ARTICLES

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Entrepreneurship and Strategy in Technology Transfer to Japan during the Prewar Period: The "Composite" Model

The Meiji Restoration in the mid-19th century was undeniably one of the most drastic social changes that Japan has experienced. In various fieldst its rapid industrialisation since the Meiji Restoration has been taken as a model (either positive or negative). The role of science and technology in that process of industrialisation has recently begun to excite widespread interest. Such traditional Japanese arts as medicine (kanpo), arithmetic (wasan) and foot-bellows iron making (tatara seitetsu) etc. existed before the Meiji period. But most of the sciences and technologies which contributed to Japanese industrialisation were from the Western countries. In this sense, Japanese industrialisation from the Meiji period onwards was a process during which sciences and technologies (e.g. Western medicinet weights and measures and blast-furnance iron making etc.) were adopted from the West.

However, science and technology transfer to Japan since the Meiji period was not simply a matter of purchasing equipment necessary for industrialisation. Japan did not merely use products manufactured abroad for the following reasons: (1) Science originating from 17th century natural philosophy and technology drawn from more ancient arts and crafts, were about to be integrated into professional engineering in the West just at the time Japan was starting to industrialise. It was extremely difficult for the contemporary Japanese simultaneously to transfer sciences and technologies still to be integrated into professional engineering. (2) Science and technology transfer (abbreviated as "technology transfer" hereafter) at that time forced the Japanese to grasp changing ideas while the Japanese themselves were in the middle of drastic social change. Such transfer required unique patterns of behaviour and appropriate social conditions. Therefore, a question must be raised: What patterns of behaviour were adopted by Japan and what kinds of social conditions proved appropriate?

This article elucidates the structure of marine technology transfer between Britain and Japan at the turn of the 2Oth century.

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The article focuses in particular upon the entrepreneurship and strategies of the actors involved. At that time Japan was already oriented towards heavy industries since the Sino-Japanese War, and had initiated full-scale development of heavy industries around the Russo-Japanese War.

Until now one of the leading industries in this period, shipbuilding, has been analysed mainly from the viewpoint of capital accumulation. These studies have dealt with various factors such as governmental financial aids, market structure, and management and labour organisations of individual companies. In contrast, no adequate study has been made of the process of technology transfer. At the turn of the 20th century, the new marine steam turbine developed by a British engineer, Charles A.Parsons (referred to as the "Parsons turbine" hereafter) embodied the emerging power revolution based upon thermodynamics for large, fast ships. Such ships held the key to the struggle for global hegemony at a time when "imperialism" was about to begin.

How Then Was the Marine Steam Turbine Transferred to Japan?

There is empirical evidence that the public sector, particularly the Imperial Japanese Navy, played an important role in this transfer (Matsumoto, 1995: 143–172). And the private sector also contributed to the transfer. However, previous studies have tended to adopt a stereotypical view of government-led industrialisation in Japan since the Meiji period.

This article focuses upon entrepreneurship and private sector strategies in the transfer of marine steam turbine technology to Japan at the turn of the 2Oth century. It examines in greater detail patterns of behaviour of the Mitsubishi Nagasaki Shipyard (abbreviated as "Mitsubishi" hereafter; cf. Nakanishi 1982; 1983 as to the origin of the shipyard).

The Mitsubishi Nagasaki Shipyard's Patterns of Behaviour Reconsidered

In order to explain why Mitsubishi deserves attention, we must go back to 1904. On 2nd November, 1904, Ichiro Ezaki, the director of the marine engine design section and Eizaburo Araki, the foreman of Mitsubishi, departed for Britain by order of the company. Their destination was Newcastle-upon-Tyne and their purpose was to study the Parsons turbine in Parsons Marine Steam Turbine Co. set up by C.A. Parsons in 1897 (Mitsubishi Zosenjo, 1905: 45). On 21st November, 1904, Mitsubishi made a contract with the company to purchase the manufacturing right for the Parsons turbine in the East. Even before the mission to Newcastle, Mitsubishi had purchased two turbine-generators in 1903 from C.A. Parsons & Co. (NEI Parsons, n.d.), which had been established by C.A. Parsons in 1889 for the production of turbine-generators and steam turbines for land purposes.

