Comparison of National Innovation Systems in China, Taiwan, and Singapore: Is Bayh-Dole One-Size that Fits All?

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Abstract

National innovation system (NIS) is an analytical tool to evaluate a country's technological development that focuses on institutional actors creating and diffusing technologies. Examining the policies shaping NIS in China, Taiwan, and Singapore reveals dramatic differences in the types of institutional actors in each country and their roles overseeing and performing research and development (R&D). These differences further exist in university-industry linkages (UILs). As an example of contrasting UIL governing transfer of public research assets to the private sector, the operation of each country's Bayh-Dole style legislation is described to illuminate indicators of technology transfer and preview future obstacles. It is finally suggested that legislation implementing innovation policy should be crafted within the context of a country's specific needs.

Introduction

One leading approach in analyzing a country's technological development is the concept of national innovation system (NIS). First proposed by economist Christopher Freeman to evaluate Japan's rapid postwar development, NIS focuses on institutional actors (public and private) and their activities (creating, importing, modifying, and diffusing new technologies). Legislation promoting the creation and transfer of technology, such as Bayh-Dole (BD), falls within a narrower slice of NIS that is the university-industry linkage

(UIL). A UIL broadly describes how basic R&D activities interact, diffuse, and transfer to the commercial sector. Because NIS varies drastically, it is easy to imagine similarly dramatic variations in UIL.

The following evaluation of NIS in China, Taiwan, and Singapore reveals dramatic differences in the structure and function of institutional actors overseeing and performing research and development (R&D). Because the role of institutional actors in different countries varies significantly, it is suggested that legislation implementing innovation policy, such as those governing UIL, should be crafted within the context of a country's specific needs.

The first section of this paper analyzes the NIS of China, Taiwan, and Singapore, looking in particular at how they shaped and defined institutional actors. The second section evaluates UIL, using the specific example of BD-style legislation in each country to illuminate existing indicators of technology transfer and preview potential obstacles.

National Innovation System (NIS): An Analytical Tool Focused on Institutional Actors' Activities and Interactions

There is no universal definition of NIS, but competing interpretations share the core principle that the function and interactions of actors are significant forces in shaping a nation's scientific and technological development.[1] The Organization for Economic Cooperation and Development (OECD) provides one framework for detailing a country's NIS, suggesting six primary roles for institutional actors. This includes: (1) performing R&D, (2) financing R&D, (3) human resource development, (4) diffusing technology, (5) promoting entrepreneurship, and (6) formulating technology and innovation policy.[2] This broad definition encompasses everything from administrative agencies coordinating and conducting public research (e.g., the National Institutes of Health), private-sector research enterprises (e.g., Genentech), higher education (e.g., Stanford University), and bridging institutions (e.g., Biotechnology Industry Organization).

Focusing on these specific roles of institutional actors provides a useful analytical tool in characterizing activities beyond rough function-based definitions. An administrative agency in one country may vary drastically from an analogous agency in another county in terms of function. As an example, the Chinese Academy of Science (CAS) in mainland communist China and Academia Sinica (AS) in nationalist Taiwan are the analogous scientific academies in each country. Both academies serve key roles in governing public research institutes and even share a common origin (with AS being relocated to Taiwan after the 1949 Chinese civil war).

However, CAS directly establishes and invests in high-technology enterprises, starting nearly 400 spinoff companies to date.[3] In contrast, AS does not directly foster such private commercialization, but rather, promotes adoption of new technologies by existing private enterprises.[4]

To provide further context in understanding the role of institutional actors in each country, this paper first summarizes the underlying technology policies shaping their creation. A brief discussion of NIS follows, first beginning with China, turning next to Taiwan and Singapore.

China: Shifting away from a Legacy of Central Planning, the Rise and Fall of the University-Research Enterprise

After the founding of the People's Republic of China in 1949, research was conducted primarily at specialized public research institutes (RIs), with universities involved in only a limited number of research activities. Adopting the central planning approach of its Northern neighbor, the Soviet Union, the Chinese government was the principle source of science and technology (S&T) funding. The government allocated specific, defined tasks to RIs through administrative orders, with the majority of science research focused on military-related applications. In contrast, "Universities did undertake research, but their most important priority was pedagogy."[5]

Furthermore, this central planning structure erected a wall, divorcing S&T innovation from industrial activities fixated with production. "As a result of this system, public research institutes had no incentive to understand the needs of enterprises for technology… state-owned enterprises were supposed to concentrate on production activities, without proper incentive systems for innovation..."[6] This artificial decoupling of research and industry eviscerated innovation incentives, causing China to lag behind other Asian nations in technology development.

