The Modern Silk Road: The Global Raw-Silk Market, 1850–1930

DEBIN MA

From the mid-nineteenth century, the raw-silk trade served as the most important trade linkage between the then still largely closed economies of East Asia and the industrialized West. This article traces the evolution of the global raw-silk market during the period 1850 through 1930. Using comprehensive data on raw-silk prices and quantities and applying co-integration techniques, I find a well-integrated global raw-silk market evolved during this period. This article also examines the evolution of technologies and institutions of the global silk industry, which exhibited characteristics of path dependency and technical interrelatedness.

Silk and its trade are almost as ancient as civilization. The lure of profits induced adventurous men to trek through unknown lands by foot and camel caravans. Centuries went by, towns, civilizations, and dynasties were formed, prospered, or perished, but the route that linked the continents of Europe and Asia survived and expanded, becoming known as the Silk Road. Traders also ventured to the open sea, carried by the wind along the shores of the South China Sea, the Indian Ocean, the Arabian Sea, and the Mediterranean. In the sixteenth and seventeenth centuries, the silk trade was extended to the Pacific Ocean, in particular, between China and the Spanish empire in Latin America. However, scholars' long-standing fascination with the ancient silk road stemmed, perhaps, less from its commercial aspect than from the important role it once played in the diffusion of culture, religion, technology, and institutions among the greatest civilizations.

The modern global silk trade began in about 1850 when East Asia regained its position as the world's major supplier of raw silk. During this period, silk was carried from East to West, reached the Mediterranean as the ancient silk road once did, and then crossed the Atlantic and arrived at the northeast coast of America, which witnessed the rise of the world's largest silk manufacturing industry. On the other side of the globe, silk from East Asia went farther eastward. During the 1870s, silk was brought to the west coast of the United States via the Pacific Ocean, then rerouted

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Debin Ma is a PhD Candidate, Department of Economics, University of North Carolina, Chapel Hill, NC 27599-3305.

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to the east coast by the transcontinental railway. Thus, the trade in silk finally completed a full circle around the globe.

This article focuses on the modern era, circa 1850 to 1930. It deals with raw silk only, the production of which involves two principal stages. The first is sericulture: the planting of mulberry trees and the raising of silkworms and silk cocoons. The second stage is silk reeling: the whole silk cocoons are boiled and softened in a water basin, so the silk threads can be drawn out and reeled (sometimes rereeled to enhance quality) onto a bobbin and later packed in skeins. Then several threads of raw silk (or reeled silk) are twisted together (or "thrown") to form a stronger thread for the weaver's loom. Raw silk is the single most important input for the finished silk product. Silk fabrics are used for a great variety of purposes, as dress goods, linings, ribbons, and as materials for shirts, ties, suits, underclothing, furniture coverings, and draperies.

The trading nations were divided between importers such as Britain, France, Germany, Switzerland, and later the United States and major exporters including Italy, China, and later Japan (which together consistently accounted for more than two-thirds of the world silk production and exports). During this period, raw silk became an important traded commodity. The aggregate value of world production and trade between 1927 and 1930 reached about 65 percent of the value of the wool trade and 30 percent of the value of the cotton trade. The exports of raw silk were crucial to the economic development of Italy, China, and Japan. The shares of raw silk in total exports hovered around 40 percent for Japan, about 30 percent for China, and 20 to 25 percent for Italy before World War I.

This article follows the tradition of market integration studies exemplified by D. McCloskey and Richard Zecher, and A. J. Latham and Larry Neal. However, the results of those studies, relying on the OLS regression technique and simple sample correlation of possibly nonstationary times series data, were questionable in light of what is now known as the spurious regression problem. This article adopts the co-integration technique to test for the degree of market integration. It also emphasizes that the world market development for raw silk saw not only the integration of the market for a traded commodity but also the integration of technology and institutions. Neither development can properly be examined separately. The remainder of the article will be divided into four sections, followed by a conclusion. The next two sections trace the origin, formation, and evolution of the global raw-silk market and report some results on the various forms of technological and institutional integration of the silk industries among the major trading countries. The article then examines the quantity and price trends of world production and exports between 1850 and 1930. The final section discusses the trends in market integration based on both historical evidence and a statistical test of co-integration.

THE ORIGINS OF THE MODERN GLOBAL SILK TRADE

Although sericulture in Mediterranean Europe only began to take firm root after the thirteenth century, silk weaving, in its early handicraft technology and institutions, dated back much earlier. In the modern era, the invention (1801) and improvement of the Jacquard loom revolutionized the manufacturing of silk in Europe. Great improvements were also made in the production of raw silk, with Italy and France at the forefront of technical innovations in sericulture and silk reeling. The adoption of steam filatures (mechanized silk reeling employing steam power) in the early nineteenth century made northern Italy and southern France the major producers and exporters of raw silk of sufficiently high quality to meet the manufacturing standards of Europe. Before the mid-nineteenth century, Europe relied largely on its own raw material supply, with limited imports coming from nearby Syria, Turkey, and later India and China. Although raw silk from sources outside Europe was cheaper, its low and variable quality characteristics as well as difficulties of transportation and communication remained obstacles to the effective use of non-European raw silk.

The situation began to change by the middle of the nineteenth century when the silkworm disease called pebrine, observed as early as the 1820s, started to spread, first slowly, then rapidly and devastated the sericultural crops in France and Italy. Beginning in 1855 the production of raw silk crumbled. In 1853 France produced 2,100 tons, the next year about 1,790 tons, but by 1855 production fell to around 600 tons. Before the disease, Italian raw silk production ran around 3,500 tons, but by 1863 it tumbled to 1,607 tons and reached only 826 tons in 1865, a decline of almost 75 percent. The disease also hit sericultural areas in Turkey and Syria. The short-fall of raw materials in the core supply center of Europe induced an intense search for new sources of supply.[1]

This was a period of increased export demand for European, particularly French, silk manufactures. The gap between the falling supply and the rising demand was made up by Asian raw silk imported through London. Britain, which failed to develop sericulture, had been importing limited amounts of raw silk from China from the eighteenth century on. Through these earlier trading experiences, in particular, through the opium trade with China, and later the establishment of the treaty port system after the

[1] This traumatic supply shock prompted immediate responses from the French government and the private sector. The famous biologist Louis Pasteur found that the disease was hereditary and could be overcome by proper selection of healthy breeds. Silkworm breeds of foreign origins, particularly the Japanese, which were more resistant to disease, were imported. By 1870 the indigenous European breed began to show signs of recovery. In particular, Italian raw-silk production experienced a vigorous recovery; output rebounded to 2,366 tons in 1873, reaching 3,000 tons in 1880 and 3,200 in 1883, almost 90 percent of its level before the disease. However, French raw-silk production never regained its previous level and stagnated around only a quarter of the pre-disease level. Cayez, *L'industrialisation*, p. 558–59.

opium wars of the 1840s and 1850s, Britain gained a dominant position in the East Asia trade.[2] France, the world's largest importer, had brought 16 percent to 18 percent of its total imports from Britain in the early 1850s. But by 1854 the import share from Britain rose to 34 percent, and by 1861 it surged to 48.8 percent.[3] This jump in French imports from Britain was also matched by the sharp increase in Chinese exports of raw silk to Britain. Between 1850 and 1860 Chinese exports to Britain more than quadrupled.[4] It is no exaggeration to claim that British Far East commerce spared the French and European silk manufacturers a major raw material supply crisis.

