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An analysis of technology market from the perspective of technology life cycle

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In many ways, technology policy as a 'visible hand' in the technology market often exerts significant economic effects on firms' investing behaviors regarding research and development (R&D) and technology transaction. In addition, proper management of technology is critical to the foundation of national and organizational competitiveness. With the ongoing rivalry between mainland China and Taiwan, national security is always a significant policy concern for all parties. Technology Protection Act (TPA) has recently been brought about by Taiwan government to better the environment of technology development and strengthen national security. An institutional perspective is taken in this paper in analyzing its potential effects on industry development. As time is one of the essential elements in understanding the characteristics of market development, both technology and industry policy makers need to have in mind the dynamic nature of technology market while crafting the framework of policies. In this paper, efforts have been made to develop an integrative model based on Technology Life Cycle (TLC) and Transaction Cost Economics (TCE) to address its potential impact on the institutional environment and thereby on both demand and supply behavior of technology market participants. Suggestions are formulated for policy makers.

Key words: Technology market, life cycle, transaction cost economics, governance, institutional theory.

INTRODUCTION

Technology is an imperative input to economic growth, as over 50% of growth has been attributed by some to technological change (Contractor and Sagafi-Nejad, 1981). The economic growth of all countries depends, to some degree, on the successful application of a transnational stock of knowledge. The complex situations that arise from technology development and sales require a sophisticated system of laws and regulations at national and international levels. Khalil and Ezzat (2005) emphasize that a well-managed technology system is what creates wealth for nations and companies. However, political issues often complicate the development of institutional systems. The recently proposed Technology Protection Act (TPA) by the National Science Council (NSC), Taiwan, has drawn heated debates and has heated debates and has provided an important context for examining the institutional effects on the technology market, even though TPA is still under legislative process. With the ongoing rivalry between mainland China and Taiwan, national security is always a significant policy concern for all parties. The introduction of Technology Protection Act (TPA) aims to establish a general institutional environment for the development and transaction of scientific technology with special attention to protecting sensitive technology from unauthorized export/trade. The body of TPA consists of 17 articles (Appendix 1) with regulations ranging from national security to industry development. Criticisms against TPA have not been uncommon. One of the most debated issues is whether the regulating mechanisms can be justified by the goal of national security since most national security since most of the technology export control measures are related to military technology.

The far-reaching regulating effects of TPA have been worrisome to technologists and scholars for fear of the visible hand in the technology market. Some critics termed

Abbreviations: TPA, Technology Protection Act; **TLC,** Technology Life Cycle; **TCE,** Transaction Costs Economics; **NSC,** National Science Council.

TPA as the ‘martial law’ on technology market, while others welcome the ‘constitutional law’ for technology. Critics also question the negative impact of the protection measures set forth by the TPA on the economic performance of industry. However, the protection of technology should be viewed from a more macro perspective, which is the technology market. A neglected question is: What are the fundamental characteristics of the technology market? It is believed by most economists that market operates by rules of both price mechanism and institutions. Institutions stipulate the rules of the game for market participants. The question that needs to be first addressed, then, is the nature of technology market to be regulated, instead of the existence of TPA. This paper attempts to answer the following question: How do institutional factors affect the technology market? In this paper, a framework has been developed to assess the effects of TPA on the industrial technology from a dynamic perspective. The structure of this paper consists of 7 sections. Section 1 introduces the background and motives of the paper, while Sections 2 and 3 develop an institutional model of technology market. Sections 4 and 5 outline respectively the dynamic and micro views of the technology market. An application of the conceptual framework is provided in Section 6. Section 7 concludes findings of this paper as well as indicates areas for future research.

THE NATURE OF TECHNOLOGY MARKET

The proprietary nature of the most vital information makes the technology market a highly imperfect one. Economists sometimes assume that technology is like a sheaf of blueprints and that all one has to do is ship off the right set of papers. However, evidence indicates that publications and reports are a much less efficient way of transferring technology than the movement of people. Moreover, while product producing sectors often demonstrate competitive advantages based on proprietary products, service sectors show advantages based on ‘soft’ technology which is managerial or information-based (Grosse, 1996). The proprietary nature of most vital information makes the technology market a highly imperfect one. While it is generally recognised that the marketing of high-technology products differs significantly from that of “traditional” products, the concept that marketing must evolve as products evolve through a technological life cycle (TLC) has not been fully developed (Popper and Buskirk, 1992). The technology life cycle (TLC) should be regarded as a tool which is useful as a guide to technology resource allocation based on the product and business life cycles used in marketing and strategic planning. The utilization of proprietary knowledge is largely determined by the life cycle stage, because a life cycle assessment will determine the perceived attractiveness of the technology. The TLC theorists are consistent in postulating the technology life cycle using the concept of S curve (for example, Forster, Beth, Ford and Ryan, and Moore). Ford and Ryan (1981) measure the technology life cycle by technology penetration and propose a six-stage framework: technology development, technology application, application launch, application growth, technology maturity and degraded technology. Each stage corresponds to specific institution and market factors. Institutional theorists posit that the economic activities are embedded in the institutional environment and therefore the firm’s behaviors are significantly influenced by routines, regulations and cultures (North, 1991; Williamson, 1993). This line of thinking leads to a micro examination of economic transactions from the perspective of transaction cost economics (TCE) which emphasizes the governance of transaction. Apparently, the introduction of TPA not only shifts the institutional environment, but also provides incentives for altering firm’s behaviour when engaging in technology development and acquirement.