Establishing Western-style economic reforms in the 1980s was coupled with an emerging emphasis on scientific research and education for economic development. The first of three major policy shifts occurred in 1985 by winnowing away the prior Soviet-style research structure through creation of new incentives. Specifically, RI and university budgets were slashed to spur increased collaboration with industry for alternative funding resources. "For URIs, the only option was to search for alternative source of funds."[7]

In concert with changing the funding landscape, new innovation incentives were offered through adoption of the landmark 1985 Chinese patent law. Together, these initiatives attempted to traverse the gap separating research and industry, providing new types of innovation incentives to spur development of new technologies.

The second step began during the early 1990s, laying the foundation for much of China's current technology landscape through creation of university and research institute-based enterprises (UREs). "The unique feature of the Chinese NIS is the URI-owned enterprises."[8] At the initial stages, the Chinese government encouraged not only strong links between universities and emerging enterprises, but direct creation of high-technology companies. Guidelines for administering UREs were promulgated, and faculty could occupy both teaching roles in a university/RI and research positions in the URE. Nearly ten years after spurring their creation, more than 2,000 UREs were founded with a combined worth of $3.8 billion.[9]

The third and most recent step, beginning in 2001, shifted the focus away from UREs. Critically, unlike Western spinoff companies, UREs were endowed with substantial control over the mother institutions' assets, including manpower, facilities, research results, and resources.[10] Earlier reforms bridging research and industry may have reached too far as "[S]ome universities might go bankrupt because of the losses their affiliated firms were suffering."[11] Furthermore, there was increasingly trenchant criticism that UREs were merely importing and adopting technology, rather than innovating. As a result, "The government began to examine the efficiency of UREs in 2001. Since then, a 'delinking' of URIs from their affiliated enterprises has been under way."[12]

Through three major phases, the overall trajectory of Chinese innovation policy has migrated away from central planning, although this further necessitated fine-tuning of the resource allocation between research and industrial activities. Nevertheless, the Soviet-style central planning legacy remains a pervasive and strong influence on modern Chinese innovation policy. "Each national S&T plan outlines the *main direction* of S&T development… The performers of S&T activities *fulfill the tasks assigned to them from above* and *depend upon official allocations* for necessary resources. These performers of S&T activities do not need to suffer the full losses resulting from failure in innovation activities, but nor do they benefit fully from success."[13]

Taiwan: Driving Policy through Consensus, Promoting Autonomy of Institutional Actors in Implementation

After the founding of the Republic of China in 1949, Taiwan's main economic areas were agriculture and exports. However, by the late 1960s, economic policy "relied heavily on labor-intensive manufacturing exports," and there was little or no R&D or innovation policy to speak of.[14] Continuing into the 1970s, R&D activities in both industrial and academic areas remained low. By this time, Taiwan's economy was studded with many small and medium enterprises (SMEs), which were ill-equipped for R&D or had no concept of R&D altogether.[15]

To address the lack of a formal R&D policy, the first National Conference on Science and Technology convened in 1978 and continues to meet every four to five years.[16] Because Taiwan's economy was dominated by SMEs with small R&D capacity, "It was decided that government research organizations should play the role of bridge between academic research and commercialization. This allowed the formation of a preliminary system of industrial innovation."[17] In short, policy-makers sought to make public research assets and resources widely accessible to a variety of existing private businesses.

Due to a generous population of SMEs and the desire to empower them with strong, accessible public research resources, Taiwanese policy-makers drove innovation policy primarily through consensus-building. Rather than orchestrating strong top-down national policy initiatives, relevant actors were tapped to shape national policy initiatives, thereby obtaining significant autonomy in implementing specific approaches.

