Why Japan, not China, was the First to Develop in East Asia: Lessons from Sericulture, 1850-1937

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Abstract
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Key words: raw silk, cocoon, sericulture, total factor productivity, induced innovation, diffusion.


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Abstract

Raw silk exports constituted the most important foreign currency-earning item for China and Japan during the period of 1860-1929. In the 1870s, China exported three times as much as Japan, but by the late 1920s, Chinese exports became less than 30% of Japanese exports. This paper focuses on the comparative performance of sericulture in Japan and the Lower Yangzi delta of China and constructs productivity indices including a price dual total factor productivity index. These indices, supported by a comparative narrative of the cocoon production and distribution sectors, suggest that Japan’s competitive success resulted from a set of interrelated technical and institutional innovations. It was the different reform policies pursued by Meiji Japan and Late-Qing China that created different conditions leading to the rise and absence of innovations in these two regions.

Although Japan and China are geographically and culturally close, today their levels of economic development are worlds apart. The origin of this gap is relatively recent. As late as the nineteenth and early twentieth centuries, Japanese exports competed directly with Chinese in the international market in such low value-added, labor-intensive products as raw silk. Between 1850 and 1930, raw silk ranked as the leading export for both countries, accounting for 20-40% of Japan’s total exports and 20-30% of China’s.¹

Raw silk consists of bundles of long, continuous silk threads used for silk weaving. Its production starts with sericulture that involves the cultivation of mulberry trees and the harvesting of the leaves to feed the silkworms that develop into self-spun cocoons. Traditionally, cocoons were hand-reeled into raw silk within rural households. However, by the latter part of the nineteenth century, the spread of mechanization was steadily shifting the reeling process to modern factories.

The performance of the Japanese raw silk exports contrasted sharply with that of China. In 1873 China exported three times as much raw silk as Japan, but by 1905, Japanese raw silk exports exceeded the Chinese, and in 1930, Japanese raw silk exports tripled those of China, gaining a dominant 80% share in the global market.² This contrast is puzzling given that as late as the sixteenth and seventeenth centuries, Chinese raw silk dominated the Japanese market, and even in the mid-nineteenth century, Chinese silk enjoyed a more favorable global reputation than that of Japan.
This paper presents a comparative analysis of this dramatic contrast by focusing on the cocoon sector that contributes between 60% and 80% in the value added of raw silk, leaving the reeling sector to future study. It also adopts a regional approach by comparing Japan with the Lower Yangzi, the most advanced region of China. They are comparable in size, population and climate, and are part of the wet-rice economies characterized by intensive agriculture, high population density and small-scale farming. The broad similarities in initial conditions, factor endowment ratios, crop choice and geographic environment offer us a rare case study of a relatively controlled experiment.

I argue that the Japanese success in silk export largely derived from the capacity of its sericultural sector to develop appropriate technology and institutions through a creative combination of traditional technology and modern science to overcome its resource constraints. These accord well with the so-called induced innovation hypothesis advocated by Yujiro Hayami to explain the overall success of Japanese agriculture for the same period. Thus, the absence of the Japanese style of innovation was the cause of the stagnancy of the Lower Yangzi sericulture.

Why did broadly similar conditions induce innovations in one place and not the other? I argue that important physical and social infrastructure built up after the Meiji reform in Japan, but largely ignored by the Qing bureaucrats of the conservative Self-strengthening movement in the Lower Yangzi during the latter part of the nineteenth century are the key to understanding this contrast. This paper shows further that the Japanese success in turn profoundly impacted the Lower Yangzi and elicited a dynamic technological and institutional response in the 1930s when a minimal set of necessary conditions were gradually being put into place since the Meiji-inspired Late-Qing reform in 1903-11.

This paper mobilizes a multitude of independent sources of information including the voluminous survey reports on the Chinese silk sector written by Japanese specialists between the 1890s and the 1930s, and offers various technical and productivity indices including a price dual
total factor productivity (TFP) index. The quantitative analysis is further supported by a careful examination of the institutional and technological developments in the cocoon production and distribution sectors in these two regions.

The rest of the paper is divided into three sections followed by a conclusion. Section I presents comparative data on output, input and prices and estimates of partial and total factor productivities. Section II, consisting of three parts, offers a comparative narrative of technology and commercialization and a summary of growth accounting results. Section III describes the 1930s catch-up in the Lower Yangzi.

I. Output, Prices and Productivity

Annual Japanese cocoon output (for both domestic consumption and export) almost quintupled from the 1890s to the 1930s to about three hundred thousand tons. Comparable data were not available for the Lower Yangzi. Robert Eng’s collection of various French and Japanese scholars’ cocoon output estimates gave a range of between seventy thousand and one hundred thousand metric tons, with growth rates largely stagnant for the Lower Yangzi between 1875 and 1930. Despite the data problem, it seems plausible that the cocoon output performance largely mirrors the regions’ contrasting performance in raw silk exports; i.e., that circa 1930, Japan was producing three to four times more cocoons than the Lower-Yangzi.\(^6\)

Various household and land productivity data seem to confirm a similar story of contrasting performance between 1890 and 1929. Annual cocoon output per household in the late 1920s Lower Yangzi was about 50 to 65 kilograms, about a third of the Japanese level during the same period, but roughly equivalent to its 1900 level. Annual cocoon output per acre of land in the Lower Yangzi was estimated to be about 150 and 142 kilograms in 1897 and 1932 respectively, about 70% of the Japanese level in the 1920s but equal to the Japanese level around 1910. The actual cocoon productivities in the Lower Yangzi would be even lower in comparison to Japan if cocoon quality deterioration in the 1910s and 20s were taken into account.\(^7\)
These partial productivity indices suffer various shortcomings. For the Lower Yangzi, most estimates were based on scattered individual observations. For Japan, as will be shown later, land and labor productivity improvements were exaggerated by the rapid intensification in Japanese sericulture that occurred between 1900-20. These problems posed formidable obstacles to the construction of Total Factor Productivity (TFP) based on the primal input-output approach.

In this context, the cost (or price) based TFP approach is more viable as time series data of input and output prices were relatively consistent and reliable. The dual equivalence of production and cost side TFP based on a Cobb-Douglas production function requires the assumption of constant returns to scale and long run competitive market assumptions (with cost side TFP expressed as \( A^d_t = \prod_{i=1}^{4} \frac{w_{it}}{w_{it}} \), \( w_{it} \) and \( \alpha_i \) being price and weight respectively for the \( i \)th input at time \( t \), \( AC_t \) as average cost of production and \( \sum \alpha_i = 1 \)). Both these assumptions are reasonably satisfied for the small-scale and scattered rural sericultural production taking raw silk and cocoon prices as given by the global market.

To calculate the dual TFP, I have used cocoon price for \( AC \) and four price series of input, namely, labor, land, sericultural inputs (fertilizer, silkworm egg seeds and etc.) and capital (silkworm rearing room, tools) for the period between 1903 and 1928. Their summary statistics are presented in the Data Appendix.

Figure 1 shows the annual cocoon (as well as raw silk) prices for Japan and the Lower-Yangzi all converted into Japanese yen. The cocoon price of the Lower Yangzi is from Wuxi, the most important cocoon-marketing center in the region. Notice that the Wuxi cocoon price, which roughly paralleled that of the Japanese cocoon price until the mid-1910s, began to dip consistently below the Japanese level thereafter.

