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The Third Wave: Innovation and Strategic Military Capacity in the Future

Peter COWHEY

SUMMARY

This brief examines the capacity of China to challenge America as a technology innovator. It assumes that the balance of innovation capacity matters for strategic strength in the long haul. Absent a fuller analysis of this assumption, this brief makes some ad hoc observations about the possible relationship. The analysis treats innovation as the successful commercialization (or strategic military application) of a technology change.

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My argument is simple. There are two kinds of innovation systems for technology—incremental product and process innovation and novel product innovation. On incremental innovation, China is making substantial progress and could surpass the United States if the United States does not take ameliorative action. In regard to novel product innovation, China is rapidly reducing the gap with the United States in terms of many inputs into technology innovation. However, it is not making proportionate gains on the output of such efforts; the flow of novel product innovations. In fact, it may be following policies that will weaken its position

This possible weakening is occurring because the system for novel product innovation is entering into a new “Third Wave” that is even more distant from China’s system of state-owned enterprises (SOEs) than the “Second Wave” of venture capital-funded startups that has dominated novel product innovation in the past thirty years. There is also a possibility that the “Third Wave” model will open a new path for incremental innovation in the United States.¹

NOVEL PRODUCT VERSUS INCREMENTAL PRODUCT AND PROCESS INNOVATIONS

Most discussions of innovation highlight novel breakthrough developments that give rise to game-changing American technology, thereby generating enormous economic benefits. Think of this as “novel-product” innovation (NPI), where the firm or lab producing it comes up with an entirely new technology or product. However, NPI is only half of the story. An even larger stream of market innovations involves an array of incremental product innovations, like continual improvements in automobile transmissions, together with innovations in production processes. This concept is known as incremental and process innovation, or I&P. The globalization of design, production, sophisticated manufacturing, and distribution has changed this form of innovation greatly in recent decades.

This brief will assume, for reasons found in the work of Breznitz and Murphee, that China has been making excellent progress in strengthening its I&P system.² In contrast, for reasons spelled out by Breznitz and Cowhey, the United States has stumbled. It is plausible to imagine that this kind of incremental

innovation has powerful consequences for the maintenance and steady upgrading of capital assets for military needs. Thus, the future of this innovation system cannot be ignored when examining the role of innovation for military capacity. The purpose of this brief, however, is to consider the ability to produce “breakthrough” novel product technologies that significantly change capabilities—think radar, nuclear power for submarines, lasers, or satellite communications.

INNOVATION SYSTEMS: THE THREE WAVES

Innovation is the product of a system, not simply a collection of inputs such as financial or human capital, although many metrics of national innovation capacity focus on R&D budgets, the number of STEM PhDs, and other such inputs. Nor is innovation simply a stream of individual outputs of roughly equal significance, such as measures built on total patent counts, nor is it predicted fully by “environmental” indicators of political-economic conditions such as transparency, corruption, independence of courts, or level of market competition.

The system of innovation depends on how the relationships among inputs, the environment, and planned output mesh. We know that every organizational form ranging from pure contracting relations to complex vertical integration has trade-offs about its proclivities, and every strategy to mobilize innovation for a market has similar trade-offs.³ Because the environment for innovation changes over time, and the characteristics of the technological possibilities shift, we should expect periodic changes in the dominant way in which we organize for NPI. Nonetheless, Breznitz and Cowhey argue that NPI systems rest on four fundamental “building blocks” that address both market mechanisms and building social capital:

1. *Shared production assets*: Firms need to fund and use assets held in common.
2. *Effective innovation network structures*: These are both market and social network structures to facilitate creative interchange among the people with ideas and the economic units that can respond creatively to the commercialization of these ideas.
3. *Flexible business models*: Restructuring the traditional definitions of supply and demand functions in markets is often as important as an innovative product.