However, the dependence on British re-exports unnerved the French importers. Not only were British merchants deriving lucrative profits from the trade, but also the manufacturers in France lacked control over the reliability, type, and quality of the raw material. French government and business began making persistent efforts to bypass British intermediaries and establish direct access to China and Japan.[5] The French shipping giant, Messageries Maritimes, established the regular direct navigation service between Suez and Calcutta by 1862 and extended it to China and Japan by 1864. The opening up of the Suez Canal in 1869 and its successful full operation during the 1870s greatly reduced the voyage distance between Europe and the East, and in particular, shifted France closer to East Asia than Britain. The first direct imports from China appeared in French customs records in 1863 and from Japan in 1866. The direct imports from East Asia then grew quickly, gradually displacing re-exports from Britain and imports from Italy. By 1870 the Chinese and Japanese share in French total imports of raw silk reached about a third. Between the 1880s and the 1930s, a stable trading pattern evolved, with France taking more than half its imports of raw silk from China and Japan, and about 10 to 20 percent from Italy, while British re-exports continuously declined, dwindling to a negligible sum by the 1900s.[6]

In the nineteenth century trade between East and West brought together two worlds: traditional and modern. When European manufacturers turned to East Asia for the source of raw material supply, they also went back in time to economies still at the preindustrial stage. Sericulture was based on a long and continuous tradition handed down for generations; raw silk was hand-reeled domestically by the sericultural farmers or

[2] The treaty port system provided for the opening of numerous ports to Western diplomatic, commercial, and missionary personnel and recognized the extraterritorial rights of foreigners to be tried by their own consuls and under their own national laws. The system was later extended to Japan in a somewhat different form. Eng, *Economic Imperialism*, pp. 4–5.

[3] Cayez, *L'industrialisation*, p. 564.

[4] Shih, *Silk Industry*, p. 112.

[5] This process took much longer than expected, as the lack of direct personnel presence, trading houses, banking, finance, shipping service in East Asia, as well as the almost impenetrable British dominance, severely handicapped the initial French efforts. Cayez, *L'industrialisation*, pp. 567–80.

[6] Chen, *Silk Industry*, p. 13.

by the local cottage firms. Compared with Italian and French raw silk, East Asian raw silk tended to be marked by unevenness and irregularity. In the crisis period of the silk-worm disease, European manufacturers, particularly those of Lyons, undertook great efforts to fit their looms to the new types of raw material.[7] However, the need and opportunity to modernize raw-silk production in East Asia through transfer of technology and direct investment was quickly recognized. As the commodities flowed from the East to the West, the technology began to go in the opposite direction.

Most of these early efforts of technology and capital transfer concentrated on China, the world's largest exporter before the twentieth century. The treaty port system in China also provided foreign investors extraterritorial protection. From the 1860s onward, various modern mechanized silk-reeling firms and factories were established. Initially, numerous governmental and institutional barriers made the profitable operation of modern silk-reeling factories extremely difficult.[8] Over time, the number and scale of modern reeling factories gradually increased in major silk-producing regions in China, most notably in Canton. This is clearly indicated by the increasing share of machine-reeled silk in the total exports, which rose from virtually nothing in the 1870s to more than 50 percent by 1900 and over 90 percent after 1915.[9]

The silk-reeling industry was among the first activities to bring the modern factory system to China. However, the impact of modern science, technology, and institutions on the vast rural sericultural areas in China was limited and slow in coming. The traditional sericultural regions still produced raw silk on a domestic or cottage industry basis. It was usually the newly expanded regions whose sericulture was induced by the export boom of the 1860s and 1870s that tended to specialize in sericulture and sent their cocoons to the modern silk-reeling factories. However, as the farmers were no longer responsible for reeling silk from the cocoons, they paid less attention to the cocoons' quality. Due to the split between the rural and industrial sectors, and more importantly, due to the lack of scientific rationalization of farming practices and of effective quality inspection (as it existed later in Japan), the quality of silk cocoons did not improve significantly. In some instances, it may have declined.[10] The quality of Chinese raw silk did improve over time with increasing mecha-

[7] Much innovation took place in the thriving sector to better deal with East Asian raw silk. The Lyon silk manufacturers responded to the raw-materials crisis by increasing production of mixture goods by combining silk with cotton and wool. In addition, they improved dyeing and printing techniques that increased the weight of the precious raw silk and allowed the creation of styles based on vivid colors rather than intricate weaves. Piore and Sabel, *Second Industrial Divide*, p. 36.

[8] In Shanghai the powerful British trading house, Jardine, Matheson & Co., and the Italian Russell & Co. were the pioneers, to be followed by French, German, and U.S. companies later in the century. In 1881 the first silk-reeling factory with exclusively Chinese capital was set up in Shanghai, using technology and machines introduced from Italy and France. Chen, *Silk Industry*, p. 16.

[9] Li, *China's Silk Trade*, pp. 78–81.

[10] Li, "Silk Export."

nization but did not catch up with that of France and Italy. Nonetheless, the introduction and integration of western technologies and institutions were important in maintaining China's position as the world's foremost supplier of raw silk before the twentieth century. The reemergence and dominance of East Asia in the global raw-silk market in many ways symbolizes the historical revival of the traditional Silk Road in the context of transportation and communication of the latter part of the nineteenth century. Silk again flowed from the East to the West, linking the two farthest ends of the Eurasian continent.

THE RISE OF THE U.S. SILK INDUSTRY AND THE SHIFT TOWARDS THE PACIFIC

As Europeans sailed east half way around the globe for raw materials, the silk-manufacturing technology was spreading west and crossed the Atlantic. If the protective tariff provided the U.S. silk industry an initial impetus, it was the continuous technological diffusion and innovation that brought sustained growth to the industry.[11] Diffusion of silk-manufacturing technology from Europe to the United States initially took its traditional form: the migration of European skilled workers and entrepreneurs. In 1860 about one-fourth of the entire silk work force in Paterson, New Jersey, the major silk manufacturing center of the United States, was English born. This phenomenon was mirrored elsewhere in other northeastern industrial centers.[12] Management and supervisory personnel acquired education in the textile schools of France, Switzerland, and Germany.[13] The first silk-working machinery was also imported, mainly from England. The industry began by following the European tradition.

However, towards the end of the nineteenth century, a unique U.S. silk-manufacturing technology, quite distinct from the European, especially the French industry, was clearly emerging. The most notable difference was the early and widespread adoption of the power loom in the United States. Table 1 gives the numbers of power and hand looms in Europe and the United States in 1900. Five years later, hand looms virtually disappeared from the United States. Moreover, the American-style power looms also tended to be larger, faster, more labor-saving, and with a higher degree of automation than the European ones.[14] The development of the U.S. machine-tool industry, in particular, the parallel growth of the machine shops in Paterson, New Jersey, as well as the increased use of unskilled immigrant, female, and child labor greatly

[11] The U.S. *ad valorem* tariffs on finished silk goods imports reached 60 percent in 1864. The rate was kept around 40 to 50 percent into the twentieth century. For the details of the tariff and its impact on the development of the U.S. silk industry, see discussions in Taussig, *Some Aspects*; and U.S. Tariff Commission, *Broad-Silk Manufacture*.