The abrupt but sustained lowering of the level of cocoon prices after the mid-1910s reflected a systematic deterioration of cocoon quality in the Lower Yangzi as captured by the rising silk yield ratio – the amount of cocoons needed to produce a certain unit of raw silk. Shigema Uehara,
the most authoritative specialist on Chinese silk industry at the time, presented data showing that the amount of dried cocoon required for producing 100 kilograms of raw silk increased from 500 in 1915 to more than 600 kilograms in 1924 – a decline of more than 20 percent.\textsuperscript{8}

Adjusting the cocoon price by the quality change is essential for an accurate calculation of TFP changes for the Lower Yangzi. The quality adjusted cocoon price in Wuxi (obtained by multiplying the cocoon price by the standardized silk-yield ratios) is displayed in Figure 1 as Wuxi(q). The price dual TFP adjusted by cocoon quality (\(A_i^q\)) can be written as

\[
A_i^q = \prod_{j=1}^{4} \frac{W_{ij}}{S_j} p_i,
\]

with \(S_i\) and \(p_i\) denoting the standardized silk-yield and market cocoon price respectively. For the Lower Yangzi, \(S_i p_i\) is equivalent to Wuxi(q). The results for both regions are presented in Table 1. Japanese TFP growth accelerated during these three decades. The Lower-Yangzi showed very promising TFP growth from about the 1900s to the 1910s but this then turned negative in the 1920s as the silk yield decline took its toll. Overall, the Lower Yangzi TFP growth rate of 0.52% was only about a quarter of Japan’s 2.05% in the first three decades of the twentieth century.\textsuperscript{9}

II. Accounting for Growth: Technology and Commercialization

The leaders that came to power through the 1868 Meiji Restoration made no pretense to “restore” Japan to her old days, but instead proclaimed, in the new imperial “Charter Oath,” that “knowledge shall be sought throughout the world…” and subsequently embarked on a reform program to forge a modern nation state modeled after the West. Japan’s decisiveness in turning outward in the face of the Western imperial challenge was matched by contemporaneous Qing’s determination to reinstate an orthodox Neo-Confucian ruling ideology to an empire that had been brought to the brink of collapse by the devastating 1860s Taiping rebellion.
The Qing bureaucrats did recognize the superiority of Western military technology and, under the so-called Self-strengthening movement (1860-1894), attempted to modernize the Chinese military through a series of either government financed, or government controlled Western style industrial enterprises. The attitude of the Self-strengthening movement towards private initiatives in the modern sector ranged from indifference to hostility and displayed little interest in supplying modern public goods and in most cases, was even opposed to private efforts to build public infrastructure such as railroads and inland steam shipping.

In comparison, Meiji’s sell-off of its limited number of government enterprises in the 1880s gave a powerful signal that the private sector was the mainstay of Japan’s industrialization. The government concentrated on building crucial social and physical infrastructures such as a legal system, public education, research and technological diffusion, a modern monetary and banking system, modern transportation and communication.

China’s shocking naval military defeat by Japan in 1895 was soon to spell the end of the Self-strengthening movement and subsequently set off a process of intellectual awakening that questioned the fundamentals of the traditional system. The Qing constitutional reform in 1903-11, itself inspired and modeled after the Meiji reform, recognized the importance of the private sector and the government’s role in public goods provision. But the imperial Qing collapsed in 1911, leaving an unfinished reform agenda to a China in disarray.¹⁰

The following three sections will show that these crucial changes in the late nineteenth and early twentieth centuries set the production and commercialization in Chinese and Japanese sericulture along increasingly divergent paths of technology and institutions despite similar starting points. This divergent path impacted directly the productivities and competitiveness of the two sectors.
1. Technology

Japan was a latecomer in the global silk market. The rise of a domestic Japanese raw silk sector, originated in Tokugawa shoguns’ 1685 restrictions against Chinese silk imports, was a case of import substitution based on the borrowing of the Chinese, particularly the Lower Yangzi sericulture technology. In the 1860s and 1870s, Japan became the most important supplier of quality silkworm eggs for Europe. Japan’s comparative advantage in the export of silk-worm eggs, a product lower in value-added than raw silk, seems to corroborate other evidences that pointed to a level of late-Tokugawa Japanese technology, while possibly converging to or even overtaking that of the Lower Yangzi in the area of silkworm rearing, still lagging behind in mulberry cultivation and hand-reeling technique.11

Meiji reform opened the Japanese sericulture to the world of European science and technology. The Iwakura mission that sent Meiji ministers on a two-year study tour of Europe and America in 1871–73 enlightened Japanese sericulturalists as well. Following the official Iwakura mission to Italy was a group of Japanese sericultural experts headed by Nagaatsu Sasaki who visited Northern Italy in 1873.

At the time of Sasaki’s visit, Northern Italy represented the frontier of Europe’s sericultural technology, being transformed by the application of modern science, particularly the discovery and diffusion of Louis Pasteur’s microscopic examination method of pebrine disease. The sericultural institute that Sasaki visited and studied for one full month in Gorizia (in Northern Italy) was the first of its kind set up in 1869. Sasaki returned to Japan with the most up-to-date silkworm rearing tools such as microscopes and hygrometers, and actively advocated the establishment of modern sericultural research and education in Japan. The visit heralded the beginning of Japan’s own national system of technological innovation, diffusion and education. In the period between the 1890s and 1940s, Japanese sericultural specialists produced a steady...
stream of survey reports on foreign sericultural technology and commercial practices, with a total of about 40 volumes just on China.  

Such keen awareness of the on-going technological revolution in European sericulture could not be found in the Lower Yangzi before the twentieth century. Preparation for the grueling, pyramid-structured Civil Service Examination system based on the memorization of Confucian classics continued to engross the intellectual energies of the Chinese elites. Among the limited efforts by the Self-strengthening bureaucrats to diffuse Western science and technology was the translation of a series of Western texts by the translating department of the Jiangnan Arsenal, a government industrial venture established to build Western style military ships. One of these texts translated in 1899 is a classic Italian sericulture book, published originally in the late 1810s. The Chinese translation, itself possibly based on a late English translation, involved the work of three non-specialists in sericulture - an Englishman by the name of John Fryer provided the oral interpretation of the text and two Chinese writers converted Fryer’s verbal explanation into classical Chinese. This Chinese style of acquiring a classic but out-dated Italian technology through a multiple of indirect media forms a direct contrast to the Japanese style of learning as displayed in Sasaki’s 1873 study tour in Italy.  

By the turn of the century, Japanese surveys on Lower Yangzi sericulture had already shown important traces of technological divergence. These reports often criticized silkworm rearing practices in the Lower Yangzi as backward, naïve, and superstitious, and most interestingly, “very much like our practices in the pre-Meiji era.” It confirms that Japanese sericultural technology only began to decisively forge ahead of the Lower Yangzi around the turn of the last century. The following comparative narrative illustrates two of Japan’s most important technological breakthroughs in the early twentieth century that laid the foundation for its global dominance.  

_Silkworm Improvement: developing the F₁ Variety_
Silkworm eggs are an essential input to cocoon production. While there were numerous technical innovations in the prevention of silkworm disease and improvement of silkworm varieties, the fundamental breakthrough came with the discovery of the so-called first filial (F₁) hybrid silkworm in the early 1910s. The performance of the F₁ variety surpassed the previous types in almost all technical indices.¹⁷

The concept of hybrid vigor behind the F₁ variety is ancient in East Asia. However previous studies and experiments with silkworm crossbreeding, including those done in the early Meiji era, were not supported by the theory of heterosis as expounded by Mendel’s genetic principle. The key element of Mendel’s discovery was that the superior traits of the two pure strain parent varieties were stable in their first generation of crossbreeds, but not in the succeeding generations derived from this cross. This important theoretical recognition led to the rise of modern experimental labs that specialized in the selection and breeding of pure strain varieties and the mass production of the crossed F₁ variety silkworm eggs for cocoon production.