As an example, the National Conference on Science and Technology, "brings together relevant experts from industries, universities, government, and foreign S&T advisers and generates *long-term plans that articulate the basic direction* of national S&T policies." With the larger guideposts in view, the specific execution of these S&T plans "in Taiwan follows principles of integrated planning and decentralized implementation."[18]

While the Taiwanese consensus-building approach creates variability in executing the overall national innovation policy, two hallmarks are sector-targeting and industrial-clustering. First, was the creation of public research institutes (RIs) and science parks to house RIs alongside private enterprises.[19] In 1973, the Industrial Technology Research Institute (ITRI) was created, focusing on semiconductor chips, computers, and opto-electronic products.[20] One of Asia's first scientific parks, Hsin-Chu Science Park (HSP) was unveiled a few years later in 1980.

Second, was the creation of strong incentives to lure private enterprises to these locations. Enterprises setting up shop in HSP were met "With several adequate incentives including abundant supply of technology and skilled engineers, tax credits, excellent infrastructure, and convenient official services…"[21,22]

Together, this approach propelled Taiwan to first-rank production volume of desktop computers and notebooks, along with becoming the third largest exporter of computer products, behind only the United States and Japan.[23] With these results in hand, "Taiwan's PRIs continue to play the role of R&D agencies for Taiwan's SMEs—as they have done for decades—to meet their technological and resource insufficiency."[24]

Perhaps due to remarkable successes with ITRI and HSP, Taiwan continues to replicate industrial-clusters for new technologies in different geographical locations.[25,26] Again, a variety of actors furnish execution details, including SMEs, local county governments, and even city municipalities. As an illustrative example, "[T]he Taiwan *national* innovation system is starting to encompass targeted technology developments within the country's capital, Taipei, *under the control of the city administration*."

However, merely replicating more industrial clusters across Taiwan has raised concerns about redundancy in R&D efforts, thereby handicapping the overall quality and level of innovation. First, as one commentator noted, "The advantage of one park cannot be easily completely duplicated to other areas. This in turn raises an important policy issue: The science-park development mode may not be implemented without limit."[28]

One additional weakness of this approach was revealed in overexposing Taiwan to global market fluctuations, such as falling demand for computer technologies after implosion of the dot-com bubble. Limiting this exposure has further required a shift in focus from rapidly gaining expertise in foreign technology to creating new technologies. Taiwan's national policy was a sophisticated strategy of fast followership—first beginning with identification of key technologies and later building expertise and capabilities in those technologies.[29] This reliance on foreign technology has meant Taiwan is "extremely dependent on inflows of foreign technologies… and so are easily influenced by global economic fluctuations. Consequently, Taiwan often suffers from the lack of R&D of original pioneering and self-contained technologies."[30]

Taken together, Taiwan faces a challenge of climbing up the technology ladder by spurring innovation, but must avoid the track of merely adopting "more of the same" policy approaches that captured initial successes. One strong point of the current approach is that, by allowing a variety of actors to implement the overall national policy, this encourages desirable heterogeneity in execution. Taiwanese policy-makers should continue the decentralized planning approach by embracing input from relevant actors, while also enhancing in-house SME R&D activities.

Singapore: Economic Planning Attracting Foreign Enterprises and Investment, Coupled with Highly Focused Intervention through State-Owned Enterprises and Research Institutes

The Republic of Singapore was founded in 1965 as an island city-state with few natural resources at its disposal. The Singaporean government initially had "little option but to turn decisively outward to export domestically made manufactures."[31] Capitalizing on its strategic location as a historic port of trade, Singapore also eventually developed a thriving professional and financial services center.

At each stage, the hallmark of Singapore development policy has been focused on long-term strategic planning to attract foreign investment, punctuated with decisive government intervention. Innovation policy has followed suit with the government maintaining a strong hand guiding R&D activities, although there are emerging views suggesting the need for a lighter touch.