Thus Mitsubishi took the first steps to transferring the steam turbine before the Imperial Japanese Navy made the first official move in 1905 (Nippon Hakuyo Kikan Shi Henshu Iinkai, 1975: 421–422). As a private company, Mitsubishi was the first Japanese organisation to start to assimilate the power revolution. This does much explain why Mitsubishi held a significant position in this transfer.

After Ezaki's and Araki's return to Japan in November, 1905, the Parsons turbine was handled as top secret product innovation at Mitsubishi (Yokoyama, n.d.: 3). As well as the purchase of turbine manufacturing rights in the East, this secrecy indicates that Mitsubishi keenly appreciated the importance of the Parsons turbine. These pioneering efforts, however, do not seem to have been taken on the basis of a full preliminary survey at least regarding the marine steam turbine. The reason lies in events in 1903, the year before the Newcastle mission and the contract. Heigoro Shoda, Mitsubishi's manager, sent the following letter to two assistant managers, Rokuro Mizutani and

Hidemi Maruta:

> As to the turbine, how about sending the following letter? The Imperial Japanese Navy does not seem about to make a decision on the turbine and there are no other potential customers. Since we are not sure whether we should pay a lump sum for the five-year royalty, and do not know whether we will receive any orders during the period, we hesitate to purchase the manufacturing rights. ... If Mr. Parsons intends to sell the rights to another company unless we make our decision immediately, we will purchase the right with a reasonable royalty. ... When I had a chance to meet Jiro Miyahara of the Imperial Japanese Navy the other day, I asked about the prospects of the Imperial Japanese Navy adopting the marine steam turbine. Miyahara answered that, since a proposal for trials by the Imperial Japanese Navy was opposed by a great majority, there is no prospect of it at the moment. (dated 4th December 1903, Iwasaki Ke Denki Kanko Kai, 1971: 323–324)

It raises two important points. (1) Neither the Imperial Japanese Navy nor private shipbuilding companies showed any intention of adopting the marine steam turbine at this time. Therefore, it was very difficult to foresee Mitsubishi receiving any order for the turbines, even if they purchased monopoly manufacturing rights. (2) Mitsubishi was willing to purchase the rights at a reasonable price because they do not want to miss the chance and leave it to other companies. Rather than evaluating the technology by its own preliminary survey, Mitsubishi evaluated the technology indirectly through Imperial Japanese Navy. It showed a negative attitude even when purchasing the manufacturing rights. The company wanted to purchase the rights not because the technology was valuable but in order to prevent its selling to other parties. We can see the similar attitude in a letter the manager sent to the two assistant managers a fortnight later. The manager wanted to adopt the technology, not to satisfy a new demand but because the technology was new.

> How about using the Parsons turbine on the Shimonoseki-Pusan ferryboat of Sanyo Railway Co. after purchasing the manufacturing rights? Although the manufacturing costs may be considerable, we can consider the extra costs as advertising expenses. ... We may be able to use the ferryboat as an effective advertisement. (dated l9th December 1903, Iwasaki Ke Denki Kanko Kai, 1971: 325)

Thus Mitsubishi's behaviour in adopting the marine steam turbine was probably speculative, aimed at acquiring a new technology, rather than rational, i.e. based upon a preliminary survey, technology evaluation and selection. Actually none were, expecting any order. However, contrary to their forecast, Mitsubishi received an order two years later for a merchant ship propelled by turbines for the first time in Japan in 1905. Toyo Kisen Co. ordered a ship of over 13,000 tons, larger than any other merchant ship previously constructed in Japan. The ship was named the *Tenvomaru*. The largest merchant ship ever made by Mitsubishi was the *Tanqomaru* of 7,463 tons completed in 1905. The technical leap from the *Tanqomaru* to the *Tenvomaru* was drastic, as is shown in Table 1.