The proprietary and imperfect nature of technology market sharply distinguishes itself from traditional product market. Ford and Ryan (1977) have identified five areas which differ between “know-how” and product marketing:

1. Technological middleman: The problem of the intangibility of technology is shared by service and know-how marketing. The difficulties of describing or illustrating know-how, or influencing customer perception, correspond to recent growth in the so-called “technological middlemen” acting on behalf of potential buyers in seeking know-how.
2. Reluctant buyer: The purchase of technical know-how may be negotiated largely by the same people who have failed to meet the company’s expectations in technical expertise (except for cases of strategic reasons) resulting in the need to acquire know-how. These individuals may be reluctant to make such a purchase as this may indicate their incompetence.
3. Short channels of distribution: Promotion of know-how is unlikely. Thus, know-how sales are likely to be direct sales or involve very short channels of distribution. The difficulty of defining the delivery of know-how is often associated with legal problems. Therefore, agents or brokers act to bring buyer and seller together, but do not take legal title to the know-how.
4. Difficulty of market identification: Market identification for the potential know-how poses considerable problems. The fact that there is a tendency for sales to be conducted on a highly confidential basis reduces the relevance of test-marketing and therefore, it is often difficult to determine potential customers and competitors in the market.
5. Price inelasticity: The pricing of know-how or technology depending on the end-product values and volumes presents certain complexities as there is likely to be a considerable variation in the realizable price between

different potential customers. Thus, the potential benefit of monopolistic market resulting from the impracticability of “test-marketing” is probably offset by the relative price insensitivity of technology.

Further, the sale of a technology may be held up or prevented by government restrictions on the seller, especially where the technology has strategic or military implications, for example, in such fields as computer networks, high-energy lasers and wide-bodied aircraft. For example, in the United States, the Technology Transfer Ban Act, updated in 1978, prohibits technology export to any communist country or to any country that fails to impose restrictions on such a sale of any “significant” or “critical” technology or product with a potential military or crime control application. China is known to have a weak IP rights legislation system and a weak level of enforcement and protection. Deng and Townsend (1996) found that China’s technology transfer regulation has been written to favour the Chinese recipient firm. Therefore, there is a high risk of dissipation of one’s proprietary know-how in China. Moreover, the allegations that satellite technology transfers to China helped it improve its nuclear missile capability has caused the attention of U.S. Justice Department and the Congress could address the export control issue focusing on aspects of technology transfers from the U.S. to China in the area of aerospace and defence technologies (RCR, 1998). These cases not only exemplify the complex nature of the technology market, but also indicate a proper context for the introduction of TPA in Taiwan.

INSTITUTIONAL PERSPECTIVE

In a world of uncertainty, institutions have been developed to stabilize interactions and transactions by human beings. Herbert Simon (1957) is one of the forerunners to emphasize the human actor’s subjective cognition of the objective world. He stresses the need to distinguish the real world from the perceived world by the actor. Bounded rationality results from incomplete information and feedback form the actor’s behaviour (Simon, 1957). Institutions, as rules of the game in society, provide specific incentive references and form various economic, political and social organizations. Wesley Mitchell, Thorstein Veblen and John R. Commons were the leading figures in the older institutional economics in the United States. Commons and his colleagues were very influential in shaping public policy towards business. Common’s intellectual contributions are summarized as follows: (1) developing dynamic views of institutions as a response to scarcity and conflicts of interest, (2) original formulation of the transaction as the basic unit of analysis, (3) developing part-whole analysis of how collective action constrains, liberates and expands individual action in countless routines and complementary transactions on one hand; and how individual wills and power, which are used to gain control over limiting factors, provide the generative mechanisms for institutional change on the other, and (4) proposing a historical appreciation of how customs, legal precedents and laws of a society evolve to construct a collective standard of prudent reasonable behaviour for resolving disputes between conflicting parties in pragmatic and ethical ways (Williamson, 1993).

The new institutionalists have appeared in two distinct streams: the historical and the rational choice theorists. Scott (1995) argues that neo-institutional theory “do not represent a sharp break with the past, although, there are new emphases and insights.” The observation that current choices and possibilities are constrained and conditioned by past choices and events leads us away from a static perspective of the market to a more dynamic view. Time is, therefore, an important concern in understanding social behaviour which shares the common ground of technology life cycle (TLC). Institutions consist of formal rules (law, constitution and regulations, etc.), informal rules (customs and ethical codes) and the effects of their enforcement (Denzau and North, 1994). The enforcement of institutions can be carried out by the third (law enforcement), second (revenge) or first party (self-discipline). In the words of Williamson (1993), the third party enforcement measures is referred to as “public ordering,” while the first and second party enforcement measures are coined “private ordering”. Public ordering is limited in effect due to the complexity of economic transactions. Therefore, the private ordering complements the public ordering in that safeguards are developed by both parties to minimize the transaction hazards. Institutions exert significant impact on economic performance through influencing the transaction cost. Thus, the market effectiveness, to a large extent, depends on the framework of institutions (North, 1992). In Scott’s (1995) definition, there are three pillars of institutions: regulative, normative and cognitive. These dimensions include the formal rules (legally sanctioned), informal norms (morally governed) and cognitive belief systems (culturally supported). In general, all scholars emphasize the regulative aspects of institutions (Scott, 1995). In this paper, a regulative perspective of institutions is applied to analyse the potential impact of TPA on the technology market.

In this paper, a research question is asked: how do institutions affect the technology market? To that end, several issues need to be dealt with before any progress: Is this market a phenomenon of demand and supply? Does this market have a life of its own? How can each stage of its development be identified? And most important of all, how are transactions realized in terms of governance? Do the institutions provide a more efficient context for firms to conduct research, development and technology transaction in both domestic and international market? In order to tackle these questions, an integrative model of technology market based on institutional