[12] Margrave, "Technology Diffusion," p. 10.

[13] Allen, *Silk Industry*, p. 25.

[14] Taussig, *Some Aspects*, chap. 15.

TABLE 1
NUMBER OF POWER AND HAND LOOMS IN EUROPE AND THE UNITED STATES IN 1900

Country	Power Looms	Hand Looms
France	30,600	60,000
Switzerland	13,300	19,500
Crefeld (Germany)	9,500	6,900
Italy	8,500	11,000
United States	44,257	173

Source: Taussig, *Some Aspects*, pp. 232, 235.

facilitated the rise of the large-scale production of standardized products in the U.S. silk industry.[15] The unified national market and the rising consumer income in the late nineteenth-century United States formed a taste for textile products that were cheap, dressy, and standardized. The consumption of silk goods, once luxurious products, became, to use F. W. Taussig's term, "democratized."

The expansion of the U.S. silk industry was extremely vigorous. The number of establishments increased from 67 in 1850 to 483 by 1900, spreading from New England to the Middle Atlantic States. More than one hundred thousand men, women, and children were on the payrolls of the silk industry in 1900, making it the third largest sector within domestic textiles.[16] By the early 1910s, the U.S. silk industry surpassed the French to become the world's largest. Before 1880 European imports dominated U.S. consumption demand for finished silk products (see Table 2). By the beginning of twentieth century, U.S. manufacturers had displaced Euro-

TABLE 2
COMPARISON OF U.S. DOMESTIC PRODUCT AND IMPORTS OF SILK, 1870–1910

Year	U.S. Silk Product ($ millions)	Imports ($ millions)	Percentage of Imports to Domestic Product
1870	10.00	38.7	387
1880	34.50	50.1	145
1890	69.10	59.9	86
1900	92.40	42.9	46
1905	118.50	45.2	38
1910	171.60	53	30

Source: Taussig, *Some Aspects*, p. 222.

[15] By the last decade of the nineteenth century, all the more important silk machinery was made within the United States, except for certain specialties. U.S. silk machines were also later exported to or copied in foreign countries. Taussig, *Some Aspects*, pp. 252–53.

[16] Allen, "Silk Manufactures," p. 210.

pean imports in all but the costliest fabrics, fashionable novelties, church vestments, and specialty items not suitable for mechanical weaving.[17] After the 1910s, there was an increase of imports of East Asian silk fabrics, mainly habutae and pongee, which were cheap, light-weight, and usually woven on hand looms.[18]

In contrast to the rise of the U.S. silk industry was the relative decline of the European, in particular, the French silk industry after the beginning of the twentieth century. Silk weavers in Lyon held unquestionable world leadership in pattern designing and sophisticated weaving. The unrivaled status of the Parisian decorative arts continued to supply impulse and inspiration to the Lyonese; their designs and patterns were copied, studied, and emulated around the Western world.[19] Taussig noted the contrasting characteristics of the U.S. and French silk industry:

> In France, which had so long been the leading silk manufacturing country, the industry clings even more to the old ways. The number of hand looms is about double the number of power looms; the domestic weaver holds his place. French silks, especially those made for the export trade, are of high quality. They depend for their sustained superiority on excellence of pattern and perfection of make. The cheap every day silks, turned out in great quantities of one pattern, are characteristic of the machine industry of other countries, especially of the United States. Limited patterns and sterling quality, catering to the well-to-do and the rich, are the typical products of the French industry; and these are precisely the traditional characteristics of the silk manufacture as it was before the machine began to invade it.[20]

Over time, the introduction of machines and standardized products gradually eroded the position of the French weavers. Progress in machinery undermined the superiority of the craftsman. From 1870 to 1900, the absolute value of French exports of silk products to the rest of the world fell by almost one half, with its export of low- and medium-grade goods affected most dramatically.[21] The changed positions of U.S. and French silk manufacturing, as it turned out, exerted a far-reaching impact on the direction and integration of the global raw-silk market.

The successful "import substitution" experience of the U.S. silk-manufacturing industry did not extend to the case of sericulture. Repeated attempts at fostering sericulture in the North American continent, extending back to colonial times, faltered due to labor scarcity and lack of sericultural tradition. The U.S. silk industry had to rely on the same raw

[17] Allen, *Silk Industry*, p. 30.

[18] U.S. Tariff Commission, *Broad-Silk Manufacture*, pp. 113, 121.

[19] Allen, *Silk Industry*, pp. 44–45.

[20] Taussig, *Some Aspects*, p. 237.

[21] Allen, *Silk Industry*, pp. 43–45. The Lyonese silk manufacturers also managed, with some success, to respond to the challenges posed by the low-cost U.S. and other European silk producers. Their early innovativeness in adapting their manufacturing to the "raw silk famine" of the 1850s and 1860s set them onto a somewhat different technological path in their use of raw materials. To reduce cost, they produced a higher percentage of mixed silk goods than the United States and pioneered the use of artificial silk fibres. This partly explains their relative decline, in relation to the U.S. silk industry, in final demand for raw silk in the twentieth century. Piore and Sabel, *Second Industrial Divide*, p. 36.

TABLE 3
COMPARISON OF U.S. AND FRENCH CONSUMPTION SHARES OF WORLD RAW SILK, 1874–1937
(percentage)

Years	United States	France
1874	4	58
1907–1910 (average)	36	19
1910–1919 (average)	52	17
1920–1929 (average)	57	11
1930–1937 (average)	58	5

Source: Xu, *Modern History*, appendix 11, pp. 639–40.

materials sources as its European counterparts. Since most of the growth of the American silk industry came after the 1860s, the imports of raw silk from East Asia formed a large share of raw materials early on. In particular, in the development of the modern raw-silk trade, the direct shipments of raw silk from China and Japan across the Pacific to the West Coast proved to be as much a major turning point as was the opening of the Suez Canal for the French silk trade with East Asia. Raw silk began to arrive at San Francisco in 1867, after the establishment of the China line of the Pacific Mail Steam Ship Co., and regular monthly shipments to the East Coast were made after the completion of the transcontinental railroads to the Pacific in 1869.[22] Compared with other commodities, raw silk was a high-value, low-weight item, a large portion of which was routed overland from the Pacific coast by the so-called special silk trains to the silk manufacturers on the northeast coast.

