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GLOBAL CHINA'S ADVANCED TECHNOLOGY AMBITIONS

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PROCEEDINGS

FORD: Hi. This is Lindsey Ford and you're listening to the Brookings Cafeteria, a podcast about ideas and the experts who have them. I'm back today for another special episode focused on Brookings' "Global China" series.

The Global China Project will be launching a new series of papers in the next couple of weeks, exploring China's technology policies and the influence of its innovation drive on the United States and the rest of the world. Brookings partnered with Georgetown's Center for Security and Emerging Technology on several of the paper in this series, and I'm really thrilled to have two CSET research fellows and authors of new papers here with me today, Saif Khan and Remco Zwetsloot.

Guys, thank you so much for joining me.

KHAN: Thank you.

ZWETSLOOT: Thanks for having us.

FORD: This is my first remote episode for the Cafeteria, so you guys are our guinea pigs as we go into the brave new world, so we're all engaging in a little bit of innovation today.

We're going to be talking today about two issues that have been important topics in the bigger conversation about U.S.-China tech competition that's really heated up in the last couple of years. And we're going to talk about semiconductor technology and the tech talent competition.

I thought it would be interesting to talk to the two of you together because while the issues are really different, they are both areas where the U.S. has really enjoyed advantages traditionally, but where China's working hard to catch up.

So, Saif, I wanted to come to you first. Your paper looks at semiconductor manufacturing

equipment and you talked about how China is working to catch up to the U.S. in this area. Can you walk us through what advantages the U.S. has, how much progress China has made, and why this matters and why it's such a big conversation right now?

KHAN: Oh, absolutely. Yeah, so there's a number of steps involved in making computer chips, so here I'm really just going to focus on the manufacturing step, which happens at chip factories, also called a "chip fab." It's the most important for our purposes.

So, China's global share in chip fab capacity worldwide is now in the range of about 15 percent. Not a huge number necessarily, but this has doubled in just over a decade, so they're rising fast. This capacity's almost entirely, though, at, you know, older technology level and they can just make out-of-date chips that are less powerful. But some of that capacity is getting more advanced.

If China can achieve the ability to make fairly advanced chips on its own, it's a huge concern for the United States and its allies because China can then use those chips to develop military AI systems, supported surveillance activities, or to design hypersonics or nuclear weapons. Really any current or future military technology will, in one way or the other, depend on chips, which underlie virtually all technology.

But here's the key points. To operate a chip fab, you need dozens of pieces of complex, expensive equipment, what's called semiconductor manufacturing equipment in the industry. China's entirely reliant on imports from three countries for the most advanced types of this equipment. That's the United States, Japan, and the Netherlands.

Just as one example. One type of tool called a photolithography tool costs about \$120 million for one unit. This is the tool that's used to draw the tiny circuits on the computer chip. To run a single advanced chip factory you need multiple photolithography tools on top of many

other tools.

If China had to use domestically produced tools, they probably can't do any mass production of computer chips at all. Even if they manage it within the next five years, it would probably be extremely old technological capabilities, maybe even multiple decades old.

So, the bottom line here is that China can make relatively advanced chips locally but needs foreign inputs to do so.

FORD: Great, thanks. Remco, I want to turn to you for a second. You talk in your paper about high-tech talent and China's strategy to cultivate more talent. And you talk about three priorities the Chinese government has identified: domestic education, how to attract overseas Chinese talent, and then how to attract foreign talent.

Can you talk about some of the steps that China has taken in each of these three areas?

ZWETSLOOT: Yeah. So, China started reforms in all of these areas at about the same time that it was opening up its economy and generally entering the development trajectory that it is still on.

On the domestic education front, a lot of the reforms that we're sort of seeing the fruits of today started in the 1990s. And the most recent plan, the medium- and long-term education plan for 2010 to 2020, really spelled out in detail some of the targets that they were hoping to achieve in the last decade, and this year we should be seeing more targets coming out for the next decade.

The university and higher education plans are what we looked at most since that is required. Domestic capacity at the university level is really required for high-tech talent competition. The most recent plan is the Double World-Class University Project that's really aimed at some of the most elite universities. In the education sector, we're seeing a lot of reforms at the university level, but it's also really comprehensive.