It is important to note that the success of the F₁ variety was founded on a series of cumulative research on embryology and cellular biology. Unlike other minor innovations, government sponsored research labs and university departments were responsible for most of the basic scientific research and biological experiments at the core of the F₁ technology.¹⁸

Aided by a diffusion network of experimental stations, specialized silkworm-egg dealers, industrial silk reelers and associations, the F₁ variety diffused rapidly among sericultural farmers. The diffusion started in the early 1910s, and by 1923, the F₁ variety’s share in the spring crop reached one hundred percent; by 1929, one hundred percent of the summer and fall crop used the F₁ breed.¹⁹

The diffusion of the F₁ variety had a direct impact on both the productivity and quality of cocoons in Japan. The most commonly used indicator for the performance of silkworm varieties and rearing was the so-called cocoon-egg yield -- the weight of cocoons obtained from a certain
amount of hatched silkworm eggs. Table 2 shows clearly that the improvement of cocoon yield accelerated from 1900-09 to 1910-19, which corresponded well with the timing and rate of diffusion of the F1 variety. This also matched the acceleration of my TFP index for Japan. By the late 1920s when the diffusion of the F1 variety was complete, Japanese egg yields surpassed the level of Italy.

[Insert Table 2]

In contrast, silkworm eggs used in the Lower Yangzi before 1925 were almost entirely produced by traditional breeding methods, with little use of the microscopic method of disease prevention. Based on various Japanese survey reports, the final column of Table 2 presents a direct comparison of the cocoon yield for these two regions. This contrast is compelling. Around 1900, the cocoon egg-ratio in Japan and the Lower Yangzi were roughly equal, but for the next two decades, the Japanese cocoon-egg ratio surged, as opposed to a largely immobile cocoon yield index in the Lower Yangzi.

Intensification: Rearing a Second Crop

The next major Japanese innovation was the rearing of a second crop of silkworms in the fall in addition to the main spring crop. Again like so many other Japanese innovations, it has its roots in East Asia. However, instability in hatching and other technical problems constrained its growth. The great merit of the fall crop was that the timing of its rearing fell in the period when rice-cultivation required the least labor, thus enabling cocoon growth without the sacrifice of cereal production. In Japan, studies of artificial hatching started in the late 1880s and Japanese farmers had also experimented with various crude methods of preserving and hatching the silkworm eggs in autumn. But it was not until Japanese scientists' discovery of hydrochloric acid processing in 1911-12 that the timing and outcome of artificial hatching stabilized.

Innovation in silkworm egg preservation and hatching was only half of the tale. The more binding constraint on the fall crop was the supply of mulberry leaves in the fall season when
mulberry trees were no longer yielding fresh leaves. Technical innovation in this area had gone through several phases of search and experimentation and eventually converged to a set of three complementary technologies: the introduction and adaptation of a fertilizer-responsive tree variety, known as “Lu” from the Lower Yangzi; a new tree-pruning technique called stem-pruning; and the adoption of new types of commercial fertilizer.

Japan had learnt of the superior “Lu” mulberry trees through Chinese sericultural texts in the Tokugawa era but only started widespread introduction after Meiji through the advocacy of the energetic Sasaki. Stem-pruning applied to the Lu types of trees reduced the tree trunks to bushes which matured faster, carried a higher yield and could bloom multiple times within a year, but with a shorter life span.22

In China, the stem pruning technique and bush type of mulberry trees (not the Lu type) were widespread in the sub-tropical Guangdong province.23 Japan’s success in transferring a sub-tropical technique to the temperate zone was complementary with the diffusion of new commercial fertilizers in 1900-1930. Among the types of commercial fertilizer used, soybean cake imported from Manchuria in northeast China was the most important.24 The commercial adoption of the soybean cake from Northern China was a major historical achievement of the Lower Yangzi agriculture in the eighteenth and nineteenth centuries. But by the twentieth century, Japan’s colonial economic activities in Manchuria as well as significant improvements in internal distribution and transportation effectively diverted this trade flow towards Japan.25

This combination of technological innovation led to the rise of the ratio of the summer and fall crop to total output from just over 20% in the 1880-1900 period to 34% in 1900-09 and after 1920, the summer and fall crops consistently made up about half of the total output, rivaling the spring crop.26

By contrast, the early twentieth century mulberry cultivation in the Lower Yangzi displayed an eco-system formed since the late Ming (about the late sixteenth century). Mulberry trees,
mostly of the Lu type, trunk-pruned, clustered along the banks of the canal system, fertilized by the canal sediments, with mulberry leaves transported to markets through the canal network.\textsuperscript{27} Scattered estimates show that 1910-30 average Lower Yangzi mulberry yields per acre while still higher than those for Gunma and Nagano prefectures for the period of 1880-90, the two most important sericultural regions in Japan, became only half of Japan’s national average yield in 1927. Consequently, the share of summer and fall crops in the late 1920s Lower-Yangzi remained at about the level of Japan before the 1880s.\textsuperscript{28}

2. Commercialization

\textit{Japan: Breaking the Resource Constraint}

In the 1880s the Suwa district of Nagano prefecture became the center of mechanized reeling factories. As Suwa was in the heart of the sericultural regions in eastern Japan, initially silk reeling factories acquired cocoons directly from the rural households in neighboring areas. With the phenomenal growth of modern reeling factories over the next two decades however, silk reelers began to reach into other prefectures for additional supplies of cocoons at cheaper prices. Nationwide cocoon procurement by silk reelers induced the growth of cocoon collection and marketing centers in all of the major sericultural regions from the 1880s to the 1910s. These collection and marketing centers usually consisted of cocoon merchant houses as well as individual merchants, some equipped with cocoon drying and storage facilities.

The mountain-locked Suwa district was a harsh environment for commercialization. Therefore, the rapid extension of the radius of the cocoon supply region was a feat of man’s triumph over geography. Nakabayashi has carefully documented how the adoption of modern insurance and transportation methods, the building of railroads, and the cooperation of silk reelers and railroad authorities had managed to break, one by one, the bottlenecks that would have otherwise constrained the enormous expansion of cocoon supply. The building of railroads, starting in the early 1880s, instantly opened up new cocoon supply regions for the Suwa silk
reelers, turning more and more traditionally integrated producers of silk reeling and silkworm rearing into specialized cocoon farmers.

From the 1910s, the development of direct purchase arrangements between reelers and farmers expanded at the expense of intermediary markets or middlemen. After WWI, the direct exchange between reelers and farmers or farmers’ cooperatives markedly increased. Statistics show that by 1923, cocoons sold directly to the reelers were 46.6% of total sales, higher than the 23.9% and 29.5% sold through the cocoon market and merchants respectively. Out of the direct exchange system evolved another institutional innovation that brought reelers and rearers even closer, the so-called “Sub-Contractual Direct Purchase” system. This system, which probably originated in 1905, entailed a long-term exchange contract between farmers and reelers. From 1926 to 1933, the share of cocoons sold through this system grew from 12.5% to 40.1% in Japan.

The Lower Yangzi Contrast: Growth and Constraints

Compared with the almost linear progression of Japanese cocoon commercialization, the process for the Lower Yangzi was far more twisted. The period before the mid-1890s saw much activity but little real spread of modern silk reeling factories. The exports of machine-reeled raw silk from Shanghai before 1894 were so insignificant that they were counted as hand-reeled raw silk in the Customs statistics.