The growth of the U.S. silk industry stimulated a demand boom for raw-silk imports. In 1900 raw-silk imports into the United States were more than ten times their level in 1870.[23] In that same year the United States also became the world's number one raw-silk importer, taking in almost a quarter of the total world raw-silk trade. The increase in imports came mainly from China and Japan. Their exports made up between 60 and 80 percent of U.S. imports between the mid 1870s and the 1890s. This trend continued into the twentieth century, with the U.S. consumption of world raw silk taking an ever increasing share.[24] In contrast, the French share of world raw-silk consumption declined continuously in the twentieth century. Table 3 compares the percentage share of U.S. and French consumption of raw silk in total world production. World War I wrought further destruction to the European raw-silk industry. It was clear that the

[22] Brocket, *Silk Industry*, pp. 208–09.

[23] U.S. Bureau of the Census, *Statistical Abstract*, p. 780.

[24] Xu, *Modern History*, p. 110. The opening of the Panama canal in 1913 further tightened the links of the two coasts of the United States and effectively reduced freight of the silk trade after the 1920s.

twentieth century saw the bulk of the world's raw silk traded carried along the Pacific route.[25]

THE DOMINANCE OF JAPAN IN THE WORLD RAW-SILK MARKET

The twentieth century witnessed the spectacular rise of Japanese raw-silk exports. Between 1909 and 1924 more than one-half of U.S. raw-silk imports came from Japan, and that proportion tended to increase. After 1912 it was larger than two-thirds, and after 1916 larger than seven-tenths. U.S. imports from China also increased absolutely though their share showed little change, but imports from France and Italy declined absolutely.[26] From the mid-1920s to the late 1930s, the stage of the world raw-silk trade almost became a one-country show: the share of Japanese exports of raw silk in total world trade during this period surged from about 75 percent to close to 90 percent.[27] This can be seen most clearly in Figure 1. The extraordinary growth of world raw-silk exports in the twentieth century came mainly from Japan, particularly after the 1920s. Most of the Japanese exports were absorbed by the ever-expanding U.S. market.

The widespread use of fast-moving power looms compelled U.S. silk manufacturers to use raw silk that was very even and uniform in quality and coarse in size. The point is well illustrated by Taussig:

> The irregularity of the raw silk fibre is ... an obstacle to its manipulation by power-driven machinery. Spindles and looms can be adjusted to the most tenuous threads, so long as they are homogeneous. No doubt the finer grades of goods always remain less easily subjected to rapid machinery; but as long as the material is even, the possibilities of delicate balance and adjustment are astonishing. Irregularities, however, always mean breakage, stoppage, loss of time, incomplete utilization of plant; they mean, also greater need of specialized skill on the part of the individual operative. Hence the American manufacturers sought to secure supplies of uniform raw silk.[28]

Knowledge of the nature of U.S. demand is crucial in explaining the rise of the Japanese raw-silk industry.

In the mid-nineteenth century, compared with China and Italy, Japan

[25] The silk trade had been extended to the Pacific for centuries. The triangular trade (Acapulco-Manila-Canton) between China, Philippines, and Spanish America existed on a quite substantial scale from the mid-sixteenth century (Li, *China's Silk Trade*, p. 64). However, three centuries later, the center of the Pacific silk trade gradually rotated northward. With the opening of China, the center of Chinese silk exports moved from Canton to Shanghai. With the rise of Japanese raw-silk exports, the bulk of the East Asian raw-silk trade gravitated north and east towards the cities of Yokohama and Kobe. Silk also departed for different destinations on the other side of the Pacific. It still went to the American continent, but towards the part of North America founded and inhabited largely by the descendants of immigrants from the Northwestern parts of Europe. The northward shift of the silk trade mirrors an emerging world economic order which had evolved over centuries, but accelerated from the latter part of the nineteenth century, a structure that is still very much with us today.

[26] U.S. Tariff Commission, *Broad Silk-Manufacture*, p. 55.

[27] Commodity Research Bureau, *Commodity Year Book*, p. 238.

[28] Taussig, *Some Aspects*, p. 233.

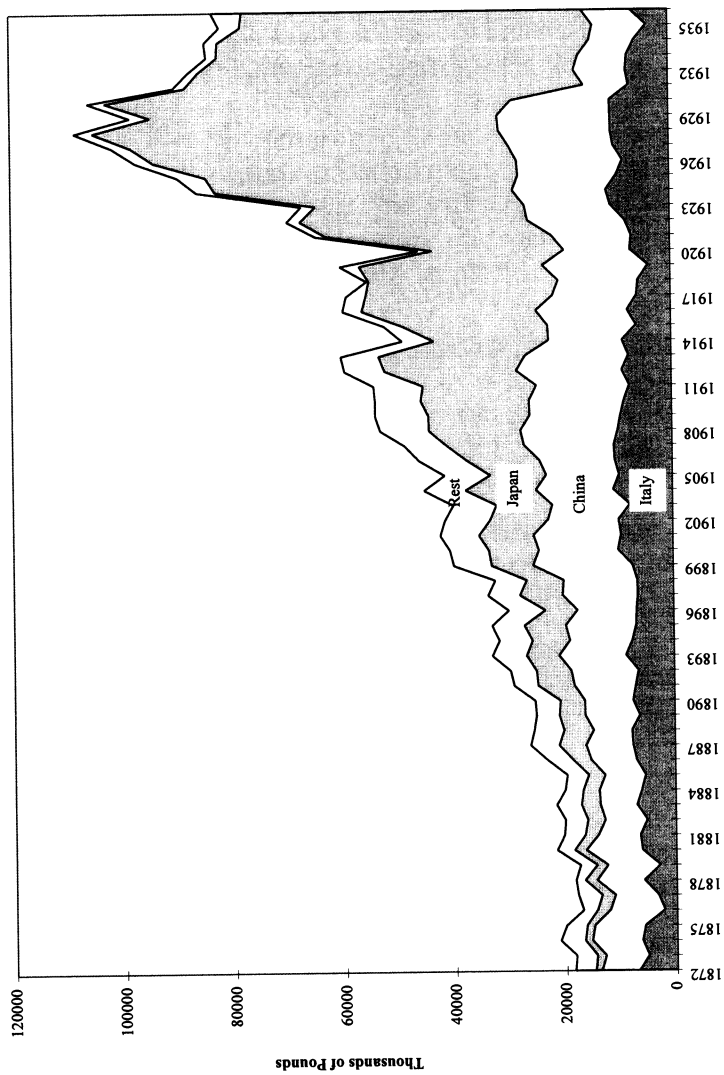

FIGURE 1

WORLD PRODUCTION AND EXPORTS OF RAW SILK: 1872–1936

Notes: The figures for China and Japan include only export quantities. Rest refers to production and exports by countries other than the three countries listed.
Source: World production and exports are based on France, Ministere du Travail et de la Prevoyance Sociale, *Annuaire Statistique*.

was a late-comer in the world raw-silk market. The enlightened Meiji government took the initiative to modernize Japanese raw-silk production. In 1872 they established a government-sponsored and financed modern silk-reeling factory, the Tomioka plant, which brought in experts and machines from France. Later, private firms also set up modern steam filatures. Machine-reeled silk began to displace *Zakuri* silk (the Japanese raw silk using the traditional method of reeling), which made up less than half of the total raw silk output by 1894.[29] A major breakthrough in the rural sector occured with the development of the summer-fall rearing technology, which shifted production away from period of peak labor demand in rice.[30] But before 1900 the Japanese raw-silk industry did not have obvious technological advantages over its competitors, and the silk-reeling technology was less advanced than in China.[31]