Among the earliest export domestic manufactures, Singapore moved immediately into electronic and electrical products. One critical enabling factor was not R&D policy, but rather, control of labor costs by leveraging Singapore's specific geography as an island city-state. By closing the nation's borders, managing labor inflow, and regulating wages, the government "pegged wage rises at or below productivity gains [which] was essential in safeguarding this required rate of profit."[32] Creating a profitable enclave for Western companies further promoted an influx of high foreign investment and foreign enterprises.[33] "[S]ound economic planning and concerted efforts by the government to attract foreign investments were key factors behind its phenomenal growth pace…"[34]

As some commentators have highlighted, strong links with the global marketplace actually favored an overall hands-off approach to allow the Singapore government to act decisively in response to swift global trends, rather than being encumbered by formal planning documents. "Planning in Singapore never involved detailed blueprints, because of the priority accorded to reaction to the international market, impossibility of predicting its course, and need for flexibility to ensure a quick and competitive response."[35] Further illustrating this approach is the surprising fact that "[Singapore's] first formal science and technology plan was only implemented in 1991."[36]

That is not to say that the Singapore government did not strongly promote R&D within its borders during earlier years. Rather, Singapore encouraged R&D through direct funding and creation of incentives in three primary vehicles: foreign enterprises, universities, and state-owned enterprises. "Tax incentives were given to manufacturing companies that undertook R&D in Singapore. The level of public commitment to R&D was confined largely to scientific research in public universities and defense R&D…"[37] Furthermore, while educational and manpower training was offered through local institutions, later efforts included overseas training for select workers and grants and subsidies for foreign companies providing specific skills to employees.[38]

Finally, a variety of state-owned enterprises were created for sectors unattractive to foreign investors. "[T]he Singapore government began as nonstatutory undertakings, a range of enterprises…the government retains a majority holding in profitable and key undertakings like Singapore Airlines and Singapore Telecom."[39] Critically, Singapore "had the advantage that public enterprise began afresh rather than through the nationalization of already loss-making firms."[40]

However, as Singapore approaches a current level of economic development on par with many leading Western nations, the focus is shifting away from attracting foreigners and importing technologies to strengthening local institutions through new technology creation. "Lately, however, there have been concerns that the development strategy that Singapore had adopted for the past few decades may no longer be sufficient…."[41] And it is in this context that Singapore's most expansive and decisive innovation policy measures have been deployed. In 1991, the first National Technology Plan was enacted, focusing on the construction of technology infrastructure, further incentives for private sector R&D, and enhanced technical manpower training. This was followed by a second plan in 1996, funding the establishment of thirteen public research institutes in sector-specific areas.[42]

Despite these efforts, Singapore is confronted by a somewhat unique challenge of promoting creativity and entrepreneurship within a highly skilled workforce, but one ranking near the bottom in entrepreneurial propensity among developed nations.[43] Addressing this concern, educational policy evolved toward "increasing creativity in schoolchildren," through migration away from exam-based educational assessment toward encouraging project-based skills systems. Nevertheless, it is necessary for Singapore policy-makers "to change the social and cultural attitudes toward entrepreneurship, acceptance of nonconformity, and tolerance of failure."[44]

As Singapore grapples with obstacles in scaling the technology value-chain, policy-makers must balance a remarkably successful model of attracting foreigners to its shores, with an increasingly interventionist approach empowering local institutions. Nevertheless, with the guiding hand of government acting nimbly in response to the country's needs, Singapore may continue to carve a unique path in reaching future successes.

Comparison of NIS Reveals Stark Differences in Types of Institutional Actors and Their Roles

From this whirlwind tour of NIS, stark differences between each country are apparent. First, the overall policy approach adopted by central government and the role of institutional actors in each country is very different. The Chinese government retains a strong central planning structure. In the midst of propelling massive institutional reform, the government must strike an effective balance between research and industrial relationships to eliminate obstacles previously hampering the country's economic development. In contrast, Singaporean innovation policy has shifted away from being focused intensely on creating attractive incentives for foreign investment and R&D to buttressing these efforts with growing investment in local institutions under the direction of government planners. At the furthest end of decentralized planning, the Taiwanese government formulated innovation policy by building consensus and granting significant autonomy to local actors in execution, although emerging limitations in expanding this approach to new technological and territorial areas may require stronger central guidance.