This is no surprise as private modern industry, distinguished from those supported by the Self-strengthening bureaucrats, had no legal status before the 20th century. The few mechanized silk reeling factories that did survive under the dubious extraterritorial protection in the treaty port of Shanghai were repeatedly harassed by the local officials representing the interests of the traditional silk weavers who feared for their source of raw silk supply. The issue was swept away by the treaty of Shimoneseki in 1895 signed after China’s defeat by Japan granting legality to private enterprises in the treaty ports.
In Shanghai, the number of modern silk reeling factories more than doubled between 1895 and 1896. But the take-off of the Shanghai reeling industry, itself located about two to three hundred kilometers from sericultural regions, soon ran into the constraint set by the nascent cocoon marketing and distribution infrastructure in rural Lower Yangzi, sending the cocoon price in Wuxi as presented in Figure 1 to surge 70% between 1902 and 1903.

In the nineteenth century, the Lower Yangzi lowlands relied on its intricate waterways for cocoon transportation, thus barely surviving Qing’s prohibition of railroads in China. Attempts by Shanghai silk reellers and merchants to introduce steamships into inner rivers were thwarted by local officials who were protecting the interests of traditional shippers. It was after 1896 with the signing of the Shimonoseki treaty that steamship and later, regular steamer routes in the inner river and canal system began. In 1908 and 1912, two railroads linking Shanghai to the sericultural heartlands of Jiangsu and Zhejiang provinces were also completed.

Lower Yangzi cocoon distribution was largely in the hands of the cocoon hangs. The hangs received fresh cocoons from farmers, dried them in their ovens and then shipped them to Shanghai. Cocoon hangs belonged to the traditional Ya-hang system where the Ya-hang obtained local trading privileges by its purchase of government issued licenses and payment of commercial taxes.

The rising demand in the twentieth century induced a steady increase of cocoon-hangs. In Wuxi, the number of cocoon hangs increased from fewer than 50 in 1895 to 140 in 1910. By 1917, Jiangsu and Zhejiang provinces had over 700 cocoon hangs scattered in major sericultural regions. In 1902, Wuxi hang merchants, whose organizing activities to regulate market practices and coordinate collective action could be traced back to the 1880s, founded their official cocoon guild. This was absorbed in 1909, into a joint guild organization representing both the Lower Yangzi cocoon merchants and Shanghai silk reellers.
Still, cocoon commercialization in the twentieth century Lower Yangzi was no smooth sailing. In the mid-1910s, at the peak of the Lower Yangzi cocoon commercialization, the traditional silk weavers guild succeeded in pressuring the provincial governments to promulgate legislations to place a ceiling on the number of cocoon hangs allowed within a certain geographical area in the Lower Yangzi. Subsequently, the pace of growth of cocoon hangs and shipments to Shanghai noticeably slackened during the 1920s.37

Commercial organization in the twentieth century Republican China as characterized by guilds and hangs was a legacy of the traditional imperial system. In the Late-Qing, strained by its deteriorating fiscal condition, the government increasingly resorted to commercial taxes in place of the rigid land tax. But the collection of commercial tax, particularly the infamous Lijing tax levied on goods in domestic transit, was in the hands of local governments whose revenue extracting measures were often arbitrary and extortionary. It was the organized guilds, taking advantage of local governments’ limited informational capacity on commercial activities, acted as tax collection agents. Through the practice and spread of commercial tax-farming, merchant guilds wielded additional leverage over the rural cocoon distribution in the Lower Yangzi.38

Throughout this period, the Cocoon Guild, like the other guilds, resorted to all means to protect their trading privileges by shutting out independent cocoon intermediaries. Their efforts to collectively bargain down the purchase price for cocoons alienated cocoon farmers who were constantly attempting to circumvent the hang system.39

A potential information problem emerged in the process of cocoon commercialization that created a division of labor between silkworm rearing and silk reeling. In scattered rural households where silkworms were reared, cocoon farmers had private information about their rearing process and the quality of their products. By the 1910s and 20s, fraudulent and dishonest practices of selling low quality cocoons had turned the cocoon market into something like Akerlof’s lemon market.40
Interestingly, Tokugawa Japan especially in the eighteenth century may have been no less
guild-oriented than the Lower Yangzi. Official chartered merchant guilds paid license fees and
contributed tax revenue to the Bakufu in exchange for trading privileges. It was Meiji reform that
abolished the merchant guild system and upheld the legality of free commercial transactions.\(^41\)

The absence of a government-sanctioned monopoly gave rise to the diversity of institutional
arrangements of cocoon transactions in Japan and created possibilities for institutional innovation,
as seen in the case of the “Subcontractual Direct Purchase” system. Through the long-term direct
purchase contract, industrial silk reelers, by providing scientifically bred silkworm eggs and
detailed technical guidance, acquired monitoring capacity of farmers’ silkworm rearing process.
In Japan, large-scale, high quality raw silk manufacturers such as Katakura and Gunze were the
main users of this system.\(^42\) The asymmetric information problem that had plagued the Lower
Yangzi in the 1910s and 1920s, possibly causing the regions’ silk yield decline, was eased by a
system of semi-vertical integration in Japan.

3. A Summary Growth Accounting

The differential pace and sequence of cocoon commercialization in the two regions have
productivity implications. Both visual observation and the standard statistical co-integration test
on the price series in Figure 1 reveal the much higher degree of market integration between
Japanese cocoon markets and the Yokohama raw silk market than that between Wuxi and
Shanghai in the first two decades of the twentieth century. Sericulture in the twentieth century
Lower Yangzi, possibly at a similar stage of commercialization as that in Japan in the latter half
of the nineteenth century, might have realized significant productivity gains from new
infrastructures and greater specialization. Such gains, however, may have been relatively
insignificant for Japan in the twentieth century as major infrastructures and a cocoon-marketing
network were already well established. If we could assign the 0.52% annual Lower Yangzi TFP
growth in 1904-28 in Table 1 to possible efficiency gains from commercialization, we have to
explain the 2.05% Japanese rate of TFP growth in 1903-28 in the context of the momentous technological and institutional innovations within its sericultural sector.\footnote{43}

Table 3 presents the growth accounting to calculate separately the contributions of input expansion (extensive growth) and TFP growth (intensive growth) to cocoon output growth for Japan. It shows that TFP growth (from Table 1) made up 37% of the total growth in cocoon output leaving the remaining 63% to input expansion in 1903-28. Out of this 63% input expansion, I calculate the pure intensification effects from summer and fall using the following counter-factual calculation:

\[
\text{Annual growth rate from intensification} = \exp\left(\frac{\log(Q_{1927}) - \log(Q_{h1927})}{24}\right) - 1.
\]

\(Q_{1927}\) = total spring, summer and fall cocoon output in 1927;

\(Q_{h1927}\) = 1927 spring cocoon output + \((Q_{1927} \times 1903\) summer and fall ratio).

This calculation, as presented in Table 3, shows that intensification through the summer and fall crop (as a part of the input expansion) was equivalent to an annual 1.15% input growth (about 21% of the total growth in cocoon output). Altogether, TFP growth and intensification accounted for 58% of the annual growth in Japanese cocoon output, leaving the remaining 42% to pure expansion in land and labor.

I showed earlier that the TFP growth was directly related to the discovery and diffusion of the F\(_1\) variety, while intensification was achieved through the application of artificial hatching in combination with the set of complementary technologies in mulberry cultivation. These constituted the core of the induced innovation in Japanese sericulture. Had such innovation not occurred, that is if we remove the 58% contribution of the induced innovation from the 5.5% annual cocoon growth rate in 1903-27, Japanese growth would have been only 2.3%. This is roughly equivalent to the 2.8% growth rate of the raw silk exports in the Lower Yangzi in the same period. Clearly, what ultimately made the difference between these regions is the race-seed-fertilizer transformation.\footnote{44}
III. An Epilogue: The Lower Yangzi Catch-up in the 1930s

The lackluster sericultural performance in twentieth century Lower Yangzi has to be placed in the larger context of China’s political disintegration and social and economic dislocation that occurred after the Qing collapse in 1911. Under a series of weak governments or sometimes no government in the Republican period, real reforms made little headway. Yet the legacy of reform and the fundamental ideological switch proved to be far more enduring.