In the early twentieth century, the superiority of the Japanese raw-silk industry clearly emerged. In the mid-1910s the combination of modern genetic science with Japan's strong indigenous tradition of biological innovation in sericulture resulted in the discovery of the F_1 hybrid silkworm.[32] The extremely rapid diffusion of the superior hybrid increased the competitiveness of the Japanese raw-silk industry in at least two ways. First, Japanese silk-reeling filatures had long maintained that the production of so many different kinds of cocoons was the greatest single cause of the uneven quality of raw silk. The widespread diffusion of a superior F_1 hybrid, with its easier reelability for the machine, helped effectively standardize the variety. Second, the F_1 hybrid contributed significantly to the productivity increase in Japanese sericulture enabling Japanese farmers to supply high quality cocoons at a lower cost than their Italian and Chinese counterparts.[33] Japanese rural dynamics, coupled with the effective diffusion network and centralized quality inspection system, formed the very foundation of the success of the Japanese raw-silk industry.

The high-quality cocoons also expanded the potential for technical innovation in the silk-reeling sector. Adapting borrowed technologies to domestic factor conditions, the Japanese silk-reeling sector experienced accelerated productivity growth, particularly after World War I. Among the key improvements were the finer control of water temperature in the boiling of cocoons, which made the cocoons more uniformly softened and easier to reel, the transition from the use of wooden reeling machines to

[29] Ono, "Technical Progress," p. 1.

[30] Traditionally, spring—April to June—was the period of cocoon culture. However, this period coincided with the peak of the labor requirement for rice production. The development of summer-fall rear technology enabled effective utilization of farm family labor underemployed during the slack months of rice production. See Hayami and Sabura, *Agricultural Development*, chap. 6.

[31] Molteni, "Development," p. 744.

[32] The F_1 hybrid was a product of the so-called experimental station technology era in Japan. Meticulous experiments in the national lab stations proved that the F_1 hybrid was superior to the different indigenous varieties in major categories of comparison. See Kiyokawa, "Diffusion."

[33] Eng, *Economic Imperialism*, p. 172.

those made both of wood and iron and later of iron alone, the increasing use of steam power and electricity, and the introduction and diffusion of reeling machines with multiple spools per basin (which brought about a partial automation of the working process). By the 1920s and 1930s, the Japanese silk-reeling industry was among the most technologically advanced in the world.[34]

The parallel growth of the Japanese raw-silk industry and U.S. silk manufacture in the twentieth century was no coincidence. It was the consequence of market integration of commodities, technologies, and institutions. It was a process characterized by mutual adaptation, by technological complementarity, or in this case, by a bilateral "technical interrelatedness." In a larger sense, for Japan and the United States, it was the integration of two systems of production and the integration of Pacific economies. The persistence of hand looms in French weaving and the related demand for raw silk further illuminates this point of bilateral technical interrelatedness. Writing in 1904, Franklin Allen found there were two commercial reasons why hand looms continued in such considerable use, despite the perfection that power loom weaving had attained. The first was the possibility of using finer sizes and cheaper grades of silk on hand looms. The more uneven and less elastic raw silks and the inferior grades of waste silk carried a lower price than the better grades, and required a slower manipulation than was possible on the power loom. Second was the fact that the highest class and most expensive productions known to the industry were possible only on the hand loom. Weaves of highly complicated design, and great variety of materials, required very slow production and the most skillful operatives. France, and especially Lyons, had always been renowned for these productions.[35] Were Allen right, we would expect that low-priced Chinese silk would do fairly well in the French market even in the twentieth century. This turned out to be exactly the case. Japanese raw silk never dominated the French market as it did in the United States. For example, in 1920 the Chinese share in

[34] Molteni, "Development"; and Ono, "Technical Progress." During this period, Japanese-style silk-reeling machines began to be exported to and copied by the Chinese silk-reeling industry (Xu, *Modern History*, p. 202). The productivity improvement can further be confirmed by the quantity and price data in Figures 1 and 3. Figure 1 shows that exports of Japanese raw silk grew gradually before the twentieth century, overtaking China as the world's largest exporter around 1910 and dominating the world raw-silk market after the 1920s. Price data in Figure 3 clearly indicate that the relative price gap between the high-quality Italian raw silk and Japanese silk narrowed over the decades and almost converged after the 1920s. These data yield a consistent picture of the rising quality and the improving competitive position of Japanese raw silk exports.

Historians and economists have long been interested in the differential development paths of the Japanese and Chinese raw-silk industry. Undoubtedly, political factors, the role of the government, the development of banking and finance and other factors had all contributed significantly to the rise of the Japanese raw-silk industry and the relative stagnation of the Chinese silk industry. This article focuses on the technological aspect. For discussions of these various factors, see Eng, *Economic Imperialism*; and Li, *China's Silk Trade* and "Silk Export."

[35] Allen, *Silk Industry*, p. 28.

French raw silk imports was still 47 percent, compared to the 27 percent Japanese share.[36]

WORLD PRODUCTION, OUTPUT, AND PRICE TRENDS

Figure 2 shows U.S. annual average import prices of Italian raw silk (both nominal and real) from 1840 to 1937. This price series can serve as a proxy for the general world price trend of raw silk given that the world raw-silk prices were highly correlated (the results of a co-integration test described in the next section show that this condition was met). We can break down the price series into three periods. The first period was between 1840 and 1880, when the nominal price exhibited much higher volatility than in later periods; its average level, however, remained roughly constant. The volatility could be explained by the frequent supply and demand shocks: the damage to European sericulture by the silkworm disease; the chaos and destruction created by the Taiping Rebellion in China, which reached its climax between 1860 and 1863; the U.S. Civil War, which brought general inflation to the United States. Between the later 1870s and 1914, nominal price variations were much smoother, and the price showed a continuously declining trend at an average annual rate of a little less than 1 percent. This so called gold-standard era coincided with the expansion of the direct trade of raw silk between East Asia and Europe and the United States. The much more diversified sources of supply and the competition among silk traders in Milan, Shanghai, Canton, and Yokohama effectively stabilized silk prices, reducing their variation. Continuous expansion of inputs, productivity increases, and the improvements in world transportation and communication all led to the gradual downward price trend both in real and nominal terms. The final period began when nominal prices shot up between 1917 and 1919, with most countries departing from the gold standard and European powers deeply engulfed by World War I. Inflation, coupled with demand and supply-side shocks caused by the war and its aftermath, induced wide swings in nominal prices of silk throughout the 1920s. When the Great Depression set in and worldwide commodity markets collapsed in the late 1920s and the early 1930s, silk prices dove to their historical low (the 1935 price was only one-fifth of the level of predepression years, say 1926 or 1927). Between 1930 and 1937, nominal prices of silk slid downward at 4 percent on average per annum.