Table 1. Comparison of the Particulars of the Tanqomaru and the Tenvomaru.[1]

	Tanqomaru	Tenvomaru
Completed	1905	1908
Gross Tons	7,463	13,454
Length(m)	134.848	166.667
Width(m)	15.758	19.091
Depth(m)	10.182	11.697
Type of Engines	Triple Expansion	Parsons Turbine
Full Speed(kt.)	15.612	20.608
Maximum Output (H.P.)	6,424	19,000
No. of Boilers	1	13
No. of Shafts	2	3
r.p.m.	95.9	270
Degree of Vacuum (mmHg)	27.3(24.9)	28

Soichiro Asano, president of Toyo Kisen

Co., which was inferior to American shipping lines on the Pacific route, determined to place the order with Mitsubishi in order to turn the tables on his competitors at one stroke. However, the Toyo Kisen order also required Mitsubishi to make a great decision. Taisuke Shiota, a Mitsubishi engineer at the time, wrote as follows:

> Britain was entering the age of turbine ships. As to large-scale turbine ships, however, only the Royal Mail was constructing the *Victorian* and the *Virginian* both weighing 10,500 tons. We were a little worried because the ship would be 13,000 tons, world's largest steam turbine ship, if completed. Mr. Shoda and I were surprised that Mr. Asano made this daring decision. Later, Mr. Shoda urged Mr. Asano to reconsidery (Shiota, 1938: 315).

There were many uncertainties surrounding the result of its adoption. These uncertainties were, of course, due to the technical leaps shown in Table 1. To supervise the assembly, installation, test trial and full-speed trial of the main steam turbine imported for the *Tenvomaru*, Mitsubishi temporarily employed an engineer, Samuel Pringle, from the Parsons Marine Steam Turbine Co. (Mitsubishi Nagasaki Zosenjo, 1907: 63–64). Pringle left Britain in May 1905 and arrived at Nagasaki in July, 1907. He stayed in Nagasaki until the ship was completed in April, 1908 and handed over to Toyo Kisen Co. He even boarded the ship as a supervising engineer when the ship was transferred to Yokohama (Mitsubishi Nagasaki Zosenjo Shokkoka, 1928: 121–122).

A lot of money was required to initiate this new business. Mitsubishi started constructing a new turbine shop in February 1906 and completed it in April, 1907, immediately before the arrival of Pringle. The equipment cost 266,585 yen in the currency of the day. This was more than 3 per cent of the company's total sales for the same year (based upon Mitsubishi Zosenjo, 1906: 19). Mitsubishi thus won the order and completed Japan's first merchant turbine ship. As mentioned above, its behaviour was not necessarily rational, i.e. based upon a preliminary survey, a technology evaluation and selection, but speculative with many uncertain elements due to the technical leaps (on technical leaps in prewar Japan in general, cf. Nakaoka, 1987).

Advice from Seiichi Terano, Chuzaburo Shiba, and other experts had a bearing on Mitsubishi's decision. Terano, an advisor to Toyo Kisen Co. and a professor at Shipbuilding Department, Faculty of Engineering, the Imperial University of Tokyo, read a paper about turbine ships at the Association of Naval Architects (Zosen Ksokai) for the first time in Japan (Terano, 1906: 57–59). Shiba was also a professor at the Imperial University of Tokyo. Because of the uncertainties accompanying this product innovation, however, even Heigoro Shoda, known as "the most innovative spirit of the days in Mitsubishi" (Yadori, 1932: 70) hesitated to use the turbine as the main engine and urged the customer to reconsider. There must have been some factors not endorsing the initial investments including the construction of the turbine shop, which make Mitsubishi's decision not reducible to the rational factors alone.

As to Mitsubishi's behaviour when concluding the contracts for the manufacturing rights and for constructing Japan's first merchant turbine ship, we cannot explain everything only from the viewpoint of profit-making activities in the market. This is particularly the case because the demand for steamers, not to speak of that for turbine ships, was just emerging at that time thanks to government subsidies such as the Shipbuilding Promotion Law (Zosen Shorei Ho) promulgated in 1896 and the Shipping Promotion Law (Kokai Shorei Ho) promulgated in the same year and revised in 1899. In particular, the Shipbuilding Promotion Law was designed to "lay the foundation of the competitiveness of the Japanese shipbuilding companies with those overseas companies" (Shoda, 1895). According to the initial plan (Shoda, 1895)[2]; (1) Government subsidies were to be given to iron or steel steamers of more than 1,000 gross tons alone; (2) The rate of the subsidies was 20 yen per 1 gross ton. This clearly shows that Japanese governmental financial policy at the time focused on demand for steamers and not at all on large turbine ships.