For overseas talent, there was opening up in 1978. In the 1970s, we saw the first wave of Chinese researchers and students going abroad. And the hope in the beginning was that a lot of Chinese researchers would get trained abroad and then come home. That didn't turn out to be the case. And so, since the 1990s or so, we've seen an expansion of that policy from only focusing on having talent go abroad, getting trained, and then coming back, to also having talent go abroad, and what they call "serving the country by multiple means." There's also a strategy called the "two bases strategy," where basically people stay based abroad, but they also help the domestic clients and technology ecosystem by doing short-term business and things like that.

Then on the attracting international talent, so non-Chinese talent, there is a lot of more recent effort there. Since 2017, we've seen several immigration reforms, trying to make the sort of Chinese employment system a little more acceptable to foreigners. There's a lot of issues there still, but we're seeing a lot of attempts there.

And then just like with overseas Chinese talent, we're seeing a lot of incentive packages being introduced to try to bring people in. So, things like start-up money for a lab, help with getting your kids into good schools, and things like that.

So, across the education and the sort of international talent sector, we're seeing a lot of effort there.

I think it's important to distinguish between plans and results. So, across all of these areas, we've seen a lot of plans and things that look impressive on paper. The results in all of these areas have been mixed, especially in terms of attracting international talent. So, some of what looks impressive on paper might not in practice amount to great success.

FORD: That's an interesting point. This issue of international talent, this has been a big issue for the U.S. Government and for U.S. tech companies, too. And you talk about that a bit in

your paper. And you sort of note that there's a real inherent tension here for the U.S. in thinking about how to protect the domestic technology base, but also how to attract top international talent.

And it's been an issue in particular in the U.S.-China relationship lately because there have been a lot of concerns from the government about potential espionage and implications of sending technology know-how back to China that might have military applications, but then, on the other side, tech companies really needing a lot of that talent.

So, you talked a bit about what China has done to try to attract talent. How has the U.S. been dealing with this sort of tension?

ZWETSLOOT: Yeah, I think the government is really still trying to find a way to balance some of these concerns. I don't think there is a clear answer yet.

The three areas where we've seen most discussions so far are, one, on the visa side. How do we do screening to try to minimize risk?

The second area where there's been discussion is export controls and trying to maybe manage where you maybe don't want to give access to Chinese talent. There's this category within export controls called "deemed exports," which is basically about transferring information that is potentially export controlled into the head of someone who is not a U.S. citizen. Even if it happens on U.S. soil, it's still considered an export. So, that's one of the tools where people have been saying, well, maybe we should use this a little more to try to control what Chinese talent, even Chinese talent based in the U.S., can get access to.

And then the third area, we've seen a lot of action from science agencies, such as the National Science Foundation and the National Institutes of Health, where it's really more of an emphasis on transparency. So, if you're a U.S. scientist or applying for these grants, you have to

fill information in about your affiliations and who else is funding you. And there we've seen a lot of cases of people hiding, for example, affiliation with Chinese talent programs. And those people are now being prosecuted more than they used to be. Charles Lieber is probably the most famous case there.

So that's really the three areas where we've seen a lot of action, but it doesn't really amount to a comprehensive strategy yet. And I think other countries as they've seen the U.S. do this, Australia's been an early leader in this, as well, but other countries are looking to the U.S. and thinking what are the policy tools that seem to be working there and are also starting their internal debates now. Both in the U.S. and abroad it's still pretty early days.

FORD: What's been fascinating in this space, in tech talent more broadly, in the whole tech competition is that policymakers are really trying to wrestle with this idea of how much do the advantages that the U.S. has had in the tech space come from the fact that we've had a very open, transparent kind of tech ecosystem? How is China maybe taking advantage of that? And so, what does that mean? How much do you actually need to focus on controls and protecting the advantages versus maintaining openness and innovation that you think helps the United States in the long run?

Saif, I want to come back to you for a second on this. One of the arguments you make in your paper is that you say that basically only a handful of these chip fabrication factories can actually profitably operate the state-of-the-art level. And so, what U.S. policymakers are wrestling with is how to protect the fact that they have advantages in this sort of state-of-the-art fabrication right now. And they basically need to decide are these fabrication factories going to be in the U.S. and partner democracies or are they going to be in China?

So, what kind of policy solutions do you think the U.S. and other allied countries need to

be looking at to retain the advantages they have in this space right now?

KHAN: So, our headline proposal here is to apply strict export controls on the advanced equipment used to operate chip fabs, which, as I mentioned earlier, is a major bottleneck for China. This way Chinese chipmakers wouldn't be able to build advanced chip fabs to make their own chips. And because of this, China would remain reliant on chip imports.