In 1897, a local magistrate founded China’s first modern sericultural institute in Hanzhou, Zhejiang province. Sericultural manuals with titles using the newly introduced term “experiment” appeared after 1900. The Late-Qing reform, which abolished the Civil Service Examination, paved the way for a modern education system with a new curriculum. Slowly but steadily, experimental stations, research institutes, schools of various levels, departments in universities and a scientific community grew, actively promoting sericultural reform, popularizing scientific principles and diffusing new technology.45

The first two decades of the century also heralded the so-called golden age of Chinese capitalism in the treaty port of Shanghai. Rapid industrial and financial growth in Shanghai was spilling over to the Lower Yangzi especially along the recently completed Shanghai-Nanjing railroad on which Wuxi was located. By the mid-1920s, Wuxi, with its cheap labor and proximity to raw materials, had emerged as a second center of modern silk reeling production in the Lower Yangzi.

The scattered mosaics of economic growth seemed to really come together with the founding of the new Nationalist government in Nanjing, Jiangsu province in 1927. The restoration of general peace and stability was an invaluable public good that a government could offer. By 1933, for the first time the number of modern silk reeling machines in Wuxi exceeded those in Shanghai.46 Most notable was the rise of a giant silk reeling conglomerate, the Yongtai Company,
which moved from Shanghai in 1926. It soon emerged as the industry leader in pushing for sericultural improvement and technological diffusion in the 1930s.

In 1928, the Nationalist government abolished the trading privileges of the Cocoon Merchant Guild and lifted the restrictions on the opening of cocoon hangs, and started reforms in commercial taxation and tax-farming. Between 1928 and 1929, the number of cocoon hangs in Wuxi county jumped by about thirty percent. The government encouraged the establishment of Silkworm Rearing Cooperatives to sell cocoons directly to reeling factories. In 1932, the Yongtai Reeling Company began to set up long-term exclusive contracts with farmers or cooperatives in the Lower Yangzi, a system very similar to the Sub-Contractual Direct-Purchase system pioneered by the large silk reelers in Japan.

Starting in 1932, the provincial governments of both Jiangsu and Zhejiang began to take a direct role in promoting sericultural improvement and technological diffusion by designating model districts across the region. In 1934, the government founded a national level sericultural research and improvement organization.

The outcome was a 1930s Lower Yangzi catch-up with Japan that was nothing short of remarkable. Figure 2 plots the Lower Yangzi diffusion curve for the scientifically improved variety, mostly of the F₁ types. For Jiangsu province, the percentage of scientifically produced silkworm eggs increased from 5% to almost 100% within only 5 to 7 years. Diffusion lagged somewhat in Zhejiang, but the overall rate of diffusion in the Lower Yangzi in the 1930s was comparable to the Japanese diffusion of the F₁ Hybrids in the 1910s and 1920s.

Following the Japanese method of artificial hatching, Jiangsu province took the leadership in rearing fall silkworms. In 1935, the ratio of fall crops to total crops was 42% for Jiangsu and 18% for Zhejiang province.
The distinctive imprint of Japanese technology and institution on the Lower Yangzi path of catch-up was unmistakable. This came about by no accident but was the outcome of two decades of conscious Japanese learning on the part of Chinese sericulturalists and later the Wuxi entrepreneurs. Lower Yangzi’s success in a near full-scale transplantation of the Japanese sericultural model attests to the binding power of comparable conditions of factor endowments and a common cultural and technological heritage between the two regions. It also bears witness to the early twentieth century momentous reversal of the historical direction of knowledge transfer between these regions from the pre-modern era.\textsuperscript{51}

Cocoon output and raw silk exports from the Lower Yangzi increased in 1935 and 1936. Equipped with the newly imported Japanese reeling technology, raw silk by Yongtai conglomerate cut into the U.S silk stockings market, formerly the exclusive territory of the giant Japanese high quality raw silk producers such as Katakura and Gunze.

The positive developments centered around Wuxi sent alarms to the Japanese competitors. Despite its global dominance in the 1930s, Japanese competitiveness in this labor-intensive product was rapidly eroding due to rising labor cost brought about by decades of economic growth. The massive outflow of Japanese technology was only chipping away its last line of defense.\textsuperscript{52} Therefore, the 1930s Lower Yangzi catch-up was riding the historical shifting tides of dynamic comparative advantage, only to be abruptly brought to a halt by Japan’s full-scale invasion of China in 1937.

\textbf{Conclusion}

Around the middle of the nineteenth century when Western imperialism opened up East Asia, China, by all measures of comparative advantage, seemed set on a course of regaining her historical supremacy in the global silk market. Instead, the six decades to follow were to witness the rise of Japan against all odds.
This paper demonstrates that induced technological and institutional innovation brought Japanese sericulture decisive productivity advantages over that of the Lower Yangzi, the key to its dominance in the twentieth century global raw silk market. It further argues that the rise of induced innovation in Japan and its absence in the Lower Yangzi during this period has to be analyzed in the context of the two countries’ contrasting ideological and political responses to the mid-nineteenth Western imperialist challenge, leading to economic policies drastically different in the provisioning of public goods, the structuring of economic incentives, and the alignment of interest groups. Therefore, the case of the Lower Yangzi’s remarkable convergence to Japan in the 1930s was as much in the areas of technology and commercialization as in ideology.

This, however, begs the larger question: why, when confronted with the same Western challenge, had Japan’s ideological or cognitive switch been earlier, and more decisive? This is a question of enormous import to our understanding of economic development that would call upon a much more comprehensive and multi-disciplinary approach than the scope of this paper allows.

This comparative analysis contributes both a historical and an East Asian perspective to the theory of induced innovation. In Japan and the Lower Yangzi, the development of technology biased towards using labor and saving capital and land as a response to the rising labor-land ratio had been a long-standing tradition traceable to Tokugawa Japan and Southern Song China (1127-1279). Even in the twentieth century, the two Japanese epochal technical innovations in cross-breeding and summer and fall crops were ancient in origin, but achieved fundamental breakthroughs with the infusion of modern science, the establishment of a national diffusion network, the build-up of modern physical and social infrastructure and the rise of new systems of production and distribution.

Clearly, what set the Japanese induced innovation in the modern era apart from that of the pre-modern is not its direction of technical bias, but rather its sharply accelerated pace of technical progress due to the availability of the newly supplied public or social capital to create economy
wide externalities. While some of these externalities, as shown by the Japanese experience, can be partially internalized by the large and integrated reeling firms who acted as powerful agents of change, such a possibility was stymied in the Lower Yangiz – the growth of its mechanized reeling industry was both belated and geographically removed from the rural sector as a consequence of China’s fragile legal environment for the private sector.

Judged in this light, the late nineteenth and early twentieth century growth record of the Lower Yangzi sericulture was quite impressive and historically unprecedented if measured by the standards of the sixteenth and seventeenth centuries when Chinese raw silk still reigned supreme globally. It only pales in comparison to Japan in its fast track of modern economic growth.