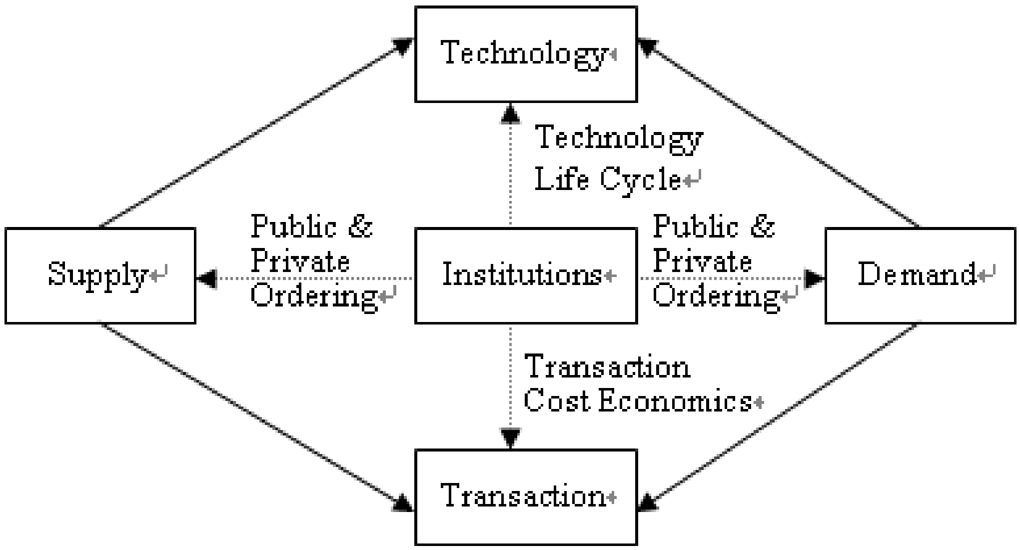


Figure 1. An institutional perspective of technology market.

perspective is formulated as a starting point (Figure 1). Based on the conception of technology market cycle (TLC), five key elements are identified in the model: demand, supply, technology, transaction and institutions, where institutions are the critical determinants of firm's behaviour in the technology market as they set out the rules of the game. To elaborate this model, a dynamic view of technology market - technology life cycle is introduced in the next part.

DYNAMIC VIEW OF TECHNOLOGY MARKET

A well-known dynamic concept in the technology market concerned in this study is that of the life cycle, which generally covers the time dimension in dynamic analyses. Time is not only embedded in nature, but also in the purposeful devices that men have created, over the immense range, from early cooking and hunting tools to the vast socio-technological complexes and mega-systems that determine humans' technological environment today. It is embedded in the sense that all these artefacts, especially technologies, are not time neutral or time independent. This notion of time is central to any theory of innovation. Technology in a certain field is subject to changes in time, constituting distinct stages of incubation, amelioration, accumulation, replication and obsolescence. Kuhn's paradigm shift must be interpreted as a radical technological change or basic innovation. His thinking reflects the same conceptual approach of the life cycle, but in relation to the development of science. In this line of thinking, the technology life cycle, derived from the product life cycle, pinpoints the changing decisions companies face in selling their know-how. The technology life cycle (TLC) traces the evolution of a technology from the idea stage, through development, to exploitation by direct sale. In the 1960s, Everett Rogers proposed a model of diffusion of innovation from a technology adoption view and was later updated by Geoffrey Moore.

Moore (1999) proposes a six-stage model in the technology adoption life cycle: early market, chasm, bowling alley, tornado, main street and end of life. Many strategic and operational decisions must be made at the corporate and functional levels of the firm before a new product can be put on the market. Rink and Roden (1999) formulate a five-stage model: pioneering, introduction, growth, maturity and decline, where new products are developed and test-marketed during the pioneering stage. On the other hand, Ford and Ryan (1981) emphasize that a company must plan for the fullest market exploitation of all its technologies to maximize the rate of return on its technology investment. The utilization of proprietary knowledge is largely determined by the life cycle stage, because a life cycle assessment will determine the perceived attractiveness of the technology. Betz (2003) indicates that there is a period of technology development prior to being brought to the market and postulates a four-stage technology life cycle based on product market size: application launch, application growth, mature technology and technology obsolescence and substitution. Different from Betz et al. (1981) six-stage model is based on the measurement of technology penetration: technology development, technology application, application launch, application growth, technology maturity and degraded technology. Ford and Ryan's model is outlined below:

Stage 1: Technology development

The first stage begins long before any production, when research indicates a potentially valuable technology. The major issue that the company faces here is whether further development of the technology should take place. Their technology might be marketable but not in its present form.

Stage 2: Technology application

After a company has decided to apply a technology to a new product, it incurs its first major costs. Further, when embodying technology in a product, a company is likely to face heavy costs in developing associated process and product technologies. A company must not base its development decisions on the projected returns from product sales alone. Instead, it should consider potential returns from the technology as a whole to include sales, license revenues and perhaps turnkey deals. There are no universally applicable rules of thumb for making sound decisions about the sale or production of a technology.

Stage 3: Application launch

The application launch stage of the TLC corresponds to the performance maximizing phase, during which a company is likely to be developing its technology further, either through product modification or through application to different or perhaps wider product areas (Abernathy and Utterback, 1975). There may not be enough companies around with the skill to employ the new technology properly. The purchase may depend on government backing for the buyer, which in turn may depend on a country's industrial policy. In addition, the sale of a technology may be held up or prevented by government restrictions on the seller, especially where the technology has strategic or military implications, for example, in such fields as computer networks, high-energy lasers and wide-bodied aircraft. The technologists who are responsible for development within the purchasing company may see a purchase as an indication of failure and therefore, may try to delay the decision to buy a technology, while pressing for funds to develop their own. Thus, the "not invented here" syndrome appears. The final market factor working against technology sales at this stage is that customer purchase usually requires major changes in the purchaser's way of doing things. A company may be unwilling to undertake these changes until a technology is proved through extensive product application or until its own technology is seen to be clearly inadequate. On the other hand, the originating company itself may now wish to delay the sale of a technology, thinking that its potential value will increase with greater market acceptance.

Stage 4: Application growth

The fourth stage is the one of sales maximization. A number of strong reasons for technology sales begin to surface. The critical issue is timing. Growth in customer demand usually coincides with great interest in a technology by the developer's competitors. To sell during this stage, is one of the most difficult decisions that a company can make. A prudent assessment of market potential could lead many companies to sell their technologies before their markets are saturated. The active sale of licenses by the originating company will help ensure that its technology is incorporated into the production of as many as possible. In general, the best strategy is to seek both wide application and standardization of a technology, while discouraging other companies from producing substitute technologies.