So, I'll give a little bit of background on the industry, attempt to explain why this would work potentially. We've seen massive consolidation in the chip industry in recent years. Not long ago, there were dozens of chipmakers operating chip fabs at the state of the art. Now there's just three. You have the American company Intel, the South Korean company Samsung, and the Taiwanese company TSMC.

So, there are a number of reasons for this. Chief among them is the rising costs of construction of these chip factories, as well as the expense of the purchase of the equipment that goes into these factors. Because of these expenses, the most advanced chip fabs are now in the range of \$20 billion to build. This makes them the most expensive factories ever built.

Another piece of it is the economies of scale. Basically these chip factories become much more efficient if they're very large.

And then a final factor is just the central importance of talent in the industry, the implicit know-how that comes along with decades of experience and the intellectual property that goes with that.

So, all of these factors have forced companies to drop out and now you just have the behemoth companies that remain at the state of the art. So, to get around this, China's heavily subsidizing its chip fabs by as much as 40 percent of their fab revenues. They've also poached thousands of engineers from and engaged in massive IT theft from Taiwan's leading chip

industry.

So, against market forces they've been able to reach a technology grade that's about five years behind the state of the art with some limited capacity at that level. And still, China's pretty far from obtaining enough chip fab capacity to serve even their domestic market. Currently, they still import over \$300 billion of chips per year. It's their largest import, even more than oil.

So, if China continues their efforts, China's top chipmaker, SMIC, may succeed in reaching the state of the art and may even begin to start displacing top chipmakers and themselves seeing the incumbency advantage that's currently held by companies like Intel, Samsung, and TSMC. That said, China's chip fabs are heavily reliant on imported equipment from the U.S., Japan, and the Netherlands. So, strict export controls on this equipment can prevent China from building any more advanced chip fab capacity.

Now, to serve global demand, new chip fabs will still be built. They'll just be built elsewhere, and at the state of the art rather than in China. The equipment companies would just get replacement business from these democracies. And then, as well, China would remain reliant on imports of computer chips.

So, an obvious question that comes up is will China be spurred to develop its own equipment industry? Maybe, but it would be quite a formidable task. We think it would be extremely challenging for them to localize their equipment industry in the foreseeable future. They'd have to retrace the work of firms who survived in an ultracompetitive industry for decades, through literally hundreds of billions of dollars' worth of effort and expertise.

FORD: So, one of the things that you say in here in acknowledging that China is still behind the U.S. in this area right now is that actually the U.S. should want to China to stay in that place and have to be dependent upon the U.S. and allies for chip imports. Why? What kind of

leverage does that actually create?

KHAN: So, advanced computer chips basically underpin all advanced technology. Any type of advanced military technology benefits from state-of-the-art chips, which includes military AI systems, hypersonics, nuclear weapons. If China remains reliant on imports, then the United States and its allies can then use end-use and end-user export controls to manage the terms under which China accesses these chips.

So, there's a few ways you could do this. One proposal would be for the United States and its allies to be presumptively vigilant about Chinese state actors, actors with close ties to the Chinese government, companies that are trying to set up supercomputers or large advanced computing facilities, like data centers that are likely to be used for military applications, or actors involved in human rights violations. The bottom line is China's reliance on democracies for these chips could preempt the development and proliferation of many dangerous technologies. It could also preempt arms races. And finally, promote global stability and democratic values and human rights.

FORD: Now, one of the things that you say is that in exporting chips to China, democracies should only be doing it for people commercial purposes. But one of the challenges here is a lot of times it's very hard to tell in China what the actual end use will be because a lot of times there are dual-use technologies that have ostensibly civilian purposes but could also be used to abuse human rights or for military purposes, as well. I mean, this is sort of the classic problem of what China does with a lot of its surveillance technology.

So, given that challenge, how do policymakers actually make sure that if they are still exporting chips to China, there is some ability to understand whether the end use aligns with our values?

KHAN: Yeah, you're absolutely right that finding the right balance here is challenging. The obvious upside to broad export controls on computer chips is a reduced chance that these chips can be later used in military systems or in ways that conflict with democratic values.