Finally, this paper also sheds light on the on-going historical debate on China related to the so-called Needham puzzle – why China, with its significant scientific achievements and relatively flexibly economic institutions, failed to become the first country to industrialize. The related grand hypotheses ranging from “high level equilibrium trap”, to “involution” and to the recent California school’s resource constraint argument, all grounded in some form of resource and factor endowment explanation seem to have neglected the important lesson from Japan’s rapid industrialization in the twentieth century in the face of over-population, labor abundance and resource scarcity. Openness, by which I mean not only opening the country to trade, but also opening the minds of its populace, clearly matters.
Table 1. Quality Adjusted TFP Index for Japan and the Lower Yangzi (numbers in parenthesis are growth rates compared with the earlier period)

<table>
<thead>
<tr>
<th>Year</th>
<th>Japan</th>
<th>Lower-Yangzi</th>
</tr>
</thead>
<tbody>
<tr>
<td>1903-9</td>
<td>105</td>
<td>68</td>
</tr>
<tr>
<td>1910-19</td>
<td>119 (1.3%)</td>
<td>1910-19</td>
</tr>
<tr>
<td>1920-28</td>
<td>157 (3.2%)</td>
<td>1920-28</td>
</tr>
<tr>
<td>Average annual growth rate 1903-1928</td>
<td>2.05%</td>
<td>Average annual growth rate 1904-1928</td>
</tr>
</tbody>
</table>

Sources:
1. For sources of input and output prices and Chinese silk yield data, see the Data Appendix.
2. Japanese silk yield data from *LTES*, vol.11, Table 49, col.4.
3. The shares of labor, land, capital and input (fertilizer being the major item) used for Japan are 0.5, 0.12, 0.2, 0.18 respectively, and 0.5, 0.17, 0.15 and 0.18 for the Lower Yangzi respectively.
4. The Japanese factor share information is from Central Committee of Japanese Sericultural Association (1924, 1925) *Souen oyobi yousan keieihi no kenkyu* (Studies on the Cost of Mulberry Cultivation and Silkworm Rearing, No.1,2,3), (1924 and 1925), p.11 in report No. 1, and p.19 in report No.2. For the Lower Yangzi, I have used information from Uehara, pp.83-84 and p.160 and also Chen, Zi-yu, pp. 60-70.
Notes:
1. For the Lower-Yangzi TFP, I used 1904 as the starting year because 1901-3 corresponded to an extraordinary period of cocoon market speculation in Wuxi due to a sudden surge of silk reeling factories in Shanghai. This is explained on Section IIB in the text. If I use 1901 or 1903 as the starting year, annual TFP growth rate in 1901-28 would be 1.5% and 1.1% respectively.
2. To test for the robustness of my TFP calculation, I have performed a sensitive test by applying alternative weights. Applying Chinese share weights on the Japanese data gives an average annual growth rate of 2.1% for Japan in 1903-28. Using Japanese share weights on Chinese data gives an annual TFP growth rate of 0.67% for the Lower Yangzi in 1904-28. Neither of these two rates was significantly different from those in Table 1.

Table 2. Yield of Silkworm Eggs (Kilograms of Cocoons per gram of Silkworm Eggs Hatched)

<table>
<thead>
<tr>
<th></th>
<th>Italy</th>
<th>France</th>
<th>Japan (all crops)</th>
<th>The Lower Yangzi as a percentage of the Japanese level in that year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1878-87</td>
<td>1.02</td>
<td>0.94</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1888-1902</td>
<td>1.48</td>
<td>1.43</td>
<td>0.86 (1899)</td>
<td></td>
</tr>
<tr>
<td>1903-13</td>
<td>1.76</td>
<td>1.55</td>
<td>0.80 (1900-09)</td>
<td>100% (1900)</td>
</tr>
<tr>
<td>1910-19</td>
<td></td>
<td></td>
<td>1.06(3.8%)</td>
<td>74% (1917)</td>
</tr>
<tr>
<td>1920-29</td>
<td>1.74</td>
<td></td>
<td>1.75(5.2%)</td>
<td>50% (1927)</td>
</tr>
</tbody>
</table>

Source Notes: Italian and French data are from Federico, *Economic History*, 1997, Table XV in Appendix. I choose the c) column for the Italian yield, which is the more consistent but also higher than the other estimate.
Japanese data are from Fujino et al, *LETS*, vol.11, Table 62.
average cocoon yields in Jiangsu province of the late 1920s and early 30s at roughly less than 1 kg per gram of eggs. See Yue, Zhongguo, page 78 and Wang, Minguo, p.50.

<table>
<thead>
<tr>
<th></th>
<th>Japan</th>
<th>Lower Yangzi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Expansion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input (excluding summer and fall)</td>
<td>2 (42)</td>
<td>-</td>
</tr>
<tr>
<td>Intensification (summer and fall)</td>
<td>1.15 (21)</td>
<td>0</td>
</tr>
<tr>
<td>Total Factor Productivity</td>
<td>2.05 (37)</td>
<td>0.52</td>
</tr>
<tr>
<td>Cocoon Output</td>
<td>5.5</td>
<td>-</td>
</tr>
<tr>
<td>Raw Silk Exports</td>
<td>7.9</td>
<td>2.8</td>
</tr>
</tbody>
</table>

Notes:
1. For Japan, cocoon, raw silk data from LTES, vol.11, Table 57,61,63.
2. The 5.5% number is the Japanese cocoon growth rate adjusted by the silk yield. The growth rate without the quality adjustment is 5.2%.
3. For the Lower Yangzi, raw silk data from Xu, Zhongguo, pp.690-2.
Notes: The “Japan” and “Wuxi” series are for Japanese and the Lower-Yangzi cocoon prices in 100 kilograms. For sources, see Data Appendix. Wuxi(q) stands for the quality adjusted price series. The “Yokohama” and “Shanghai” series are for raw silk export prices in 10 kilograms from Japan and the Lower-Yangzi. The Shanghai series is from Chen, Zi-yu p.62 for 1896-1917, and Xu, pp. 692, 698 for 1917-1932. The Yokohama series is from *LTES*, vol. 11, p.296-7.

Source Notes: Diffusion figures for Japan were adapted from Kiyokawa, “Diffusion,” p.41, Figure 1. (A) includes all crops while (S) only includes spring crop. For China, see Benno, “Chugoku,” p. 43 and Wang, *Minguo*, p. 10, and 49, Eng, *Economic Imperialism*, p.136.
Data Appendix

I. Averages of Nominal Input and Cocoon Price Indices for Japan and the Lower-Yangzi

<table>
<thead>
<tr>
<th></th>
<th>The Lower-Yangzi</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Labor</td>
<td>Land</td>
</tr>
<tr>
<td>1901-09</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>1910-19</td>
<td>169</td>
<td>152</td>
</tr>
<tr>
<td>1920-28</td>
<td>220</td>
<td>197</td>
</tr>
</tbody>
</table>

Sources: for the Lower Yangzi, cocoon price in Wuxi: 1901-1920 From Ikawa, *Kindai Nihon*, Table 2, p.304-5, 1920-24 converted from Uehara, *Shina*, p.225. Data for 1925-27 unavailable, I projected it from the 1924 cocoon price level using the 1925-27 market price of raw silk. The 1927-29 cocoon price is from Gao and Yan, *Jindai*, pp.89-9. The market price of raw silk in Shanghai is from D. K. Lieu, *The Silk Industry of China*, (Shanghai-Hongkong-Singapore: Kelly and Walsh, Ltd.), Appendix, Table IV. The original 1912 price for fresh cocoon in Ikawa is 24, which seems implausibly low. I adjusted it to 28.5 using cocoon price in Chen, *Jindai*, p62. Farm wage index, land price index and farm animal price index in the Lower-Yangzi from John Buck, *Land Utilization in China*, (Nanjing: University of Nanking, 1937), Vol.3, Tables 5, p 151-2, Table 10-1, p.168, and Table 6, p.153. Soybean cake price is from Hsiao, *Foreign Trade*, p.80-81. There were no consistent long-term price series data for fertilizer and capital stock in the Lower Yangzi, I used the prices of bean cake and draft animal as proxy prices. None of these two inputs were used on a large scale in the Lower Yangzi and their inclusion could lead to possible biases in TFP. Considering their share is relatively small (12 and 18%), the biases may not be so serious and could potentially offset each other.