Despite such milieu, the technological uncertainties and risks of the marine steam turbine, Mitsubishi made prior investments (such as the turbine shop construction etc.) for constructing the turbine ship. In hindsight, at leat two interpretation of Mitsubishi's activities are possible. First, Mitsubishi pioneered the introduction of initial turbine technology in order to monopolize the design technology. Second, it only made a great decision as far as introducing the turbine was concerned. Whichever, we can at least say that a kind of entrepreneurship was operating when the decision was made. During this period, Mitsubishi showed an active innovationoriented attitude unique to private companies in such situations. The attitude differed from that of the Imperial Japanese Navy, which was rational throughout (Matsumoto, 1995: 143–155). This active attitude enabled Mitsubishi to monitor the new technology from the beginning, and facilitated the early transfer of the marine steam turbine.

Relationship Between the Mitsubishi Nagasaki Shipyard, the Imperial Japanese Navy and the Imperial University

When the Imperial Japanese Navy concluded a contract to purchase the manufacturing rights for the Parsons turbine in 1911, the Mitsubishi Limited Partnership, to which Mitsubishi belonged, was the joint contractor (Nippon Hakuyo Kikan Shi Henshu Iinkai, 1975: 454–455). This indicates that the Imperial Japanese Navy and Mitsubishi had common interests. Terugoro Fujii, a shipbuilding supervisor dispatched by the Imperial Japanese Navy to Britain, contacted Ichiro Ezaki, the director of the marine engine design section from Mitsubishi, about acquiring blueprints of the Parsons turbine for the Royal Navy, during his stay in Britain (Nippon Hakuyo Kikan Shi Henshu Iinkai, 1975: 430). Hidemi Maruta, a Mitsubishi's assistant manager (who became manager in 1906), was a former Imperial Japanese Navy officer (Mitsubishi Nagasaki Zosenjo, n.d.). From these facts, we can guess that the Imperial Japanese Navy and Mitsubishi had not only a customer-supplier relationship but also other social and personnel connections. This evidence may help to explain the common interests between the two organisations.

In addition to these connections, however, we must pay attention to another important condition. Both parties played different roles, and displayed unique patterns of independent behaviour. Nevertheless their actions converged on the transfer of the marine steam turbine. This being the case, those conditions which integrated both parties must have combined to achieve the transfer based upon mutually independent behaviour. If such integration was possible between the Imperial Japanese Navy and Mitsubishi at that time, there must have been something which coordinated and linked the two organisations in introducing the marine steam turbine to Japan.

It is worth pointing out here that there was no great difference in ability between the technical personnel of the Imperial Japanese Navy and Mitsubishi. If several actors working together on a technology are not balanced in the quality of technical personnel, the joint work often fails (e.g. technical cooperation between an advanced country and a developing country often fails due to an imbalance of this sort). The Imperial Japanese Navy and Mitsubishi each employed a significant number of graduates from the Shipbuilding Department of the Imperial University of Tokyo (established in 1898). This department had grown out of the Shipbuilding Department of the Faculty of Engineering of the Imperial University established in 1886. This seems to have prevented an imbalance of personnel quality,

Table 2 Professional Careers of Graduates from Shipbuilding Department, Imperial University of Tokyo: 1883 to 1903. Source: Miyoshi (1904: 13–16).

The Imperial Japanese Navy	35
Shipbuilding Companies	28
Maritime Officials	20
Shipping Companies	10
Teachers of the Imperial University of Tokyo	6
Independent Enterprises	5
Dead	4
Graduate School	3
Military Service	2
Study Abroad	1
Total	114

Table 3 The Curriculum for the Freshmen of Shipbuilding Department, Faculty of Engineering, Imperial University in 1886. Source: Tokyo Daigaku Hyakunen Shi Henshu Iinkai (1984 Shiryo 2: 535).