That said, there are major downsides to overbroad controls. For one, computer chips are broadly necessary for so much technology that it's contributed to great gains in the standard of living and welfare in Chinese citizens in recent decade. The goal here is not to put a dent in that progress. In fact, quite the opposite. The goal here is to promote democratic values and human rights, things that Chinese citizens could stand to benefit from if the Chinese government is not able to employ technologies enabling their authoritarian apparatus, like advanced AI-enabled surveillance systems.

Another downside, these U.S. chipmakers, like Intel, AMD, and Nvidia and Qualcomm get about one-quarter of their revenue or even as much as two-thirds of their revenue from the Chinese market. If they lose access to large parts of the Chinese market, their R&D investments in international competitiveness will be significantly impacted. If we continue to export chips for civilian uses, it means that the Chinese commercial sector is effectively subsidizing the chip industry in democracies, even as the Chinese government is trying to subsidize an authoritarian counterpart. There's far more money in the commercial sector for chips than there is in government spending.

So, the right balance here is difficult and there's no precise solution. The principles I laid out earlier hold. Be vigilant about obvious state and military end uses and end users. But on top of that, the United States and its allies should keep close watch on private companies in China. For example, export controls could vigorously be enforced if private companies are found to be collaborating with the Chinese military. They should be put on the entity list and deprived of any

exports at all from democracies. Even the risk of being discovered could itself be a strong incentive for Chinese companies to avoid collaborating with the military and to engage in ethical uses of the advanced technologies incorporating computer chips.

FORD: So, Remco, I want to turn to you for a second because you talk about some similar issues in your paper in terms of how the U.S. needs to think about controls and less exports controls, more thinking about visa policies. And you really say that America's ability to not just attract but retain Chinese talent is an advantage that the U.S. has over Beijing, and that the U.S. needs to be careful about adopting really broad policies, similar to what Saif was just talking about, that could actually put that advantage at risk.

That seems like a different argument to me than the one that the Trump administration has been making or perhaps a slightly different calibrated policy than what we're seeing right now. What's your analysis of the current administration's approach on visas for Chinese talent? And are there any specific policies or proposals you think should be revisited or that are counterproductive?

ZWETSLOOT: Yeah, it's a great question. And I agree that there's a lot of overlap with some of the problems Saif is talking about and then in a talent space. I think in export controls, this is a longer debate and people have kind of seen both sides of it for a while and so that's a little bit more established. And I think in the talent space, people are still trying to navigate this issue and it's a little newer, so the conversation is still a little bit more messy.

I think this is really a tough issue and the Trump administration is perhaps the first one that has sort of tried to publicly grapple with it in a very big way. I think a lot of the people that's in government right now really have a good sense of these tradeoffs, which is why I think there are not really clear sort of negative policies yet.

In 2018, we saw perhaps the broadest proposal. Early in the year there was consideration of basically banning all Chinese students. There was a conversation in the Oval Office at the time and it was basically decided not to do that, but that it was a serious conversation is significant. I think since then, there's both a recognition that underreaction is risky, but also a recognition that overreaction is risky.

The way in which overreacting could be risky is, first, if you don't have enough talent at home what that usually does is force companies to set up facilities abroad, including in China. I think when you look in the AI space, which I know that Facebook says things like we just basically go where the talent is, where we set up our labs, because AI talent is so sparse.

So, if you reduce the amount of Chinese talent in the United States and that might reduce the risk of technology transfer somewhat, but, at the same time, that means companies are going abroad and that increases the risk of technology transfer somewhat. Is that a tradeoff you want to make? I think nobody really knows or has done that analysis yet.

Second, as the paper suggests and as we were just talking about, you know, there's really competition between different developed countries for Chinese talent, as well, so it might just be that you move the problem elsewhere if the U.S. acts unilaterally. And the only way to avoid that is really to coordinate with allies and partners. And the U.S. has taken some small steps in that direction. The State Department has, over the past two years, organized the Multilateral Action on Sensitive Technologies Conference, which is kind of exploring this with about a dozen allies and partners.

So, I think there's really a recognition that overreaction is risky and there should be steps taken to try to avoid that. At the same time, underreaction is also risky, so, you know, we're still trying to figure out how to strike that balance.

You asked about specific policies that would be counterproductive. I think one of the things that certain parts of the Trump administration is considering is cancelling or otherwise sort of restricting the Optional Practical Training program, which is a program that's part of sort of student visas that allows students to stay in the United States and work for one to three years after they graduate. This program is not as well-known was, for example, H1B visas, but there are now about 250,000 students roughly each year who use this program, which is about 2-1/2 times the size of the H1B program.