Second, the result of each country's NIS has spawned markedly different *types* of institutional actors. The Chinese R&D landscape is populated by universities/research institutes and their closely associated high-technology enterprises, UREs, while Taiwan possesses many domestic SMEs empowered through broad access to public research resources. Further contrasting these two nations, Singapore is predominated by foreign and state-owned enterprises interfacing with expanding university and research institute resources.

Nevertheless, a common goal is enhancing the efficiency of innovation through creation of new technologies, while reducing mere importation and application of foreign technologies. Proper formulation of incentives is a common theme and appears to be a critical enabling factor in rising up the technology ladder. For example, in China, transformation of RIs was accomplished through funding cutbacks coupled with new opportunities to form UREs.

In Taiwan, a variety of financial, technological, and infrastructure incentives were provided to enterprises setting up shop in science parks and engaging specific technology sectors. In Singapore, strong profit incentives attracted foreign investment, with additional benefits provided to those businesses conducting R&D and manpower training. This brief summary of incentives deployed in each country's NIS highlights that the specific types of incentives varies drastically, but that formulating a proper incentive scheme is a critical balancing act in defining institutional actors and their roles.

University-Industry Linkages: The Wide Embrace of Bayh-Dole Style Legislation in Asia

Given that the earlier evaluation of NIS in China, Taiwan, and Singapore reveals dramatic differences in the structure and function of institutional actors, it is remarkable that each nation has nevertheless adopted BD-style legislation as a keystone in its modern innovation policy governing the diffusion and transfer of public research assets into the private sector. As an illustrative example of university-industry linkages (UIL) in different countries, Bayh-Dole (BD) is particularly attractive because of its widespread adoption around the globe.

As has been noted, "[C]ountries from China and Brazil to Malaysia and South Africa, have passed laws promoting the patenting of publicly funded research…"[45] This wide embrace provides opportunity to compare and contrast the variable impact of BD-style legislation in circumstances composed of divergent cultural, social, political, historical, and economic conditions.

Thirty Years of the American Bayh-Dole Experience Shows Good Successes Coupled with New Obstacles

Prior to Bayh-Dole's adoption in 1980, discoveries in American public research institutes were commercialized in murky legal waters. Specifically, there were few bright-line rules governing ownership of research products originating from public research funding. One of the key roles of BD was clarifying ownership and administrative rules, providing a framework for individual researchers and their universities to patent and license research products—a key step in starting university spinoff companies. In short, American policymakers fashioned a *novel incentive scheme* to encourage innovation and spur commercial adoption, which is an important formulation in NIS.

Bayh-Dole has been effusively praised for spurring innovation in providing individual researchers and universities with potentially lucrative royalties or with opportunities to privately commercialize their technologies. In 2002, *The Economist* called BD, "possibly the most inspired piece of legislation enacted in America over the past half century."[46]

Routinely highlighted as indicators of BD's success are patent and licensing metrics demonstrating rising numbers of patent application filings, license grants, and royalty revenues. As an example, patent application increased from below 2,000 filings in 1991 to more than 11,000 in 2004. During this same period, royalty income spiked from approximately $200 million to $1.4 billion.[47]

Despite these remarkable numbers, there has been criticism that BD has gone too far in actually erecting new barriers in university-industry research collaborations in the United States. As one commentator recently highlighted, "The broad discretion given to public funded research institutions to patent upstream research raises concern about patent thickets, where numerous patents on a product lead to bargaining breakdowns and can blunt incentives for downstream research and development."[48]

Furthermore, technology transfer practices in patenting and license negotiations may have "contributed to a change in academic norms regarding open, swift, and disinterested scientific exchange."[49] In short, impressive patent and licensing metrics may mask significant chilling effects on American research and industry relationships.

This criticism that BD may have led to undesirable consequences in creating new barriers provides basis for additional criticism that BD may not be workable in different countries. "[W]ithin the United States, the effects and desirability of the BD Act remain controversial…it is necessary to explore *under what conditions* the U.S. approach to UILs can serve as a useful framework for policy elsewhere."[50]

Among these important conditions necessary for fostering successful BD-style legislation, one commentator has noted that BD's "success" in the United States was highly dependent on the specific nature of actors in American NIS. "[I]t is unclear whether any of the positive impacts of BD in the U.S. would arise in developing countries following similar legislation, absent the *multiagency federal pluralism, the practically oriented universities, and other features of the U.S. research system…*"[51]

Considering that there is at least reasonable disagreement about BD's positive impact, the discussion turns to an analysis of BD-style legislation in each country. Evaluating the prospects for success in any given country certainly cannot be conclusive, given that even thirty years of the American experience with BD is still under considerable debate. However, the prior analysis of NIS describing institutional actors in each country provides informative waypoints for evaluating how BD-style legislation could operate in different countries.

