. This has been fully deductible on an annual basis since 1954, like every other country in the world except Belgium. But the Tax Cut and Jobs Act of 2017 included a provision that require capitalization and amortization over 5 to 15 years, beginning January 1, 2022. That moves an above the line impact to below the line. The R&D Tax Credit (Research and Experimentation Tax Credit) extended by the 2015 PATH Act provides a credit amount that equals the applicable credit rate times the amount of qualified research expenses (QRE) above a base amount, but this reduces the amount of deduction for R&D expense, so 90% of corporate taxpayers elect a reduced credit.

In my mind the advantage of using taxation as a tool is that we avoid picking winners and losers. Rather, we focus on ensuring that our playing field is at least a competitive venue for firms to want to field a team, play, and stay here.

Finally, let me conclude with a few thoughts that go beyond your questions. I believe in America, and I believe in our system of market-based competition. Importantly we foster a competition of ideas, we can accept failure and the idea that people should be given another chance. We have long been that shining light on the hill that has attracted the best and the brightest to come here to be all that they can be. My parents came here with that belief, as did countless others. And this country has been good to us. If you believe, as I do, that we have a superior system, then lets address some of the imbalances that occur at the interfaces with other less-than-market systems. As for China, their leadership believes in their system. There's a side of me that says step aside and see how their top-down model will work facing the challenges in the years ahead. Their zero Covid strategy provides a lot of insight, as does the way they have treated their private education industry and their tech sector.

That also means we need to address our weaknesses and penchant for watered-down short-term solutions. I have told this Commission before that a little long term planning would benefit us all.

Thank you for the opportunity to address the Commission.