And this is a program that was created through regulation, not through Congress. So, that's actually something the administration could roll back if it wanted to. I think that would be a really big mistake and we don't really know what the state of that conversation is right now. But that would be an example of, I think, an incredibly broad measure similar to sort of banning all Chinese students. I think striking that balance really requires a more targeted approach.

FORD: Thanks, Remco. What strikes me about the talent competition in particular is a lot of the conversation right now is about how to handle Chinese students and Chinese talent, and that makes a lot of sense and there are important policy issues to be considered here. But part of the reason that the U.S. needs talent from abroad is that in some places we don't have as much of the talent as probably ought to at home. That's a bigger problem and a much more fundamental problem for U.S. policymakers.

So, China has made this enormous push on cultivating talent, on promoting innovation, from the top down as a national strategy. What would it actually take for the U.S. to do the same kind of thing?

ZWETSLOOT: Yeah, it's a great question. I think people in the talent policy conversation often talk about it as we need to both protect and then we need to also promote. I

think the conversation is really focused on this protection question of how do we protect our technology? But it hasn't focused as much on the question of how do we promote sort of growth in the U.S. ecosystem. You can slow China down, but if at the same time the U.S. slows down, that's not giving you much of a competitive advantage.

So, I think a promote strategy would have two overarching elements. One is immigration reform. I think it's important to build out the domestic talent pipeline, but, ultimately, China is about quadruple the size of the United States and as it continues to improve its domestic system, you know, the U.S. can't compete with American talent alone. And immigration reform is really key, I think, to attracting and retaining international talent.

It's a key strength of the U.S. already, so one of the things we didn't mention before, but we have good statistics on how many international Ph.D. students stay in the United States. Chinese Ph.D.'s stay at a rate of about 85 to 90 percent in most STEM fields. That's immediately after graduating and then 5 to 10 years out, 80 percent are still in the United States. For Indian students, which is the second largest country of origin, about the same. But structural issues with the immigration system are making that a lot harder. So, right now if an Indian Ph.D., for example, would apply for permanent residency, the projected wait time for them is about 40 to 90 years, depending on your assumptions about how the immigration system evolves, but unless there are major changes, that just becomes untenable.

The second piece aside from immigration reforms is the domestic talent piece. So, making sure that there are more Americans, for example, going to graduate school. If you look at the semiconductor sector, actually, is an interesting example of this. If you look at the American university sort of graduate pipeline in semiconductor-related fields, there hasn't been an increase in the number of American graduate students since 1990. So, the last 20 or 30 years, all the

growth at U.S. universities in those fields have come from international students. So, I think that is something that policymakers probably want to think about, how do we change that?

I think how you do that depends a little bit on the field because labor markets really vary a lot across different technical fields. The life sciences, for example, look very different from semiconductors. But broadly speaking, immigration and domestic workforce policy are going to have to be the two-pronged approach that the U.S. takes.

FORD: I like that sort of idea of both protect and promote. And it seems to me like that's actually a great frame overall for the kinds of debates and conversations that we're having around tech policy because the U.S.-China tech competition isn't going away. And most certainly, there is an aspect of this where the United States needs to think more about how it does protect its own advantages. But it also has to be thinking not just about how you protect what you already have, but how you grow the pot, how you create and promote new advantages. So, I really appreciate that aspect of the conversation.

Well, Saif, Remco, this has been a fantastic conversation today. I hope that everyone will go read your papers and the rest of the papers in the new "Global China" series that are coming out because they're fascinating. And for someone like me, who hasn't spent a ton of time in the tech space, I learned so much from reading them and I'm sure other people will, as well.

So, thank you, guys, again for joining me for this conversation.

KHAN: Thank you.

ZWETSLOOT: Thank you so much for having us on the podcast and all the great questions.

FORD: And with that, we're going to wrap up. I'm Lindsey Ford and this has been another episode of Brookings Cafeteria.

DEWS: The Brookings Cafeteria Podcast is the product of an amazing team of colleagues, starting with Audio Engineer Gaston Reboredo and Producer Chris McKenna. Bill Finan, Director of the Brookings Institution Press, does the book interviews, and Lisette Baylor and Eric Abalahin provide design and web support. Finally, my thanks to Camilo Ramirez and Emily Horne for their guidance and support.

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Until next time, I'm Fred Dews.

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