From the 1870s to 1937, while real prices of raw silk declined at an annual rate of a little less than 1 percent, world production and exports of raw silk, according to Figure 1, displayed a steady upward trend. Within a span of more than 60 years, they increased by almost five times (from about 18.5 million pounds in early 1872 to about 105.8 million pounds in

[36] Eng, *Economic Imperialism*, fig. 7.2, p. 168.

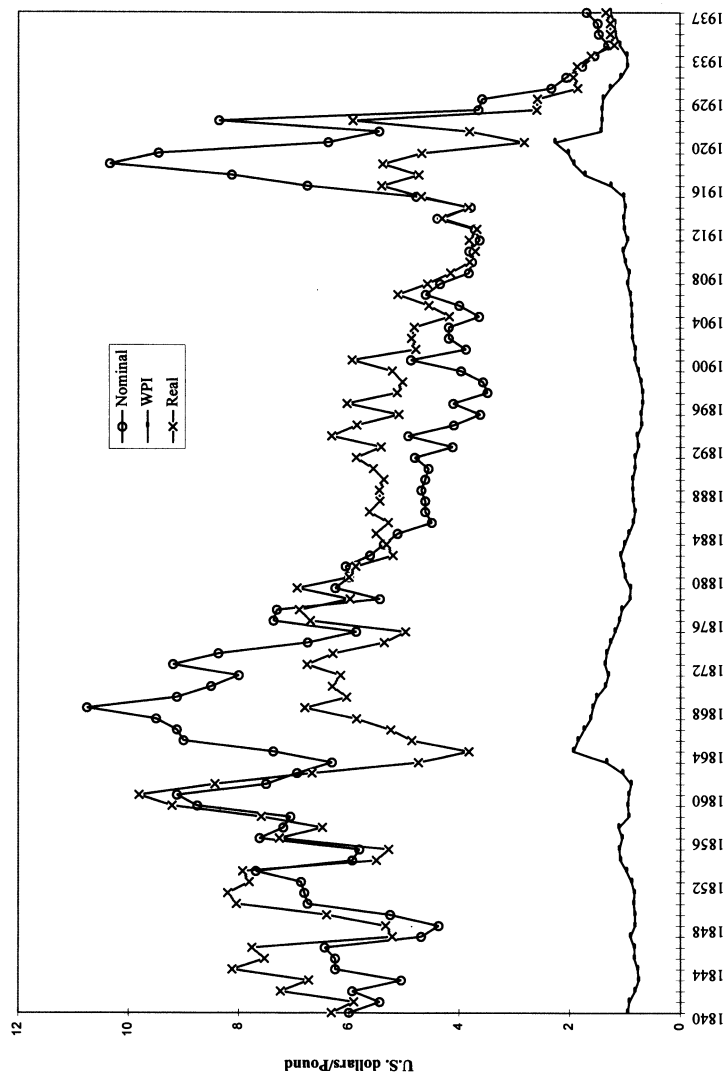

FIGURE 2

NOMINAL AND REAL PRICES OF U.S. RAW SILK
(U.S. dollars per pound)

Note: The real price is equal to the nominal price divided by the wholesale price index.
Sources: Nominal U.S. import price of raw silk is based on Commodity Research Bureau, Inc., *Commodity*; and Fujino, et al., *Estimates*. U.S. wholesale price index is from Mitchell, *International Historical Statistics: The Americas*.

1930). For Japan, the increase during this period was pronounced, at an average annual rate of between 6 and 8 percent. Since the output figures are measured in weight (pounds), this growth rate is an underestimate, with no consideration being given to quality and grade improvements. With annual raw-silk output growing at about 3 percent and real price decreasing at about 1 percent annually, supply curves must have shifted farther than demand curves during this period. Raw silk became one of the fastest growing commodities in the twentieth century.[37]

Output did fluctuate, particularly during World War I. The Great Depression sent both the prices and the output of raw silk into a downward spiral. Silk production and trade never fully recovered after the Depression. One of the major reasons was the rise of synthetic substitutes: rayon and later nylon. Rayon was first discovered in France in the late nineteenth century. After numerous technical improvements, it began to assume importance during the later 1920s. By 1929 the world output of rayon reached 430 million pounds. Although it took almost five decades for world raw-silk production and export to quintuple, it would only take rayon eight years (between 1929 and 1937) to triple its volume.[38] The rise of a close substitute, at a price only about one-third of that of raw silk, gave the demand curve for a silk a near fatal inward push.

GLOBAL MARKET INTEGRATION OF RAW SILK

The period of about 20 years following 1865 saw a veritable revolution in intercontinental transport and communications. The application of steam ships to transoceanic shipping, the opening of the Suez Canal, the diffusion of the transcontinental telegraph, and the improvements in sea charts all effectively reduced the barriers and distance in international trade. Many researchers have used the market-integration approach to test the degree and magnitude of the linkages of the world economy via international trade during this period.[39] Such an approach comes down to a dynamic test of the law of one price in international trade theory. The idea is that a traded commodity, measured in a common currency, net of transportation and transaction costs, should fetch the same price in different but integrated markets. Prices in different markets should move in unison and within certain narrow bands of import and export points, as any significant divergence would allow arbitraging opportunities. Presumably, an efficient, integrated market would quickly and fully exploit these opportunities. Price and the price mechanism, adopting F. A. Hayek's sense of the word, can thus be understood as a means of efficient information transmission. If the world is truly linked through trade, then

[37] Royal Institute, *World Agriculture*, p. 30.

[38] Bacon and Schloemer, *World Trade*, p. 467.

[39] McCloskey and Zecher, "How the Gold Standard Worked" and "Success"; and Latham, "International Market."

large supply and demand shocks in a single area would be transmitted to the rest of the world through the prices of traded goods. The degree of price co-movement over time would give us a measure of how effective a role price played in transmitting signals.

There were both favorable and unfavorable factors in the silk market for the achievement of a single price during this period. There were three unfavorable ones. First, the major trading countries spanned three continents, with very different socio-economic and institutional backgrounds and trading practices, which may affect the price adjustment process of raw silk. Second, although most Western countries, such as Britain, France, Italy, and the United States adopted the gold standard during the latter part of the nineteenth century, Japan was on a silver standard until 1897, and China was on silver with fluctuating exchange rates throughout the whole period. The strength of price correlation could be weakened simply due to exchange rate noise. Third, raw silk produced in different countries was usually of different grades and possessed varying quality characteristics for different end uses. The degree of substitutability and complementarity sometimes was uncertain. Prices of raw silk may have failed to move together closely due to product differences. These factors would likely add statistical noise to the test of the law of one price.

On the other hand, three features of the raw silk trade make a strong case for testing the market-integration hypothesis. Compared with most of the commodities traded at this time, raw silk was a high-valued item. In terms of unit weight price, for example, raw silk was about 50 times the value of cotton, hemp, or coffee. The high investment in the raw-silk trade led to shorter trade cycles and encouraged the use of reliable and rapid transportation methods, such as the fast steamer and "silk trains." Transportation costs for raw silk formed a small percentage of its total value (between 1 to 5 percent), contributing to the close integration of the silk market. Second, raw silk was also one of the most commercialized and export-oriented commodities. Fifty nine percent of raw silk produced in the late 1920s was exported, the second highest percentage (next to coffee) among the 20 major commodities traded at the time.[40] Global market factors exerted a large impact on the raw silk trade. Lastly, unlike grain, raw silk was not considered by most countries as an essential commodity and was imported as a raw material for manufacture. Few tariffs existed, and those that did were eventually abolished.[41] These factors, perhaps unique to raw silk, make it a strong test case for market integration.