1. Mathematics (Suqaku)
2. Physics (Butsuriqaku)
3. Applied Mechanics (Oyo Juqaku)
4. Mechanical Engineering (Kikaiqaku)
5. Naval Architecture (Zosenqaku)
6. Ship Drawing (Zosen Seizu)
7. Physics Experiment (Butsuri Jikken)

helped mutual communication, and served as one of the social conditions that paved the way for the introduction of the marine steam turbine into Japan. By the turn of the 20th century, it had become a general trend that graduates from the Shipbuilding Department of the Imperial University of Tokyo, originally set up to "provide education on steam engine manufacturing for war and merchant ships" (Tokyo Daigaku, 1884: 125), found employment in both the Imperial Japanese Navy and private companies including Mitsubishi (see Table 2).

Thus the university played an important role in providing both public and private sectors in Japan with a common yardstick for human resources quality. When transferring a technology such as the marine steam turbine that was deeply related to both science and engineering, an independent supply of human resources of this kind may have helped communication between the parties involved. The human resources of both the Imperial Japanese Navy and Mitsubishi had been brought up since their freshman days on a university curriculum containing both science and engineering (see Table 3).

From the twin viewpoints of Mitsubishi's behaviour and its relation with the Imperial Japanese Navy and the Imperial University, the structure of the marine steam turbine transfer to Japan may be expressed as follows: The transfer had a "composite" structure based upon different but equally important roles independently played by the public and private sectors. A unique set of social conditions, namely an infrastructure for human resources formation in both science and engineering provided by the government (Imperial University), a highly rational behaviour by the public sector (Imperial Japanese Navy) and highly speculative behaviour by the private sector (Mitsubishi) contributed independently but equally to the technology transfer. By means of this "composite" structure, a military-industryuniversity complex was formed endogenously in Japan, and remained in place until 1945. The existence of this structure provides a powerful argument against a merely chronological description of prewar Japanese industrialisation, and particularly of heavy industrialisation led by shipbuilding. Such chronological description is, understandably, standard in the single-minded framework for analysing government-led industrialisation since the Meiji period and its revised versions.[4]

The risk-taking role played by a private company (Mitsubishi) at the initial stage of the technology transfer without a full technology evaluation and selection is noteworthy. This is evidence against the schematic explanation of Japanese industrialisation assuming that a so-called rational selection of Western science and technology was made from the start. Private companies' role in Japanese industrialisation was to watch for opportunities to take risky actions in a technical leap rather than considered pragmatic behaviour.

The Japanese Industrialisation Process in Comparison with That of Britain

From the perspective of the "composite" structure mentioned above, the marine steam turbine was an important example of the rapid transfer of Western science and technology to Japan. Of course this structural argument is based upon only one typical case of the power revolution at the turn of the 20th century. But the "composite" structure idea does givei us significant insights y into the Japanese industrialisation process at a time when heavy industrialisation led by shipbuilding was gathering speed. The key issue is that the marine steam turbine was still in the process of innovation at the time of the transfer (cf. Constant II, 1980: 63–82).

The marine steam turbine was patented in 1894. Japan started official measures for the transfer of the marine steam turbine in 1905 (Imperial Japanese Navy) one year later than Mitsubishi. Why the ten-year gap after the turbine was patented? Both the public and private sectors in Japan had dispatched personnel to Europe, mainly to Britain regarding shipbuilding, particularly since the 1880s. So it is inconceivable that the marine steam turbine was not known for ten years in Japan after the patent was announced publicly.

The fact is that the ten-year period was used for testing in Britain to eliminate as many uncertainties of the marine steam turbine as possible and to secure superiority to the conventional marine engine (high-pressure multiple expansion engine). All marine engines must be reliable. The marine steam turbine additionally had to reduce propulsion loss attributable to the propeller's cavitation. One of the greatest advantages of the marine steam turbine, its high propeller revolution, deteriorated propulsion efficiency by cavitation, thereby drastically lowering the economic efficiency (e.g. coal and water consumptions per unit of time). If this problem were not solved, the marine steam turbine would never fulfil its potential as a commercial technology superior to the conventional marine engine.