China's "De Facto" Bayh-Dole Regime

China's version of BD-style legislation was adopted only very recently in 2008, accompanied by a visit by former U.S. Senator Birch Bayh himself.[52] While the legislation enacted a framework for establishing intellectual property rights (IPRs) developed from publicly funded research, the potential role of BD legislation in China is perplexing, considering the expansive powers that Chinese UREs already possess in claiming ownership over public research assets.

Unlike an American-style spinoff company where academics may use private capital funds to commercialize an invention, "UREs are usually endowed with the de facto right to exclusively take advantage of the mother institutions' various assets including research outcomes or resources, such as financial resources, physical spaces, manpower, social links, and even the title of the university as a commercial brand."[53] In short, in China "there has long been a de facto Bayh-Dole regime (even before the Chinese patent law was legislated in 1985)."

As provided in the earlier description of China's NIS, the most recent policy focus has been to move away from UREs, which are increasingly seen as merely importing and applying technology, rather than truly innovating. As an example of this delinking of research and industrial relationships, 6,634 UREs existed in 1997, dropping to 5,451 in 2000, and 4,563 in 2004.[54] Perhaps it is envisioned that redefining these relationships will be a new slate of American-style spinoff companies relying on newly adopted BD-style legislation to commercialize promising research technologies through private finance investment.

Nevertheless, it is easy to imagine that Chinese BD legislation is a severely limited tool in redefining the current Chinese R&D landscape. The mere presence of several thousand UREs across China argues strongly that they will remain a significant force in implementing Chinese R&D policy. Stakeholders in the current URE scheme are unlikely to easily relinquish their current roles in exchange for the potentially arduous and risky road of an American-style spinoff company.

If Stanford University researchers had significant control over the university's facilities, research results, and could even adopt the Stanford name for their own private companies, it is hard to imagine they would eagerly embrace a more challenging commercialization model requiring pursuit of private financing to practice entrepreneurial activities. Together, it appears China is embarking on a long campaign in altering the scope and relationship of research and commercialization activities, and BD is only one piece of this massive puzzle.

Taiwan Adopted Bayh-Dole in Lockstep with IP Manpower Training, Education, and Promotion of Technology Adoption

In 1999, Taiwan first adopted BD-style legislation in the "Basic Law on Science and Technology."[55] Notably, a multipronged approach was adopted in facilitating and promoting technology transfer practices. First, the government spurred creation of technology transfer offices in universities and RIs by imposing stricter research funding criteria, while encouraging patenting and licensing of technology as an alternative funding resource.[56] Second, for Taiwan's many SMEs, the government fostered competence in "intellectual property management, including aspects, such as law, patent engineering, licensing, and negotiation."[57] An example of early success is National Taiwan University's (NTU) growing collection of licensing and royalty fees. Beginning in 2001, NTU collected only about $100,000 in fees, rising to nearly $1 million by 2004.[58]

One evaluation of patenting rates has highlighted that Taiwan "has arguably been the East Asian country that has made the most progress in shifting from imitation to innovation."[59] A significant number of Taiwanese patents arise from Taiwan's leading research institute, ITRI, with more than 3,000 patents.[60]

Further analyzing ITRI's activities, an increasingly critical patent portfolio established learning opportunities for strategic IP management. Rather than simply nurturing a propensity for patenting, ITRI *assigned specific patents to multiple SMEs* to "develop a stronger position in patent negotiations and [they could] take the lead in developing new technologies and setting standards."[61] This hands-on experience in IP portfolio management is "now seen as a key contributor to the enhancement of the country's innovative capacity."[62]

Taken together, the Taiwanese experience with BD, while recent, indicates some good predictors of future success. If anything is in common with the United States, it is a strong entrepreneurship capacity in the creation of SMEs. However, this is where any similarities end, as it appears that adoption of BD-style legislation was coupled with dedicated campaigns to further educate and train manpower in IPR management. At least some of this experience was gained through strategic portfolio management at leading RIs, such as ITRI, with precise efforts to strategically position patent portfolios through assignments to specific companies, thereby maximizing IPR benefits.