Japanese cocoon price, land price, current input and capital prices are from col.11 of Table 7, cols.3 and 13 of Table 34, col.6 of Table 31 in M. Umemura, S. Yamada, Y. Hayami, N. Takamatsu, M. Kumazaki, *Agriculture and Forestry, vol. 9, Estimates of Long-term Economic Statistics of Japan Since 1868. (LTES)* (Tokyo: Toyo Keizai Shinposha, 1966); Number in parenthesis indicates the earliest available data.

II. Lower Yangzi Silk Yield Data:

The following table from Uehara, p.225 is the Wuxi silk yield data in kilograms of dried cocoons required to produce 100 kilograms of raw silk:
Uehara also listed silk yields of three other sericultural districts in the Lower Yangzi. They all showed similar declining trend as in Wuxi.

Silk yield in the 1900s and the early 1910s were around 500. (See Minemura, p.148 for 1903, and Ootori, Kouhisa, *Shina Seijyou no Kenkyuu*, [Tokyo: Houbunsha, 1919], pp.177-8 for 1910). Various reports confirm that by the late 1920s and early 1930s, it had become a standard practice in the Lower-Yangzi to use 620 to 650 for cocoon silk conversion (Gao and Yan, p.75, Benno, p.32 and 43).

For computing the TFP, I used the Wuxi silk yield. For 1903 and 1910, I used the silk yield of 500. Linear interpolation is applied for the interval years between 1903 and 1916. For silk yields after 1924, the averages of 1920 through 1924 are used.

<table>
<thead>
<tr>
<th>Year</th>
<th>Before 1916</th>
<th>1916</th>
<th>1917</th>
<th>1918</th>
<th>1919</th>
<th>1920</th>
<th>1921</th>
<th>1922</th>
<th>1923</th>
<th>1924</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wuxi</td>
<td>520</td>
<td>550</td>
<td>510</td>
<td>560</td>
<td>620</td>
<td>600</td>
<td>670</td>
<td>590</td>
<td>680</td>
<td>620</td>
</tr>
</tbody>
</table>


4 The Lower Yangzi region, located in the central eastern part of China, consists of the provinces of Jiangsu, Zhejiang and Anhui. The average size of a sericultural farm in Japan was about 0.5 acre in the 1900s and 0.7 acre in the 1920s. For the Lower Yangzi, the average size was a little less than 0.5 acre in the early 1930s. For Japan, see Shoaburo Fujino, Shiro Fujino and Akira Ono, *Estimates of Long-Term Economic Statistics of Japan since 1868. (LTES)* vol.11 (Tokyo: Toyo Keizai Shinposha, 1979) p.151. For the Lower Yangzi, see Toua Kenkyujyo, *Keizai ni Kansuru Shina Kanko Chosa Houkokusho* (Investigative Report on Chinese Customs Related to Economic Activity) (Tokyo: Toa Kenkyuu Jyo, 1944), pp.26-8. In this study, I did not specifically include, another major export-oriented silk producing region, the Guangdong province in the southern China. The subtropical Guangdong reared the multivoltine type of silkworms that could hatch and spin cocoon 5 or 6 times in a year. The quality of Guangdong raw silk was inferior and possibilities for technological transferability from the temperate zones were also more limited.

6 For Japanese cocoon output data, see Fujino et al (n. 4 above) Table 57, Col.5. For the Lower Yangzi, see Eng, Y. Robert, *Economic Imperialism in China, Silk Production and Exports, 1861-1932*. (Berkeley: University of California Press, 1986), Table 2.7 on p. 35.


8 Uehara’s book (n. 7, above), totaling over 1000 pages, was an encyclopedic coverage of the Chinese silk sector, based on five years of travel through 18 provinces. For details on silk yield data by Uehara, see Data Appendix.

9 Federico did a primal input-output based TFP calculation for Japanese sericulture from about 1890 to 1929 using only land and labor as inputs. His estimate of annual TFP growth of 2.6% (for spring crop only), ignoring other inputs such as fertilizer and equipment that grew much faster than land and labor, represents an over-estimate. (Federico, n. 2, above, p.85). This lends further support to my 2.05% price dual TFP estimate based on a more complete coverage of inputs.


In the 1880s, Paul Brunat, the French silk reeling expert and entrepreneur who had helped found Japan’s large-scale government run Tomioka Silk Reeling plant in the 1870s, was the manager of a American-funded silk reeling plant in Shanghai. In 1886, when Li, Hongzhang, the leader of the Self-strengthening movement, visited his factory, Brunat made a direct appeal for the need of introducing microscopic examination in China. Brunat’s appeal, reported in the Shanghai newspapers but clearly ignored by Li and others, caught the attention of Japanese bureaucrats at the Ministry of Agriculture and Commerce who translated this news piece into Japanese. Alarmed by the potential possibility of silkworm disease in Japan, technicians at the Ministry conducted microscopic examinations on silkworms eggs in Japan - only to be shocked by the prevalence of disease already in Japan. This finding, according to these bureaucrats, was one important reason behind the promulgation of the Silkworm Disease Prevention Law in Japan in that year. See Dai Nippon Sanshi Kaihou (Report of the Sericultural Association of Japan), No. 178, March 20th 1907, p.39. Also see Kazuko Furuta “Kindai Seishikyou No Douryu to Kounan Shakai no Taiou” in Kindai Nihon to Ajia (Modern Japan and Asia) edited by Hirano Keniichirou, Tokyo: University of Tokyo Press, 2000. p.96.

This Chinese translation of this Italian sericulture book by Vincenzo Dandolo, can be found at the East Asia Library of the Hoover Institute at Stanford University. I thank Claudio Zanier for the information on Dandolo. For John Fryer, see Fairbank (n.10, above) Vol.10, part I, p.536. For the tradition of Japanese directly translating Chinese and Western works (especially in the Dutch Studies period in Tokugawa) and the contrasting tradition of Chinese intellectuals dependent on Western scholars’ oral interpretation of Western works in Ming and Qing, see chapter 8 of Tingjiu Li, Atsushi Yoshida, Zhongre Wenhua Jaoliu Shi Dashi: Keji Juan (History of Sino-Japan Cultural Exchange: Science), (Hangzhou: Zhejiang People’s Publishing, 1996).


It is worthwhile to note that Europe had for long sought East Asian sericultural technology whose global leadership may have been maintained as late as the eighteenth century. This European quest culminated in the publication of two translated works of Chinese and Japanese sericultural texts in 1837 and 1848. See Claudio Zanier, Where the Roads Met, East and West in the Silk Production Processes (17th-19th Century) (Kyoto: Italian School of East Asian Studies, 1994), pp. 71-94.

Lab tests confirmed that the F₁ variety shortened the rearing period, produced longer fibers, yielded fewer defective cocoons and were better suited to the demands of machine reeling. See Yukihiko Kiyokawa, Nihon No Keizai Hatten To Gijutsu Fukyu (Japanese Economic Development and Technological Diffusion), (Tokyo: Toyo Keizai Shimpousha, 1995), pp.91-92.

For a diffusion curve, see Kiyokawa (n.18, above). The diffusion of the F₁ variety led to the standardization of silkworm egg varieties used nationally, thus more uniform types of raw silk, a feature highly favored by the increasingly mechanized U.S. market. For the growing importance and eventual dominance of the U.S market for raw silk in the twentieth century, see Debin Ma, “The Modern Silk Road: the Global Raw-Silk Market, 1850-1930” Journal of Economic History (1996) Vol.56, No.2. pp.330-355.