Descriptive evidence on the evolution of a well-integrated global silk market during this period is plentiful in government publications, consular reports, and trade and industrial journals. The annual reports published by the Silk Association of America in the United States since the 1870s

[40] Royal Institute, *World Agriculture*, p. 6.
[41] Taussig, *Some Aspects*, p. 222.

contain special sections on world raw-silk production and trade. Covering a span of almost 60 years, these reports record information on world sericultural crops, raw-silk quantities and quality, trade stocks and flows, price adjustment lags, and technological and institutional development with increasing specificity, sophistication, and speediness with the passing of time. Perhaps the strongest statement in support of the law of one price comes from the U.S. Tariff Commission report of 1926:

> that the domestic [U.S.] industry obtains its raw silk on substantially equal terms with other countries, including the countries of production, ... Prices in New York ordinarily differ by only about the cost of transportation and insurance, etc., from those prevailing in Yokohama, Shanghai, Canton, and Milan, and the total of such costs for a commodity of such high value in small bulk generally forms but 1.5 to 2 per cent of the total cost to American manufacturers.[42]

Conventional tests of market integration typically posit an equilibrium relationship between two markets in which price changes in one market are reflected by equilibrating changes in the other market. If we hypothesize that global raw-silk markets were well integrated, we would expect that, although individual nominal price series of raw silk in different markets might be drifting apart without reverting to a stationary mean value, a long-run equilibrium relationship due to the forces of market integration would tie together or co-integrate the movements of these price series. The co-integration method is particularly useful for testing the law of one price because many nominal price series exhibit some unit-root characteristics. One of its most attractive features is the use of traditional OLS regression on levels of nonstationary time series price data (rather than differenced) with some changes in statistical interpretation. However, such regressions (on levels of nonstationary variables) are meaningful if and only if these variables are co-integrated. Therefore, the co-integration method provides an effective way of distinguishing meaningful regression from the so called spurious regressions.[43]

Figure 3 illustrates the logs of five nominal price series of raw silk from 1868 to 1937. They are the French import price of Chinese silk, the U.S. import price of Italian silk, the Chinese export price of hand-reeled silk, and the Japanese export prices, and Italian export prices. All the prices were collected from different independent sources.[44]

In the first step, I performed a Dickey-Fuller unit-root test on each of the five price series and detected the presence of a single unit root.[45] The

[42] U.S. Tariff Commission, *Broad-Silk Manufacture*, p. 56.

[43] For methodology and tests on co-integration and spurious regression, see Banerjee et al, *Co-integration*.

[44] For the data source and exchange-rate conversion methods, see source notes for Figure 3, which gives a plot of the five price series.

[45] The unit-root tests are performed with a linear time trend. They are not presented here but are available from the author on request. I have applied the Box-Jenkins test to check for residual autocorrelation in the error term. In every case, the error terms turn out to be white noise. Therefore, I used the Dickey-Fuller test instead of the Augmented Dickey-Fuller test. I find this holds for all other

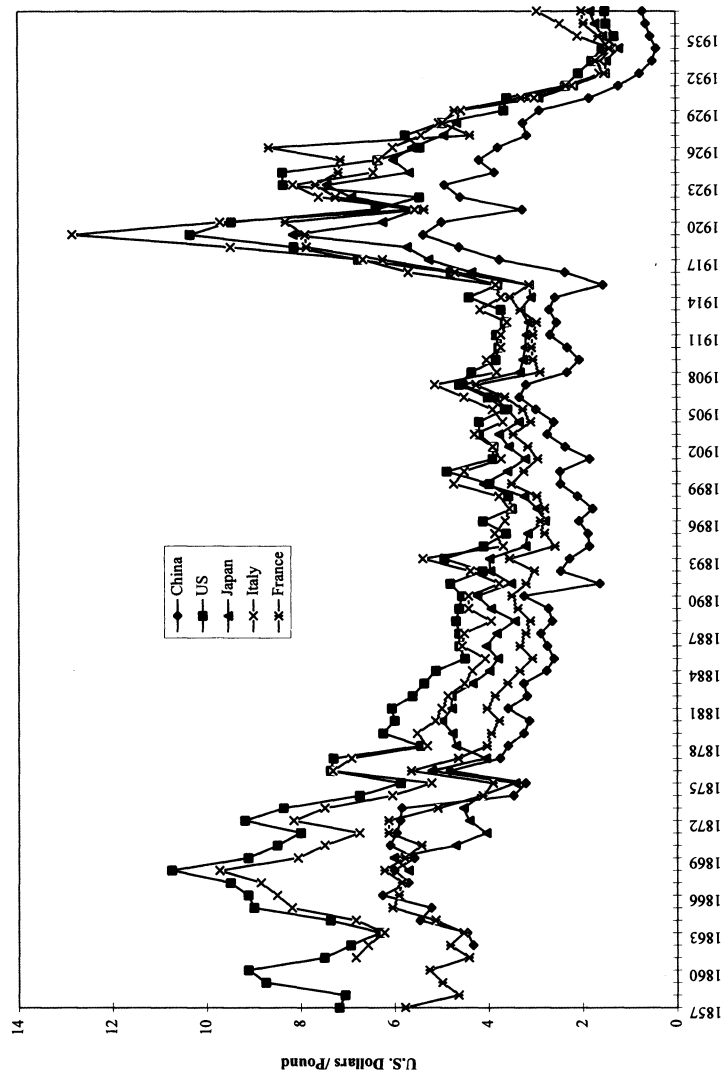

FIGURE 3

NOMINAL PRICES OF WORLD RAW SILK
(U.S. DOLLARS PER POUND)

Notes and Sources: The Chinese price of hand-reeled raw silk is based on Chen, *Silk Industry*; and Lieu, *Silk Industry*. The U.S. price is the same as in Figure 2. The Japanese price is from Fujino, et al., *Estimates*. The Italian raw-silk price is based on Italy, Istituto Centrale di Statistica, *Sommario*. The French import price of raw silk is from France, Ministere du Travail et de la Prevoyance Sociale, *Annuaire Statistique*. Par exchange rates are used for French and Italian currencies prior to 1914. After 1914 exchange rates for French and Italian currencies are based on U.S. Bureau of the Census, *Statistical Abstract*. The exchange rate for Japanese currency is based on Japan Statistical Association, *Historical Statistics*. The exchange rate for Chinese currency (Haikwan taels) is based on Xu, *Modern History*.