Stage 5: Technology maturity

Before a technology reaches maturity, it would have been modified and improved, not only by the originator but also by competing companies. The originating company will be concerned with its production costs, the involvement with buyers that technology sales would now bring and the relationship between those sales and its own production. The only fresh markets for the technology will now be found in less advanced countries, which are eager to substitute their own production for imports. Technology transfer to a Third World country often takes place on the basis of standard turnkey deals.

Stage 6: Degraded technology

The fact that a technology has reached the point of virtually universal exploitation triggers the final stage of the TLC. In the mean time, license arrangement will probably have expired and the technology will be so well known as to be of little commercial value for direct sale. However, many older technologies may still have market value in Third World countries. The challenge is how to identify what, is old hat to the Third World countries, and may just be what other countries need. An uneven rate of technological advancement is often characterised within countries, between industries and firms (Ford and Ryan, 1977). Certain industries, for example, electronics and communications, have been heavily sponsored by government contracts for defense and space programmes. These contracts have given firms technological leads, whilst subsidies given to low technology industries, such as motor cars and textiles, have merely been to maintain employment during trade recessions. The uneven rate of technological advancement has increasingly motivated the high research industries to invade the territory of the technology, backward. In some cases, the diffusion of advanced technology occurs through a natural process of industrial diversification and in some cases by government intervention and financing.

Swan and Rink (1982) caution that reliance on the classical product life cycle (S-curve) for marketing decisions can be misleading and propose eleven different product life cycles, each one having different implications for marketing decisions. They further stress that a particular life cycle is not fixed. In fact, the product life cycle is sensitive to marketing efforts. The stages of product life cycle are not necessarily consecutive nor does each product necessarily experience all stages (Rink and Fox, 2003; Swan and Rink, 1982). This line of reasoning is based on the assumption that the product life cycle is determined partially by demand conditions that are generally beyond the control of business firms and partially by the firms' marketing efforts. The most important concept is the degree to which the TLC is sensitive to industry and firm efforts. However, the technology market often demonstrates specific characteristics along the consecutive stages as the diffusion of innovation exhibits a staged pattern (Rogers, 1976). In the analysis of a developing economy, industry, organization, technology or product, the life cycle concept has become a widespread tool. Industrial sales go through life cycles and the cycle that best correlates to these sales is the TLC (Ford and Ryan, 1997). The technological trajectory is built up from a basic and related inventions added as part of normal progress within the same technological paradigm. The TLC should be regarded as a tool which is useful as a guide to technology resource allocation based on the product and business life cycles used in marketing and strategic planning. It is evident that building patent positions can be regarded as an activity that is independently conducted from the preceding build-up of market positions. This cumulative development tends to follow the S-curve, which is typical for the life cycle.

Measurement of TLC

The concept of the technology life cycle basically describes the evolution of a technology, as measured by its sales over time. Every technology passes through a series of stages in the course of its life, with the total of the stages considered as the technology life cycle. The neglected question is: Can technology life cycles actually be calculated? Existing literatures have emphasized the value of life-cycle model as a basis for planning and control. However, they emphasized a qualitative concept but failed to consider problems encountered in the measurement of life cycles.

A study of the products reaching commercial birth established that the average length of time in the growth stage is six months. Virtually all products (95 per cent) reach maximum revenue within thirty months following commercial birth. In the study of product life, two rules were employed, that is, 20 and 10% of maximum monthly revenue. It was established that the median time which span between maximum monthly revenue and commercial death is fifteen months under the 20% death rule and twenty months under the 10% rule (Cox, 1967). The Cox (1967) study selects the ethical drug industry for the initial development of a life-cycle model. The sample was drawn from records of new product introductions in the drug industry. However, the absence of technology introduction's records for most industries means that the construction of life-cycle models in these industries must begin with a compilation of new technology introductions. The difficulty of preparing such a compilation is perhaps the most serious obstacle to the widespread development of technology life cycles for a variety of industries. If a record of new technology introduction is available, the next step in the construction of quantitative models of the TLC in an industry requires that 'technology life' be carefully defined and measured. Technology life may be defined as the time span between birth and death.

A MICRO VIEW OF TECHNOLOGY MARKET

Williamson (1993) identifies the following connections between TCE and the early institutional theory: (1) institutions respond to scarcity as economizing devices, (2) the transaction is expressly adopted as the basis unit of analysis, (3) conflicts are recognized and relieved by the creation of credible commitments and ex/post governance apparatus, and (4) the institutional environment is treated as a set of shift parameters that change the comparative costs of governance. The main proposition of the transaction cost economics (TCE) is that contractual designs or governance structures are created to minimize the sum of production and transaction costs between specialized factors of production (Coase, 1937). Williamson (1993) elaborates a three-level schema (Figure 2) where governance is bracketed by more macro (the institutional environment) and micro features (the individual). The institutional environment treated as the locus of shift parameters, changes in the alternate comparative costs of governance and the individual is where the behavioural assumptions originate. The major behavioural assumptions of TCE are bounded rationality and opportunism, where bounded rationality can be understood as 'intendedly rational, but only limitedly so', while opportunism implies "self-interest seeking with guile." Both behavioural assumptions form the basis of the contractual hazards.