Thus, while BD-style legislation in Taiwan may prove to be significant in shaping that country's innovation capacity, it is notable that any successes may take on a markedly different path than the American experience.

Singapore Bayh-Dole-Style Practice Promulgated through Agency Rules Has Led to Mixed Results

Singapore promulgates BD-style practice through internal agency rules at leading public research institutes such as the National University of Singapore (NUS) and the Agency for Science, Technology, and Research. As an illustrative example, "Since the early 1990s, NUS has implemented an intellectual property (IP) policy whereby all IP created by NUS staff are assigned to NUS with INTRO [NUS' tech transfer office] tasked to license the IP and distribute any return from commercialization…"[63]

Despite these early pioneering efforts, technology transfer at leading institutions in Singapore, such at NUS, has seen mixed results. As an example, NUS collected $116,000 in 2001, rising to only $290,000 in 2003. "[T]he propensity for technological collaborations between universities and private industry was still relatively low and that universities were not highly regarded by industry as an important source of technology."[64] However, one encouraging result was that prior to 1999, only one issued U.S. patent was jointly owned between private industry and NUS. By 2001, more than 40 percent of patents were jointly owned.

Perhaps taking a cue from the Taiwanese experience, some recent initiatives in Singapore have focused on IP manpower training. Recognizing that "Singapore suffers greatly from a lack of expertise in various fields of IP and technology transfer," policy-makers established an IP educational academy in 2003 to provide professional training in IP management.[65]

Together, it appears too early to tell if Singapore's efforts in encouraging technology transfer through adoption of BD-style practices will lead to better and more consistent results in patenting and licensing. However, it appears that the country is at least being informed by the earlier experience in Taiwan, providing IP manpower training with educational programs to promote technology adoption.

Comparison of BD-Style Legislation Suggests There Is No One Size Fits All

Perhaps the only thing in common between BD legislation in these countries is that they are very recent. China enacted legislation within the past two years and is in the paradoxical position of using modern BD-style incentives to chisel away at an existing regime where public resources are already expansively exploited for commercial use. Taiwan and Singapore are more relevant examples for comparison with the American experience and even these two countries show remarkable differences.

Taiwan can claim some early successes through rising royalty revenues and patenting rates. However, the illustrative example of ITRI's strategic IP portfolio is remarkable, given that a public research institute strategically assigned patents to private companies to maximize IPR benefits. This is akin to the National Institutes of Health handing off patents to Amgen and Genentech to ward off disfavored competitors or provide them with better leverage in negotiations for standard setting or litigation settlements.

In contrast, Singapore appears to be delivering mixed results, although as described, some initial results are encouraging. Rising numbers of jointly owned university and industry patents are a strong sign of increased collaboration. Unlike the earlier ITRI example, this appears to be a more earnest approach in building relationships (albeit a potentially more challenging one).

However, Singapore may merely be in the earlier stages of patenting, as ITRI only adopted increasingly sophisticated and aggressive IP techniques after amassing more than 3,000 patents, including key technologies to ward off competitors. Further contrasting Singapore is that BD-style technology transfer is promulgated through agency rules. Again, this is akin to the NIH unilaterally deciding that its technologies can be commercialized under its direction.

Together, it is clear that stark differences existing between each country's NIS further extends into the specific example of UIL governing technology transfer practices. As one leading commentator has noted, "There is a widespread perception that U.S. leadership in industrial innovation owes much to the capacity of its higher education system to provide multiple and dense interlinkages between university research and innovation in enterprises…Unfortunately, very little scholarly research is available to guide policy debates in the Pacific Rim on this important issue…."[66]

Recognizing that Asian nations, including the discussed examples, have diverse development trajectories propelled by markedly different institutional actors is a good first step in crafting effective technology transfer legislation for developing nations.

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