1 The analysis in this brief draws materially on the discussion of the two types of innovations found in Dan Breznitz and Peter Cowhey, “America’s Two Systems of Innovation: Innovation for Production in Fostering U.S. Growth,” *Innovations: Technology, Governance, Globalization* 7 (Summer 2012):127–54, but it also expands upon that argument.

2 Dan Breznitz and M. Murphee, *The Run of the Red Queen* (New Haven, CT: Yale University Press, 2011).

3 See Oliver Williamson, *The Economic Institutions of Capitalism* (New York: The Free Press, 1985); and Carl Shapiro and Hal Varian, *Information Rules* (Cambridge, MA: Harvard Business School Press, 1999).

4. *Specialized financial institutions*: Risk assessment capacity and lending/investment models appropriate to different types of innovation are necessary.⁴

In my view, the United States has gone through two dominant systems for NPI since 1945, and it may be entering a third. In contrast, a single model, China's SOE system, has dominated its NPI since its introduction of market economics, even though there have been big attempts to shift to a second model. The challenge for China is that much of the technological opportunity for NPI and the environment for innovation may favor the third wave of NPI organization now emerging in the United States. To explain the waves of innovation, I focus on the U.S. experience.

THE FIRST TWO WAVES

U.S. research spending and technology production after 1945 involved large enterprises conducting both novel and I&P innovation in house. Typically, they were highly vertically integrated (from production through final sales), and many had substantial elements of product diversification. Many enterprises worked, for example, in both defense and civilian markets. Thus, these firms had production and design know-how plus basic research talent that could be shared within the firm as new ideas emerged for commercialization. Moreover, these firms had enormous financial and human capital resources. Firms internalized many of the financial risk management functions for innovation, including pools of "patient capital" that could be invested in novel products without expecting rapid returns. In many cases, the U.S. Government defense (broadly defined) and infrastructure programs provided early piloting and scale-up resources through government procurement.

Significantly, these companies internalized social networking among specialist groups in different phases of design and production. For example, AT&T's Bell Labs designed its facilities with long halls, forcing researchers to walk past other labs and opening chances for conversations and unforeseen collaborations. (Of course, this didn't always work fully, as witnessed by the failure of Xerox to network its PARC research center findings into commercial strategy.) Finally, these firms took advantage of their scale and scope to roll out big innovations in novel business packages, like IBM's leasing arrangements for its "bet the company" innovation of the IBM System/360 mainframe computer, which departed sharply from traditional sales models. Boeing also understood that global sales of

the jet airplane would require it to create an informal "foreign aid" group to provide technical assistance for other countries to upgrade their airports, air traffic, and aviation safety systems. This assistance became an important reason countries bought Boeing.

This model of innovation receded sharply after U.S. corporations were battered by the Japanese economic challenges beginning in the 1970s. Japanese firms had studied the U.S. innovation model and found ways of significantly refining the performance of American firms. (Much of the challenge came in I&P innovation, embodied in the "Toyota Way," but it also spilled over into microelectronics and other NPI fields.) In response, by the 1980s, American giants began corporate restructuring that focused more narrowly on their "core competencies" where they had sustainable advantages and could constantly renovate cost and product structures. This reduced the amount of product diversification. Just as importantly, it led these firms to prune support for general R&D groups to align research more closely to anticipated commercial needs, and it shifted finances. Financial markets began to "monitor" publicly traded firms by emphasizing quarterly financial returns and investment in only the highest return alternatives. While not impossible (as shown by Intel), massive spending on capital intensive investments with long-term paybacks had a steeper threshold for approval under this approach.

The changes in the leaders of the First Wave led to a dominant Second Wave as the basis for NPI. In this new landscape, a great deal of innovation was driven by entrants focused on specific stages of production. This significant change enabled the development of new arrangements for financing and networking the newly fragmented ecosystem of innovation.