There are three main effects in the schema, which are shown by the solid arrows. Secondary effects are drawn as dashed arrows. The institutional environment set out the rules of the game and constitutes shift parameters. The circular arrow within the governance sector reflects the proposition that organization, like the law, has a life of its own. Governance is the means, by which order can be infused, thereby to mitigate conflict and realize mutual gain from voluntary exchange. Williamson (1986) further elaborates the relationship between the governance structure and transaction (Figure 3). Figure 3 is a two-dimension matrix: transaction frequency on the vertical

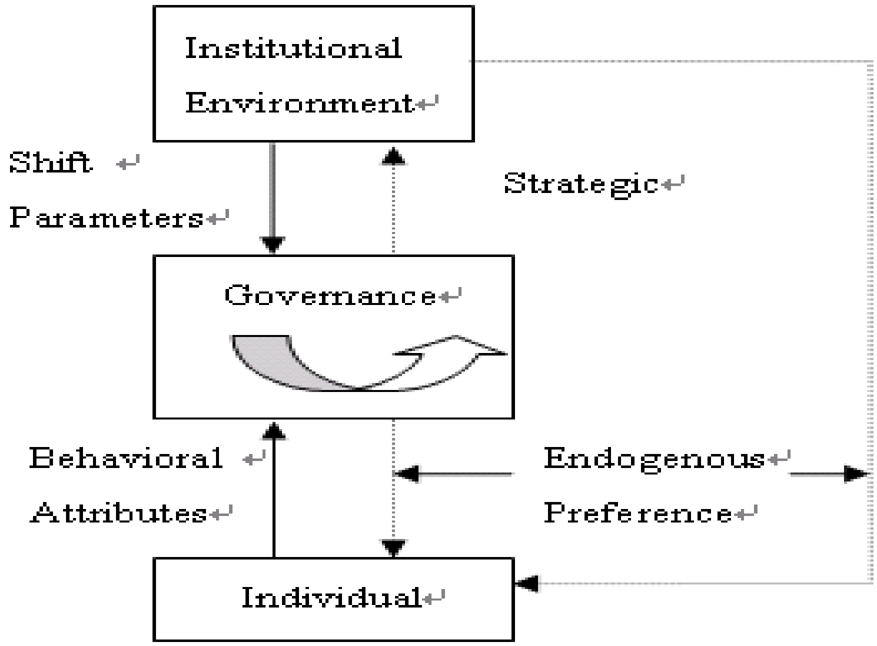


Figure 2. A layer schema (Source: Williamson, 1993).

		Investment Characteristics		
		Non-specific	Mixed	Idiosyncratic
Frequency	Occasional	**Market Governance** (classical contracting)	**Trilateral governance** (neo-classical contracting)	
	Recurrent		**Transaction-specific governance** Bilateral Governance (relational contracting)	Unified Governance

Figure 3. Governance Structure and Transactions (Source: Williamson, 1986).

axis and characteristics of Transaction-Specific Investment (TSI) on the horizontal axis. A typology of three governance patterns is conceptualised: market governance (where TSI is non-specific regardless of frequency), transaction-specific governance (where TSI is specific with recurrent buying frequency) and trilateral governance (where TSI is specific with occasional buying frequency). According to the level of TSI, the transaction-specific governance can be subdivided into unified and bilateral governance. A fundamental insight from transactions cost economics is that simple market contracts do not adequately safeguard against expropriation when investments in specific assets are involved, that is, when the assets cannot be redeployed to the next best use or user without significant loss of value. Williamson (1985) predicts that firms will either (1) internalize transactions involving highly specific assets (that is, “make” instead of “buy”, or (2) under-invest in areas where risks of expropriation are high.

The study of governance also appeals to bounded rationality, but the main lesson for the study of contract is different: All complex contracts are unavoidably incomplete. If human actors are not only confronted with needs to adapt to the unforeseen (by reason of bounded rationality), but also given to strategic behaviour (by reason of opportunism), then costly contractual breakdowns (refusal of cooperation, mal-adaptation and demands for renegotiation) may be expected. For the fact that problems of un-verifiability are posed when bounded rationality, opportunism and idiosyncratic knowledge are joined, dispute resolution by the courts in such cases is costly and unreliable. In that event, private ordering efforts are required to devise supportive governance structures in order to mitigate prospective contractual impasses and breakdowns. Knowledge is inherently a public good. The issue of tacit knowledge measurement associated with the technology transaction poses further challenges in organising transactions. TCE considered the impossibility in measuring tacit knowledge during transaction as the cause for a series of contractual and moral hazards as well as agency problems. In order to garner profits from technology transaction, the firm must prevent its dissipation to, and its use by, its competitors. Namely, the firm's knowledge must be protected by a tight "regime of appropriability". Misappropriation hazards arise when profits generated from knowledge is improperly captured by competitors of the original owner of knowledge (Han, 2004). When technology transactions are conducted, ownership rights of knowledge are frequently incomplete. Therefore, misappropriation hazards are caused by incomplete property rights, rather than the threat of hold-up due to asset specificity. Moreover, even if legally enforceable property rights in knowledge can be established, enforcement still entails high costs, which is due to the "natural non-excludability" of knowledge (Han, 2004). Incomplete contracting in knowledge transactions imposes a threat to the owner of knowledge to perfectly appropriate benefits from its use.

As a result, the firm may consider internalization of these transactions to resolve this problem. To mitigate the hazards and economize the transaction, research based on TCE suggested hierarchical contractual arrangements that accommodated transferors' concerns on non-measurable and uncompensated effort in transferring tacit knowledge, which is an effort that had high degree of asset specificity (Bao and Zhao, 2004).