As mentioned earlier, Japan began to construct the first merchant turbine ship, the *Tenyomaru* in 1905. Work on the *Tenyomaru* started just after the problem was solved temporarily in Britain by a full-scale ship trial using the *Amethyst* (turbine ship) and the *Topaze* (steamer). The results of the full-scale ship trial, which was designed to make the turbine a commercial technology, were made public in 1904. According to these results, "Economy is the one great element proved by the exhaustive and very carefully-conducted trials" (Unidentified Author, 1904: 689–692). When the speed of the ships exceeded 14 knots, the turbine ship (*Amethyst*) was more fuel efficient than the steamer (*Topaze*) (Unidentified Author, 1904: Table IV; Table V). Accordingly, the following conclusion was reported:

"the steam turbine, when running at its full designed speed, is capable of an economy better than that of the ordinary reciprocating engine. As merchant ships are, for 99 per cent of their time, running at their full speed, the gain must be very considerable." (Unidentified Author, 1904: 689–692)

The first Japanese merchant turbine ship constructed by Mitsubishi, the *Tenvomaru* owed its success to this efficiency since its full speed was far more than 14 knots (20.608 knots as shown in Table 1).

But from the patenting of the marine steam turbine until this conclusion was obtained, model and full-scale ship tests were repeated in Britain by constructing and testing an experimental ship, developing a torsionmeter, importing a Siemens water gage (Parsons, 1903: 284–311).[5] Even the Marine Steam Turbine Co. was established in 1894 only to procure sufficient capital for full-scale testing of the marine steam turbine. The company was capitalised at 25,000 pounds (Appleyard, 1933: 91). When in 1911

Japan began domestic production of the Parsons turbine thus established as a commercial technology in Britain, Mitsubishi together with the Imperial Japanese Navy paid 3,000 pounds on the purchase contract for the manufacturing rights (Nippon Hakuyo Kikan Shi Henshu Iinkai, 1975: 454–455). Japan could reduce uncertainties regarding product innovation and acquire the commercial technology after a comparatively short delay at a cost of less than one-eighth of what Britain had spent on the product innovation.6

Such technology imports became a very effective riskavoiding strategy for Japan in undertaking product innovations. They enabled Japan to acquire a commercial technology with minimal prior investment on research and development. The country was entering the era of heavy industrialisation led by shipbuilding industry, but lacked enough capital. Under these circumstances, it was not a "miracle" but rather the result of bold pragmatism that such strategy became an optimum path for the country to assimilate Western science and technology.

Conclusion

The above account of Mitsubishi role in the transfer of the marine steam turbine to Japan suggests that Japanese "success" in technology transfer has been made possible by combining two contrasting attitudes:

(1) The promptness of Mitsubishi in taking action even before the Imperial Japanese Navy had made a move showed risk taking attitudes which may be called a kind of entrepreneurship. These attitudes were manifested in the daring decision (to build the *Tenyomaru*) and the unprecedented risky investment despite the uncertainties accompanying the unknown technology. These actions cannot be explained as purely rational behaviour.

(2) The subsequent behaviour of Mitsubishi displayed risk avoiding attitudes which may be called a waiting strategy. These attitudes were manifested in avoiding huge test costs for commercialising the new technology by purchasing the manufacturing rights of the new technology by purchasing the manufacturing rights of the new technology already commercialised.

n addition, steady flows of human resources provided by the Shipbuilding Department of the Imperial University of Tokyo gave both the public sector (Imperial Japanese Navy) and private sector (Mitsubishi) a common yardstick for mutual communication and served as a unique enabling social condition for the technology transfer. Of course we cannot deny that Japanese shipbuilding industry enjoyed a "latecomers' advantage". However, this is not the whole story. First, the technology transfer process itself has a structure specific to a latecomer. Second, the timing of a technology transfer is not determined by the technology gap alone but determined strategically by the latecomer itself (in this case, Mitsubishi's waiting strategy).