The current U.S. system for NPI focuses on "regional clusters" that are tilted toward start-up-driven NPI. This Second Wave focuses on the interaction between the national and regional level through technology clusters. Anchor universities are critical to both knowledge creation and human capital. Significantly, common economic and research assets for firms (such as mass spectrometers) are frequently created in anchor universities. Essential to this model are new laws and regulations that allow and incentivize the creation of financial vehicles, such as venture capital (VC), and the creation of markets (such as NASDAQ) that allow realization of financial gains within a short time span. Technology clusters also strive to develop an ecosystem of professional support services for new technology-based firms (such as law and accounting firms).

The great success of this model and the immense financial gains to founders and financiers make it the focus of policy discussions. Regional anchors and sup-

⁴ Bresnitz and Cowhey, 2012.

porting federal measures made the conventional model politically viable in both “Democratic” and “Republican” states.⁵

Successful NPI clusters addressed both market failures and social/informational networking. Courting venture and “angel” capitalists attuned to the region and promoting incubators that lower costs and identify prospects for early investors helped to address the costs associated with seeking finance when researchers are not part of internal corporate innovation systems. Cluster leaders routinely acknowledge that people are the most important asset for NPI industries. Clusters provide a social institutional solution for the loss of the human networks in vertically integrated firms. Strong social networks, abetted by formal and informal institutions, are essential both to the circulation of knowledge and people and the building of trust that make for successful clusters. The divergent path of the California and Massachusetts information industries has been attributed to the difference in their social networks.

Underlying the regional clusters are the national policies that fund basic and applied R&D. These policies induce the training of researchers and engineers, protect intellectual property central to novel technologies, and enforce competition rules that keep markets open to newcomers. Significantly, the strengthening of intellectual property protection allows this knowledge sharing while reducing commercial risk.

Policies supporting business model innovation were important part of the Second Wave. These included changes in how universities could commercially license results from federally funded research (the Bayh-Dole Act), SEC rules changing how pension funds could invest their funds (critical to funding VCs), federal competition policy (including the breakup of AT&T, which opened up many markets for new technological entrants), and the federal decision to use a “light hand” in technologically dynamic markets, like refraining from government selection of mandatory technology standards and initially taking a greenfield view of e-commerce markets.

Many of today’s corporate giants began as Second Wave startups. These firms share some characteristics with the restructured giants of the first wave, but the most successful gravitated toward two models. One group became extremely powerful players in specialized market/technological niches. They owned a piece of technological expertise used by many other players. By ownership I mean that they commanded the core know-how more fully than rivals, successfully scaled global supply and service support, and used intellec-

tual property to reinforce their position. But the technology was, in many senses, highly specialized in its role in larger product spaces. Qualcomm and Cisco are representatives of these companies.

Another group successfully created platforms—a technical competence that is foundational to all of a market’s products and those found in its supporting technology ecosystem—that has unusual stability because it is “sticky;” once others have invested in the platform they are reluctant to leave it.

THE EMERGENCE OF A THIRD WAVE?

The pervasive impact of new information and communications technology (ICT) capabilities changes both how we organize to innovate and how we commercialize successfully for many goods and services. We are familiar with the idea that innovations like e-commerce for music gutted part of the traditional revenue for music stars, yet reinvigorated the “Long Tail” of markets for specialized musicians. The Third Wave features “ultra-lite” management and production structures, even compared to startup models of the past thirty years, with much greater reliance on outsourcing of many traditional business inputs. The financial and business models change as a result of lower upfront development costs, alternative ways of aggregating specialized pools of capital, and different ways of serving the market. The key here is that the NPI frontier in many respects is in using new ICT and production capabilities to meet long-standing development, production, and performance challenges in a radically different way. It is particularly good at enabling novel innovations that may not have large-scale markets.