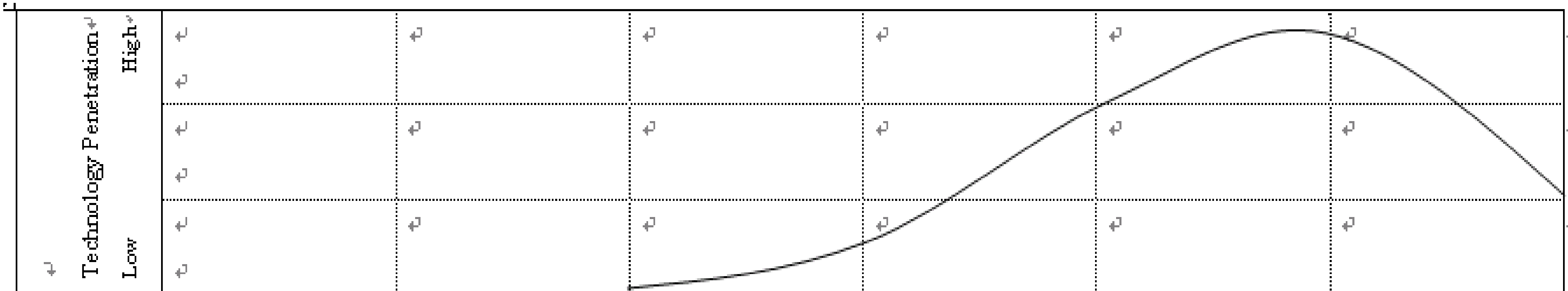
DISCUSSION

With the aim of national security protection, TPA stipulates principles for selection of sensitive technologies to be protected as well as the protection measures. By Article 3 of TPA, National Science Council (NSC) is designated as the 'competent authority' and has the authorization to organise the technology protection committee which decides upon the inclusion and exclusion of sensitive technology. In addition, TPA set out three principles to be met when applying the protection measures: (1) the technology is not generally known to persons in that field, (2) it has realizable potential economic value from its confidentiality and (3) owners of this technology have adopted reasonable protection measures (Article 2). Infringement of TPA, such as export of sensitive technology without prior approval, constitutes criminal offence and a variety of penalty schemes (namely, public ordering), such as monetary fines and jail sentence, are laid out in Articles 11 to 14. The severest penalty leads to seven years in prison.

In defining sensitive technology, these flexible principles also require efforts from the first party. In other words, they have to take cautionary safeguards in the course of technology research and development. Therefore, it is problematic if the designated sensitive technology fails to comply with these principles, for example, reasonable protection measures made by the owners of that technology. Since the condition of private ordering is antecedent to the enforcement of public ordering, it leaves room for purposeful evasion of criminal punishment. Thus, in terms of transaction cost, the TPA provides a marginal net effect of minimizing transaction cost. It may be expected that governance pattern of technology transaction at different stages of technology life cycle is minimally affected (Figure 4). Although, it is believed by most observers that high-tech industries are most prone to the governance of TPA, the effects of TPA on the technology market also depend on the stages of industry-specific of TLC, since the advance rate of technology varies in different industries. The institutional effects of TPA on each stage of TLC, which are applicable to all technology markets, are presented in the following analysis:

Stage 1: Technology development

The first stage, so to speak, is the incubation of new technology with potential development value. During this stage, the form and application of technology awaits clarification, which poses an opportunity for undesired idea diffusion and causes potential conflict over the ownership of intellectual property right. Article 2 of TPA suggests precautionary safeguards against leakage of innovative ideas at its original form. Safeguards may take the form of incentive-compatible arrangements for critical research and development (R&D) staff. As a result of the sensitive nature of technology development, unified governance is favourable at this stage, while R&D consortium is recently not uncommon. Article 12 of TPA provides protection measures against unlawful behaviours, such as deliberate deletion and leakage of scientific technology. While it is best to determine the



Firm behaviour \ TLC	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5	Stage 6
	Technology Development	Technology Application	Application Launch	Application Growth	Technology Maturity	Degraded Technology
Technology developer	Establish safeguards against know-how leakage.	License out the mature technologies.	Introduce technology-embedded products to market.	Seek wide application and standardization of technology.	Expand overseas technology market for cost reduction.	Seek overseas market for exploiting the residual value of technology.
Technology buyer	Seek potential technology substitutes.	Acquire the peripheral technologies for application.	Seek performance maximization (early adopters).	Build Competitive Advantage via new technology options.	Less developed countries: Import substitution with likely national protectionism.	Third-World countries: Buyers seek low cost and quick fix solution.
Governance (efficiency)	Unified governance (as a result of high TSI and recurrent frequency).	Market governance (non-specific TSI regardless of frequency).	Trilateral governance (middlemen/broker of technology).	Market governance (non-specific TSI).	Bilateral governance (close involvement with supplier and buyer).	Trilateral governance (middlemen/broker of technology).
Technology Policy Issues	Sensitive technology control and subsidies.	Protection of intellectual property (IP) right.	Institutional environment for technology trading.	Efficient public ordering.	Government support on technology export.	Government support on technology export.
Effects of TPA	Median	Strong	Strong	Strong	Weak	Weak

Figure 4. Technology life cycle.

sensitive technology at this stage for minimal marketintervention on one hand, it may discourage the initial R&D investment on the other. Although, subsidy incentive is provided, the uncertainty of technology performance renders the early control of specific technology less feasible. Thus, a thorough evaluation of sensitive technology and a flexible policy of sensitive technology control require more attentions from policy makers.

Stage 2: Technology application

The second stage is the embodiment of the technology into products. The attention turns to product development and preparation for market launch. During this stage, peripheral/complementary technologies (relatively standardized ones) are often required for product application. Technology transactions often take place in the form of market governance or, to a less extent, relational governance depending on the extent of TSI during transacting. Technology transfer occurs frequently in the form of licensing or purchasing. Unlawful market behaviours, such as intentionally acquiring technology from illegitimate origin, are defined in Article 12 of TPA. This change of shift parameters is expected to reduce contractual hazard and transaction costs.

Stage 3: Application launch

This stage indicates a formal introduction of the technology-embedded product to the market. The market is facilitated by pioneer users and early adopters, since new technology implies change of user behaviours. These early adopters act as a medium for technology diffusion. Therefore, trilateral governance is often observed in this stage. Governmental intervention and regulation often appear at this stage as the effects of technology performance become evident. More often than not, the importance of national policy overrides the market efficiency. Most of the technology export controls in developed countries (for example, the U.S. and E.U.) are country or technology specific. On the contrary, TPA provides rather general guidelines to better the technology development and ensure the national security. The critical issue of identifying sensitive technology is left to the technology protection committee. To some extent, this regulation poses uncertainty for technology developers as the potential economic loss is expected from banning the export of sensitive technology. Although, compensation in the form of subsidies is offered to the developers, the implication may encourage a relocation of R& D activities of advanced technology in other countries. It is evident that the sensitive technology control is better made at pre-market stages in order to minimize the disruption of technology market.