Advanced technologies from other countries did not necessarily flow into low-tech Japan at the turn of the 20th century as water flows from a higher place to a lower. Neither the so-called life cycle of technologies nor capital accumulation explain everything. Risk-avoiding strategies of the firm involved and its risk-taking entrepreneurship intervened in the later and initial development stages of the technology respectively. It is a popular view that the government-led industrialisation went on since the Meiji period. Even if the roles played by private sectors are pointed out, they have been usually confined to those in light industries (e.g. textile industry, cf. Saxonhouse, 1976). By analysing in detail the behaviour of private sectors involved in the transfer of the marine steam turbine to Japan, particularly Mitsubishi, this view should be revised.

It is true that the development of Japan in those days owed a lot to government-led industrialisation. However, private sector entrepreneurship and strategies also played a unique and active role. Japanese "success" in industrialising must be reconsidered from the viewpoint of this "composite" industrialisation model based upon equally important but mutually independent roles played by the public and private sectors. Without such a model, the stereotypical views of Japanese "success" based upon government-led techno-nationalism policy (rich nation, strong army policy) cannot be tested. These views allow too much slack in interpreting Japanese industrialisation, by assuming the rational selection of the best technology regardless of the detailed structure of attitudes and behaviour patterns of the private sectors as well as the public sectors.[7]

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NOTES

[1] Source: Nippon Hakuyo Kikan Gakkai Hakuyo Kikan Chosa Kenkyu Iinkai (n.d.: Minkan Hen); Zosen Kyokai (1911: 699–701); Mitsubishi Nagasaki Zosenjo (1957: Shuyo Seihin Ichiran Hyo 1). The Parsons turbine of the *Tenyomaru* was imported from the Parsons Marine Steam Turbine Co. The degrees of vacuum of the *Tanqomaru* indicate the value of the port side (without parentheses) and that of the starboard (within parenthese) respectively.

[2] The object of the subsidies was changed to iron and steel steamers of more than 700 gross tons when the law was enacted.

[3] This department of the Imperial University originated from that of the University of Tokyo (established in 18773> which further originated from the Engineering College (Kobu Daigakko, established in 1873). The name of the Imperial University of Tokyo or the Imperial University is used depending uson the context.

[4] Among frameworks for the description of prewar Japanese industrialisation with the general account of the contemporary history of science and technology in Japan for Western readers, see Morris-Suzuki (1994) and Nakayama (1995). Kamatani (1988) gives an excellent standard work on the government-led industrialisation in prewar Japan. See also Maccormack & Sugimoto (1988); Checkland (1989); Bartholomew (1989); Hayashi (1990) et al. As for the postwar regime, MacKenzie (1993) gives an excellent exemplar to the historical sociology of science and technology which goes far beyond chronological descriptions.

[5] The value of the experimental ship, the Turbinia, was estimated in itself as 10,000 pounds (Parsons Marine Steam I Turbine Company Limited, 1897).

[6] If we consider the value change of currency since 1894 to 1911 in accordance with various price indices, the cost becomes less than one-ninth of the sum spent by Britain (estimated based upon Mitchell & Deane, 1962: 471–476).

[7] For further details of such a model, see Matsumoto & Sinclair (1994); Matsumoto (1995). Studies on the aspects of the risktaking entrepreneurship in Japanese industrialisation started from Schumpeterian tradition (e.g. Hirshmeier, 1964), though they have tended to focus upon biographies of successful businessmen without connecting them with institutional patterns of behaviour and the risk-avoiding strategy of an institution at the same time. The institutional patterns of behaviour at least in technology policy in postwar Japan have been conceptualised by Freeman (1987) as "national systems of innovation". Unfortunately reliable detailed and comprehensive studies particularly on prewar Japanese science, technology and society from such viewpoint have not yet been attempted by Japanese scholars. The so-called Japanese "success" in technological learning in prewar period is discussed in relation to Mitsubishi in Fukasaku (1995), though its description of the history of Japanese technology seems to leave several controversial points (e.g. the description of shipbuilding technology in the Tokugawa period etc. cf. Adachi, 1983 etc.) For an interesting study of the transformation of technology policy in Japan since 1868 to the 1990s, see Samuels (1994).

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