Why may a third wave be emerging? It is a product of both nagging problems and emerging opportunities. The problems are not at a crisis level, but they are not trivial. For one, the cluster model, for all of its virtues, has proven difficult to replicate successfully. In the United States, the clusters of Silicon Valley, Boston, the Research Triangle of Raleigh-Durham-Chapel Hill, Seattle, and San Diego usually dominate the list of successes. Smaller clusters like the ones in Pittsburgh and Austin have also scored gains, but for all of the talk of cluster dynamics, places like Atlanta and New York did not prove to be big winners under the cluster model for many years.⁶ Two possible reasons are:

1. *The expert density level:* In ICT and biotech you either have one of the biggest clusters

5 Jonathan Sallet et al., “The Geography of Innovation,” *Science Progress*, Sept. 1, 2009.

6 Dan Breznitz and Mollie Taylor, “California Dreaming? Cross-Cluster Embeddedness and the Systematic Non-Emergence of the ‘Next Silicon Valley,’” working paper, 2012.

of talent and have enough local geographic fluidity or you don't quite succeed. Atlanta lacked short distances with easy transport.

2. *The high cost of ramping up startups based on other forms of regional expertise:* For example, New York's Silicon Alley had ample cultural/content/media talent, but New York was not good at attracting large numbers of IT engineers at affordable prices.

Another issue is the declining base of federal support for the underlying basic research and training missions of anchor universities. Universities are scrambling to find alternative revenues, and this will influence a vital "shared asset" for innovation change. Moreover, the VC model has a goal to invest in companies that offer financial returns of a hundred or more per dollar invested within five years. While a VC will invest in many companies to find a few winners, as the number of big hits has declined in proportion to the growing pool of VC capital many VC firms are turning to a more conservative approach whereby they decline to invest in the earliest stages of innovation.⁷ Moreover, as observers of pharma innovation have bemoaned, there are many medical problems where there is promising science but not a viable economic model, including the VC model, for pursuing opportunities.

On the flip side, today there is a changing opportunity set for innovators that invites a Third Wave model. One key is three changes in the information and communications infrastructure for innovation:

1. Ideas (enshrined in intellectual property), information (software), and services are becoming a much higher share of value added in all products, including manufactured products. They constitute a much bigger share of the value differentiator of these products and are becoming centers for anticipated revenue streams.⁸ Consider a company like Nest, a firm that has revolutionized thermostat control systems, traditionally an electro-mechanical technology that fully incorporates simple-to-use ICT systems. Nest proclaims that "We take what's familiar and look at it in a new light. Our team focuses on making technology that's simple, fresh and helpful."
2. The emergence of cloud computing, ubiquitous broadband, and modular interfaces facilitates

7 Robert Litan and Carl Schramm, *Better Capitalism* (New Haven, CT: Yale University Press, 2012),

8 They also permit new management strategies. See Andrew McAfee and Erik Brynjolfsson, "Big Data: The Management Revolution," *Harvard Business Review* (October 2012).

the "mix and match" of digital building blocks and the spread of ICT applications to markets (implanted medical devices, farm field plowing and harvesting) that previously did not depend so heavily on ICT as part of innovation dynamics.⁹ It also substantially lowers the cost of many forms of NPI. For example, conventional estimates are that startup ICT costs (hardware/software plus personnel) have dropped by 70 to 80 percent since 2000, and capital can be aggregated and organized in alternative models far more easily.

3. The result: Faster innovation with more specialized products and novel business models becomes easier. While it is still possible to create a platform, it is much easier to challenge a platform because of greater volatility in business models and lower costs for specialized innovation.

The other key is new means of physical product production. There are new tools for production that reduce costs of specialized products such as the much-discussed chemical "printers" that can manufacture sophisticated low-batch products, like product prototypes of specialized orders, with short production runs. Perhaps more significantly, improved ICT services to integrate design and testing with manufacturing more effectively and continuing experimentation with "shared" manufacturing facilities open the way to lower costs for scaling manufactured products.

The Third Wave takes advantage of these opportunities in several ways. While it is still too early to determine the dominant model, we can see signs of two ways in which these inputs could coalesce in an NPI model. The first way is a less radical departure (think of it as Wave 2.5) from the Second Wave than the second way, which would truly be Wave 3.0.