Stage 4: Application growth

The growth stage indicates the importance of technology sale. Except for the market factors set forth by Ford and Ryan (that is, market size, technological leadership and standardization), the institutional parameters are also critical in facilitating or obstructing technology transactions. Article 12 of TPA set out a favourable context for technology trading by strengthening the protection of Intellectual Property (IP) rights. Nevertheless, the intangible nature of technology implies potential arguments and conflicts about the misappropriation of critical technology, even under the patent or copyright law protection. Public ordering is an essential part of governance mechanism. As timing is crucial for technology sales at this stage, the third-party arbitrators, often the judges in the court, are then required to be equipped with the technical and market knowledge of the technology. In Taiwan, the passage of the Intellectual Property Court Act in 2007 will lead to the establishment of a special court system designed for IP lawsuits, which will ensure the efficient resolution of conflicts. In addition, firms will license technology more aggressively than otherwise expected when markets for technology are highly fragmented (that is, ownership rights to external technologies are widely distributed). This effect should be more pronounced for firms with large investments in technology-specific assets and under a strong legal appropriability regime. Market governance is observed during application growth stage as the subject technology undergoes fast market demand and non-specific investment.

Stage 5: Technology maturity

Technology in the fifth stage has been comprehensively modified, therefore, leaving little room for further improvement. The cost down imperative drives technology developers to be involved closely with buyers and suppliers. Thus, bilateral governance is observed at this stage. The likely new market for the product, based on the technology, will be less developed countries that are eager to substitute their production for imports. The dangers of overseas transfer are two-fold. First, the importing countries are likely to impose protectionism measures which may be unfavourable or unfair to the technology sellers. Secondly, the recipient countries may enjoy comparative advantage in resource endowment and present a threat for the market of technology originator. In terms of overseas transactions, market governance is relatively efficient at this stage. While TPA focuses on domestic transaction environment and export control (as it is unavoidably constrained by sovereignty), the safeguard mechanism against hazards of international technology transfers is thus, entitled to the technology sellers (a form of private ordering) and non-governmental organisations. It is expected that the information of information of institutional system of foreign technology market is included in the compilation and publication of technology white paper stipulated in Article 5 of TPA. With the globalisation of technology market, there is a need to elaborate on the safeguards against the afore-mentioned hazards.

Stage 6: Degraded technology

The final stage refers to the scenario when a technology has been universally exploited and leaves little commercial value. The degraded technology may find new market in the Third World countries. As a result of the incomplete trading information regarding the Third World countries, many transactions at this stage are arranged by middlemen, who bring together potential buyers and sellers of technology (Ford and Ryan, 1981). Thus, the governance takes the form of tri-lateral, one which, according to Williamson (1986), exhibits occasional purchase on the side of technology buyer and idiosyncratic transaction-specific investment, such as obtaining proper market information and crafting mutually agreeable contracts on the side of technology seller. The trilateral governance is required to ensure efficient transactions in a context of incomplete information and ex-post enforcement hazards. Trilateral governance may shift to market governance when the means of minimizing transaction-specific investments are addressed. Again, it is beneficial for technology sellers that the information of institutional system of foreign technology market is included in the compilation and publication of technology white paper stipulated in Article 5 of TPA. In general, the effect of TPA on the technology market at each stage of TLC shows favourable implication at the early stages of TLC, even though several critical issues still need to be addressed in a timely fashion. The above analysis is summarised in Figure 4 where the effects of TPA on the technology market are identified form the integrating perspective of TLC and TCE.

Conclusion

Although technology policy is the major source of institutional system in support of industrial activities, the foundation of national and organizational competitiveness is determined by proper management of technology (Khalil and Ezzat, 2005). As time is one of the essential elements in understanding the characteristics of market development, it is paramount to assess policy impact from the perspective of technology life cycle (TLC). Both technology and industry policy makers need to have in mind the dynamic nature of technology market, while crafting the structure of policies (Figure 4). In addition, a micro review on the nature of technology transaction and its governance provides more insight into the practical market operations whereby participants make decisions on modes of transaction governance based on the basis of efficiency within the institutional boundaries set forth by technology and industry policy makers. Contrary to the conventional wisdom of deregulation, I believe that a regulated technology market shows prospect in shaping a more efficient transaction environment and thereby inducing more R&D investment and performance. In this conceptual paper, several key dimensions of technology market are discussed in detail based on which an integrative model is formulated.

Technology protection act (TPA) has recently been brought about by Taiwan government to improve the environment of technology development and strengthen national security. This paper takes an institutional perspective in looking into its potential effects on industry development. In overall, the aggregate influence of TPA on the technology market shows favourable effects at early stages of TLC even though several issues (such as clear definition of technology under regulation, enforcement mechanism, etc.) still need to be elaborated in a timely fashion. It is evident that TPA fails to deal with the issues that occurred at the late stages of technology life cycle (Figure 4), which often involves international transfers of technology. From the viewpoint of institutional theories, TPA provides rules of the game and hence the basis of public ordering for technology transactions. However, the policy makers should be cautioned that the expected and unexpected outcomes of the TPA must be considered equally, as the rules bring about incentives and disincentives for motivating the behaviours of technology developers and purchasers. Thus, the behavioural assumptions that Transaction Costs Economics (TCE) theories propose deserve careful attentions. Moreover, governance structures are created to minimize the sum of production and transaction costs between specialized factors of production. The institutional factors obviously play a role in shifting the governance structures. The costs and benefits resulting from TPA's introduction should be thoroughly calculated to improve economic/industrial performance. In summary, it is believed that a dynamic view of technology life cycle (Figure 4) combined with transaction cost theories proves to be a promising framework for analysis. This paper presents a preliminary investigation. Several issues remain for future researchers of interest; such as the measurement of the TLC stages which may require extensive field survey, the comparison of technology protection laws in developed and less developed countries and the economic implication of technology policy.