For the cumulative improvements of the Lu mulberry trees in the Lower Yangzi over almost a millennium, see chapter 4 of Shichou zi Fu Huzhou yu Sichou Wenhua (Silk City Huzhou and Silk Culture) Fagen Ji (ed.) (Beijing: China International Brodcasting Publishing House, 1994). European sericulturalists had long learnt of and experimented with the “Lu” variety in Europe (which they named as the “Philippine variety”), see Zanier (n. 16, above), p. 74. Sasaki himself recalled that he owed his knowledge of the “Lu” tree to the works of Kaibara Ekiken (1630-1714), Tokugawa Japan’s foremost scholar on Confucius philosophy and Chinese botany. See Dai Nippon Sanshi Kaihou (Reports of the Sericultural Association of Japan), No. 176. 1907, p.24-26, Editorial Committee (n.12, above) Vol. 4, p.80. For the advantages of stem-pruning technique see Katsuhiko Ikawa, Kindai Nihon Seishigyo to Mayu Seisan (Modern Japanese Silk Reeling Industry and Cocoon Production), chapter 3, (Tokyo Economic Information, 1998).


Other commercial fertilizers used were fish cakes and later modern chemical fertilizer, see Ikawa (n.22, above),chapter 8 and Hayami and Yamada (n.21, above), chapter 4.

For soybean in the Lower Yangzi, see Adachi, Keiji, “Daizukasu Ryutsuu to Shindai no Shougyouteki Nougyo” (Distribution of Soybean cake and the Commercialization of Qing Agriculture) in Touyoushi Kenkyu, Vol. 37, No. 3, 1978, p. 35-63. For Japan’s internal transportation and distribution improvements and the activities of large Japanese shipping companies and trading houses, such as Mitsui and Mitsubishi in Manchuria, see Ikawa (n.22, above), chapter 8.

Data on the ratio of summer and fall crop in the 1880-89 are from Kiyokawa (n.17, above),pp. 60-2. The rest is from Fujino et al (n. 4, above), vol.11, cols. 6 & 7 of Table 57. The Lu type and its close relatives represented the single most important variety, accounting for one-fifth of mulberry acreage in Japan by 1920. Lu trees also crossed with other varieties and could use different names. Besides Lu, Meiji Japan introduced other varieties of mulberry from other
sericultural regions in China as well as other parts of the world that included Italy, India, and South America. By the 1910s and 1920s, the stem-pruned type of mulberry tree formed about 60% of all mulberry trees in Japan. By the 1920s, almost 70% of the mulberry fields in Japan could supply leaves for both the spring and fall crops in a year. See Editorial Committee (n. 12, above), vol.4, p.114 and p.105-113, Ikawa (n. 22, above), chapter 3 and Fujino et al (n.4, above), vol.11, p.155.

27 Ikawa (n.22, above), p.227-231.


29 The narrative so far is based on Ishii (n.11, above), p.397-405 and Masaki Nakabayashi, Masaki, “SeishiGyo no Hattatsu to Kansen Tetsudo” (Development of Silk Reeling and Main Rail Lines) in Mei ji no Sangyo Hatten to Shakai Shihon (edited by Naosuke Takamura) (Meiji Industrial Development and Social Capital) (Tokyo: Minerva, 1997).

30 Ishii (n.11, above), pp.423-9.

31 For the troubles of modern silk reeling factories in Shanghai, see Tommo Suzuki, (no.10, above), pp. 325-333. The fragility of private enterprise in nineteenth China can best be illustrated by the fate of an indigenous modern private silk reeling industry in rural Guangdong. The mechanized silk reeling factories, set up by a overseas Chinese merchant in 1872 grew rapidly within a few years but were met with riots from traditional silk weavers and subsequently ordered to close by the local magistrate. See Debin Ma (1998), “Europe, China and Japan: Transfer of Silk Reeling Technology in 1860-95” in Asia Pacific Dynamism 1550-2000, edited by A.J.H. Latham and Heita Kawakatsu, (London: Routledge Press, 1998).


33 Steamship companies were allowed to ply the Yangzi river and the coast under the treaty system, but not in the inner rivers or canals. The government did compromise in 1889 to grant the use of steamers in towing traditional boats in 1889. Suzuki (n.10, above), p.347.


36 See Chapter 4 of Lynda Bell’s One Industry, Two Chinas, Silk Filatures and Peasant-Family Production in Wuxi County, 1865-1937, (Stanford University Press, 1999); Suzuki (n.10, above), p.406; Soda (n.34, above), pp. 416-22.

37 Soda (n.34, above), pp.423-444 and Bell (n.36, above), p.79-80. The average metric tons of annual cocoons shipped from the sericultural regions in the Lower Yangzi to Shanghai in the period of 1900-09 were 9767. This number increased to 21303 tons for 1910-19 but only to 27152 tons for 1920-28. See Uehara (n. 7, above), pp.227-8 for 1913-28 and Akira Sitou, Shinkoku Sansigyou Ippan (An Examination of Chinese Silk Sector), (Tokyo: Raw Silk Inspection Bureau of Ministry of Agriculture and Commerce, 1911), pp.120-22 for 1898-1911.

38 For Qing’s fiscal system, see Wang, Yeh-chien, Land Tax in Imperial China, 1750-1911, (Harvard University Press, 1993). Bell (n. 36, above), p.83-87; Mann (n.33, above).

39 Bell (n.36, above), p.82 and Soda (n. 34, above), p.427. The cocoon hang system had a control of about 40 to 60% of all total cocoons sold in the Lower Yangtze. Federico (n. 2, above), pp.148-9.

40 There were systematic efforts by the farmers to mix inferior quality cocoons with better quality cocoons. See Li (n.1, above), p.185 and Soda (n.34, above), p.433-444.


42 Ishii (n. 11, above), pp.57-83 and p.429. Among the eight variables used in Kiyokawa’s probit regression, the Subcontractual Direct Purchase system was the leading variable in explaining the rapid diffusion of the F1 variety, (n.18, above), p.47.


44 In chapters 5 and 6 of Hayami and Yamada (n.21, above) conducted counter-factual statistical analysis on what the performance of Japanese agriculture would have been like had developments in commercial fertilizer and summer and fall crop not occurred. Had Hayami conducted a comparative study of China and Japan, he would have felt less need for his counter-factual exercise. The Lower-Yangzi sericulture unfortunately supplied exactly the factual side of the Hayami’s counter-factual of Japanese agriculture in the early twentieth century

It is important to note that the emergence of the Suwa district as Japan’s premium silk reeling production center was the spread of modern banking and other service facilities throughout Japan in the nineteenth century. See Ishii (n.11, above), chapter 2. For banking and service developments in Wuxi, see Chen (n.7, above), chapter 2 and Gao and Yan (n.28, above).

Susan Mann argued that tax-farming practices did not disappear but was taken over by specialized tax-farming agent, (n.34, above), chapter 9.

See Toua Kenkyujyo (n.4, above), pp.63-69, Gao and Yan (n.28, above), pp.305-8.


For cocoon output and raw silk exports, see Chen (n.7, above), p.109 and Okumura (n.49, above). For imports of Japanese silk reeling technology in Wuxi and Yongtai’s marketing activities in the U.S, see Gao and Yan (n.28, above), pp.325-9, 362-4. For Japanese investigators’ warnings of the Lower Yangzi competition in the 1930s, see Benno (n.49, above), p.32 and p. 39.


For a recent debate on this issue, see articles appeared in The Journal of Asian Studies 61, no. 2 (May 2002), pp. 501-663.