Wave 2.5 takes the new ICT support capacities (much faster ICT application innovations at lower costs and with much lower requirements for hardware and support engineers) to propel the emergence of specialized new innovation clusters in regions that did not emerge as the big winners of the second wave. As an illustration, think of how the introduction of ICT intensive forms of agriculture (more tractors resemble a cockpit of real time information collected by sensors in fields, GPS guidance of plowing patterns, and other inputs designed to double crop yields by 2030) opens the way to local experts growing to create specialized agriculture design (for sensor nets) and systems management firms that could market their skills globally.

With the ability to use virtual ICT platforms (from the "cloud" and its ecosystem of services) plus special-

9 See Peter Cowhey and J. Aronson, *Transforming Global Information and Communications Markets* (Cambridge, MA: MIT Press, 2009),

ized batch production, such concepts no longer require dense manufacturing clusters or big groups of ICT engineers. In the pure content world, consider how New York City (according to people who tend the world of applications ecosystems) is now finally emerging as one of the major application content innovators because it no longer needs to have an indigenous ICT platform located in Manhattan.

A second variation is also emerging, and it represents a more radical departure from the Second Wave. ICT and new production tools allow innovation to develop in “on-line” (Web-based) communities that do not depend on geographic proximity for networking and are even more specialized than traditional start-ups. Think of these as having “ultra-lite” organizational characteristics that are custom-built to the task. For example, by around 2007, a prototype existed for taking a traditional environmental air monitoring station (cost around \$250,000) into a low-cost chip technology (cost about \$10). But the creation of a viable commercial product required marrying this to an appealing consumer model that created a user-friendly front end for the sensors with a way of networking them via conventional cell phone networks. The problem has been solved by the Node. The Node created a modular attachment for a cell phone with sensors at a total cost of \$72,000 because of the lower costs of development. Just as strikingly, it raised all of the funds through “crowd sourcing” on Kickstarter.com.

Lower upfront costs for ICT are not the only reason development costs are dropping. ICT also enables new business development models. Instead of expensive marketing feasibility and prototype development efforts, Third Wave innovators are putting ideas and preliminary mock-ups on the Web and inviting public comment on the attractiveness of the idea and the preliminary design. With the help of tools like Skype, they are reducing office space needs and using flexible contractors, even for highly skilled core tasks.

There are four even more subtle stories involved in Third Wave firms.

- On-line collaboration is becoming powerful enough that studies of knowledge diffusion indicate that geographic proximity matters less, at least for the research side of the commercialization function.¹⁰ The “ultra-lite” models are trying to integrate ad hoc clusters of experts into very particular innovation efforts. The “Open Source” software model that operated on a global scale was an “early” forerunner of this development.

10 Josh Graff Zivin, Pierre Azoulay, and Gustavo Manso, “Incentives and Creativity: Evidence from the Academic Life Sciences.” *RAND Journal of Economics* 42 (2011): 527–54.

- Shared production assets. A key question is whether geographic clustering still matters heavily for transfer to successful commercial efforts, particularly if physical production is part of the innovative product. For example, DOD’s DARPA is supporting a hybrid model of physical and online space with its hacker spaces such as “Pump Station: One” or the “Hacktory” that mainly operate in virtual communities but have physical “clubhouses” or “workshops” where tools like laser cutters are available as a supplement.¹¹ Such workshops may require anchor universities, but it may also be possible to support them in many more places at far lower costs.
- The revenue model for many of these Third Wave innovations will depend on the use of information services to earn revenues more than on profits from the original product sale. This approach is not a new strategy (making money on razor blades, not razors, had a similar market logic), but it is becoming much more pervasive in an ICT intensive world.
- The financial models for funding innovation are becoming more customized. The relative importance of “angel investors” is rising as VCs are more cautious. Even more interestingly, crowdsourcing on the Web allows innovators to propose ideas and gather investors based on their desire to have the innovation with rights to early use—think of a specialized machine tool that many small companies might desire but none would ever dream of developing—or because they have a passion to see this innovation for society; a form of the rapidly growing sphere of social investing.