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APPENDIX

Technology protection act

Article 1

This Act is enacted for the protection of scientific technology and enhancement of the competitive advantage of technology in order to ensure the national security and public interests.

Article 2

The term "scientific technology" used in this Act shall mean the technology used in production or business transactions which include non-academic technique, method, program, design, process and formula, which meets the following requirements:

(1) It is not generally known to persons involved in the specific area;
(2) It has economic, actual or potential value, due to its secretive nature and
(3) Its owner has taken reasonable measures to maintain its secrecy.
The term "sensitive technology" as used in this Act shall mean the scientific technology which significantly influences the national security and is promulgated by the competent authority.

Article 3

The 'competent authority' under this Act is National Science Council.
In cases where provisions set forth in this Act involve the business of other authority, the 'competent authority' of this Act shall consult, hereunder, jointly with that relevant authority.

Article 4

The 'competent authority' shall set up a technology protection committee to review the scope of sensitive technology. The composition of the committee shall include representatives of relevant authority, experts, scholars and industrial representatives. The percentage of experts, scholars and industrial representatives shall not be less than thirty percent of all committee members. The 'competent authority' shall stipulate the operational rules of the committee.

Article 5

The 'competent authority' shall regularly compile information about the demand, supply and placement of technological talents and publish an annual white paper to the public in compliance with the related information regulations.

The 'competent authority' shall establish a report system of technological security and periodically publish to the public the information of technological security. Where there is a significant threat to national security from the export of sensitive technology, the relevant authority and owner of the sensitive technology shall report it to the 'competent authority'.

Article 6

The government should adopt measures to manage scientific technology and these measures should conform to the international standards. The scope of sensitive technology should be based on the minimal principle. The 'competent authority' should hold regular meetings as regards the scope's review. When necessary, the 'competent authority' may activate the review process. The scope of sensitive technology is promulgated after it is determined or amended by the technology protection committee and approved by the 'executive yuan' (the top administration body). Those who conduct research and development of sensitive technology are entitled to subsidies with preferable considerations. The 'competent authority' shall enact the subsidy procedures.

Article 7

No export or disclosure of sensitive technology is allowed without prior approval from the 'competent authority'. Nevertheless, the export between a legitimate foreign company's branch office in Taiwan and its parent or subsidiary company is not subject to the restriction above.

Article 8

Applications seeking approval according to the preceding article shall be reviewed by the technology protection committee and the 'competent authority' may invite the applicants to address the committee when necessary. The preceding review process shall be completed within one month, but the process may be extended for another month when necessary. If the result of the applications fails to deliver after the extended time, it shall be regarded as approval by the 'competent authority'. The 'competent authority' shall issue an approval certificate to the applicant when approved. Applicants whose applications are disapproved shall receive from the 'competent authority' a written notification containing reasons for rejection and the appeal procedure. The 'competent authority' shall stipulate regulations for deadlines, procedures and other binding matters for the application of sensitive technology in the foregoing article.

Article 9

Those involved in the review process shall keep matters relating to the applications as confidential. Members of the technology protection committee who have conflict of interest in certain applications should stay out of the related review process.

Article 10

The export and import of technological products should conform to the technology protection policy and be dealt with according to the Foreign Trade Act, relevant Acts and regulations. The 'competent authority' should be consulted during the enactment and amendment of Foreign Trade Act, relevant Acts and regulations referred to in the preceding paragraph.

Article 11

Any person who violates the Article 7 shall be punished with imprisonment of not more than seven years in detention, or in lieu thereof or in addition thereto, a fine of not more than ten million new Taiwan Dollars.

If the representative of a juristic person, or the agent or employee or other worker of a juridical or natural person, commits the offenses referred to in the preceding paragraph in execution of its professional duties; apart from the actor who shall be punishable, the referred juridical or natural person shall also be punished with a fine prescribed in the preceding paragraph, except that the representative of the juristic or natural person has done its best in preventing the occurrence of the violation.

Article 12

Any person who intends to gain illegal benefit for himself/herself or the third party is aware of the damages to the right owners. As such, if he/she still conducts the following behaviours, he/she shall be punished by imprisonment for not more than ten years in detention, or in lieu thereof or in addition thereto, a fine of not more than ten million new Taiwan Dollars.

1. Acquisition or possession of scientific technology by way of deception or fraud.
2. Disclosure, delivery, damage, concealment or deletion of scientific technology without proper causes.
3. Acceptation, transportation, concealment, storage or purchase of scientific technology which is known to be from larceny and fraud.

If the representative of a juristic person, or the agent or employee or other worker of a juridical or natural person commits the offenses referred to in the preceding paragraph in execution of its professional duties; apart from the actor who shall be punishable, the referred juridical or natural person shall also be punished with a fine prescribed in the preceding paragraph, except that the representative of the juristic or natural person has done its best in preventing the occurrence of the violation.

Article 13

The punishment for any person who violates the preceding two Articles with a clear intention or awareness to benefit governments, institutions or representatives from other countries is increased up to fifty percent more of the punishment stipulated in the preceding two Articles.

Article 14

If there are provisions set forth in other Acts which provide more severe punishment for the offence sanctioned under the preceding three Articles, those provisions, therefore, govern.

Article 15

In cases of likely transfer and export of scientific technology caused by unlawful activity, the 'competent authority' shall coordinate the relevant authorities for prevention of further damages.

Article 16

The data of scientific technology which involves the critical technology innovation or national security are subject to confidentiality. The relevant competent authority shall consult the 'competent authority' to enact the regulations for the confidential measures, declassified conditions and other binding matters.

Article 17

This Act shall come into effect upon the date of promulgation.