These examples illustrate how the building blocks of any NPI model—shared production assets, social networking institutions, specialized financial institutions, and novel business models—might coalesce in a distinctive Third Wave. They are also changing how winners in the Second Wave are thinking about their future growth.

IMPLICATIONS FOR THE BALANCE OF NPI CAPACITY

The lessons of the Third Wave are that a significant amount of the NPI potential requires continuous experimentation to escape traditional organizational,

11 *New York Times*, October 6, 2012, A1.

financial, and business model practices. The startup model of the Second Wave is no longer the sharp cutting edge, although it is certainly going to continue to play a large role in NPI. At a minimum (which I dubbed Wave 2.5), the Third Wave restructures how traditional expert communities can organize their knowledge for commercializing innovation. At a maximum, (which I dubbed Wave 3.0), it networks and recombines talented people in very flexible ways (ultra-lite management) with a very different way of designing, prototyping, marketing, and fund raising for innovation.

The Third Wave puts a strong premium on the ability to incent and implement very novel structures for organizing innovation. Simply duplicating the most successful technology clusters of the Second Wave will not suffice.

New models of innovation require adjustments in public policies. The United States will have to explore how it creates ready access to shared production assets, and reform laws and regulations governing finance (to incentivize social capital, crowdsourcing, and other novel techniques) and intellectual property (to eliminate barriers to various kinds of hybrids of traditional intellectual property and creative commons systems). Nevertheless, the U.S. experience with the Second Wave leaves it in a strong position to embrace the Third Wave. This includes its remarkably vigorous ICT and services expertise. The United States also remains a market where firms can scale in a relatively flexible regulatory environment, strongly supporting competition and new entry, and research universities that are eagerly looking for new ways to engage the innovation community beyond the traditional roles of educating the talent and licensing products from labs. As the specialist groups necessary for successful innovation become smaller, more and more of the regional research universities of the United States will be able to successfully support Third Wave innovators.

The challenge of the Third Wave for China is significant. It is still largely dependent on a state-owned enterprise system of innovation that resembles the First Wave without much reform. Some of the subsequently privatized firms, like Lenovo, look more like U.S. firms with heritage from early in the Second Wave, like HP. The efforts to duplicate the Second Wave have produced giant industrial parks and start-up clusters with

lots of talented people and money, but, to date, they have produced less NPI than one might expect. This may relate to the negative effects of the cluster organizations being too large, or from the incentives that still pervade from top-down incentives super-charged by the SOEs and state influenced banks. But these questions become all the more significant when dealing with the Third Wave. The strength of China is that its success in I&P innovation has left it with very interesting production communities that could be workshops for Third Wave innovators. “Cellular manufacturing” systems in second- and third-tier suppliers in China may emerge as a new model for production of small batch, flexible products of great sophistication,¹² but SOEs may bypass even these production innovations in an effort to move toward larger-scale automation in factories.

The implications for military capacity, aside from the importance of the relative robustness of the NPI systems of each country, are necessarily speculative. Though if there is any merit to the idea that military capacity is becoming increasingly informational intensive and situational aware, and it is becoming tied to a variety of “environmental” contexts such as biosecurity, cyber security, or disruptions of populations by natural disasters, then the Third Wave matters a great deal. The Third Wave is precisely about how to restructure the NPI system to take advantage of ICT and novel production assets to allow for unconventional sources of pinpoint innovations. Many of these innovations did not have enough commercial scale to be practical in the past. Now it is conceivable to imagine that many military related innovations will be possible because the Third Wave can be faster and cheaper in delivering “boutique” solutions on a flexible basis. The “Long Tail” of Third Wave innovations may be the tail that wagged the strategic dog of the future.

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¹² I thank Erica Fuchs for this observation.