nonstationary nature of the price series calls for the application of the co-integration method. Then, I ran OLS regressions of the natural log value of one country's price series onto that of another, plus a constant. Table 4 presents the results of the regression. The first number represents the value of the constant, the second the value of the slope coefficient. Numbers in brackets are *t*-ratios. Theory suggests that if two price series are indeed co-integrated then we should find that the residual term from the above regression estimation should be stationary or integrated of order zero. So in the final stage, I applied to the residual term the following Dickey-Fuller *t*-test: $\Delta e_t = \alpha + \beta e_{t-1}$ (where e_t stands for estimated residual term from Table 4). We are testing $H_o : \beta = 0$ (e has a unit root and the price series are not co-integrated) against $H_a : \beta < 0$ (e is stationary and the series are co-integrate). The results of the OLS regression are printed in Table 5 (the first number denotes β, and the number in the bracket is its *t*-ratio). Except for the case of Japan versus Italy, all the other nine cases have absolute values of *t*-statistics exceeding those of the 5 percent critical values.[46] For these nine cases, we can reject the null hypothesis that the estimated residual terms are nonstationary and thus, the price series are co-integrated. Therefore, with at least nine out of ten cases tested passing the co-integration criteria at a 5 percent significance level, I believe the statistical evidence strongly supports the proposition that there existed a long-run equilibrium relation that tied together the price movements of the major markets of raw silk in the world during the period of 1868 through 1937.

The significant co-integration test results enable us to interpret the OLS regression estimates in Table 4. Both the *t*-statistics for the individual slope coefficients and the R^2 are very significant and stable across the ten equations (the average R^2 values are above 80 percent for the ten regressions).[47] Two important and interesting results can be found from the OLS regressions. The first is that the law of one price held out with no exceptions for Japan, which joined the gold standard in 1897, and China, which was on the silver standard the entire period. China did not even have a single unified money and its silver-based currencies experienced persistent exchange-rate depreciation due to the declining value of silver. However, the significance of the co-integration test shows that these short-run exchange-rate fluctuations probably had only minor or negligible

tests in this paper, where Dickey-Fuller critical values are used. For details and critical values of the Dickey-Fuller test, see Hamilton, *Time Series Analysis*.

[46] Limited sample size and low power of the test may have contributed to the failure of affirming co-integration for the price series of Japan and Italy at 5 percent significance level. But still, a *t*-ratio of −2.802 for the price series of Japan versus Italy is not far from the 5 percent critical values of −2.93 and −2.89 (it passes the test at a 10 percent significance level). Applying the Box-Jenkins approach would further lead one to believe there is significant first order autocorrelation rather than unit root in the estimated residual term. Therefore, I am not particularly concerned about this anomalous case.

[47] As these regressions involve integrated series, the *t*-ratios do not have the usual *t* distribution. Therefore, we cannot apply the critical values from the *t* distribution.

TABLE 4
REGRESSION RESULT OF THE LOG PRICE SERIES
Countries: Dependent Variables

Independent Variables	Japan			China			United States			France		
	Constant	Coefficient	R^2	Constant	Coefficient	R^2	Constant	Coefficient	R^2	Constant	Coefficient	R^2
Italy	0.606	0.8323	0.863	−1	1.295	0.856	−0.022,	1.025	0.875	−0.038	0.89	0.869
	(0.949)	(20.668)		(−10)	(20.94)		(−0.3)	(23.07)		(−0.59)	(22.46)	
Japan				−0.95	1.434	0.843	0.784	1.098	0.81	−0.011	1	0.849
				(−9.12)	(19)		(0.88)	(17.08)		(−0.16)	(19.6)	
China							0.833	0.739	0.893	0.74	0.6	0.785
							(23.86)	(24.9)		(17)	(16.45)	
United States										0.147	0.758	0.784
										(1.97)	(17)	

Note: The numbers in the parentheses are *t*-statistics.
Source: See the text.

TABLE 5
CO-INTEGRATION TEST
Countries: Dependent Variables

Independent Variables	Japan	China	United States	France
Italy	−0.2419	−0.288	−0.543	−0.347
	(−2.802)	(−3.03)	(−4.46)	(−3.9)
Japan		−0.3	−0.5113	−0.4
		(−3.478)	(−4.844)	(−4.09)
China			−0.663	−0.26
			(−5.958)	(−3.26)
United States				−0.397
				(−4.335)

Note: The 5 percent critical values for the Dickey-Fuller test with sample sizes equal to 50 and 100 are −2.93 and −2.89, respectively. The first number denotes β. The figures in parentheses are t-statistics.
Source: See the text.

effects on the long-run equilibrium relationship of price co-movement. Second, for the China series, I have consistently employed prices of hand-reeled raw silk, which were lower than the machine-reeled silk due to quality and grade characteristics. This showed up in the regression results. The four regressions involving the China series all have significant t-ratios for the constant terms (−10, −9.12, 23.86, 17), and slope coefficients significantly different from one (1.295, 1.434, 0.74, and 0.6). However, the strong fit (significant R square values and t-statistics for the slope coefficients) for these four regressions is one more piece of evidence in support of the market-integration hypothesis; that is, despite quality and grade differences, the price of Chinese hand-reeled raw silk still correlates strongly with other price series.[48]

In conclusion, the statistical results show a strong case of global raw-silk market integration. The favorable factors for integration as I have hypothesized have outweighed the unfavorable ones. It seems that during

[48] To examine the effects of inflation trends on the nominal price movements, I have also run co-integration tests on the U.S. French, and Italian price series against their respective domestic wholesale price indices (the French and Italian price indices are from Mitchell, *International Historical Statistics: Europe*). Both the U.S. and Italian price series failed to co-integrate with the price indices at the 5 percent significance level. The French series barely passed. However, all the OLS regressions with nominal price series of raw silk on a wholesale price index give very poor fit, with R square values less than 10 percent and t and F ratios insignificant. I get roughly the same result by running co-integration tests on French and Italian nominal silk prices versus the U.S. wholesale price index. This shows that the nominal prices of raw silk in international markets correlate much more closely with each other than with the general inflation trends in domestic or foreign countries. While the wholesale price index may contribute some explanatory power to the long-term trends of nominal silk prices, as well as some of the extreme short-term price fluctuations, it is very poor in accounting for the annual nominal silk-price movements. This can be seen by visual inspection of Figure 2. This result is particularly interesting in comparison with a case studied by Lillian Li. She found that during the eighteenth century, when China, under self-imposed export restrictions, was exporting limited quantities of raw silk abroad, the movement of nominal raw-silk prices in China was much more sensitive to domestic monetary and inflationary trends and internal growth of demand than to foreign demand. See Li, *China's Silk Trade*, pp. 68–69.

this era there emerged in the major raw-silk markets around the world, a single price of raw silk.[49]

CONCLUSION: MARKET INTEGRATION AND THE TRANSFORMATIONS IT WROUGHT

Perhaps the most distinguishing feature of the silk trade is its continuity over time and space. The evolution of a global silk trade and its culmination in the latter part of the nineteenth century can be regarded as a geographical and historical continuation and extension of the ancient silk road. The profit-driven motivation for trading silk in the nineteenth and twentieth centuries remained more or less the same as in earlier times. However, the means of transport, the volume, the scale and the speed of trade, the role of intermediaries, and the way information and knowledge flowed were fundamentally changed. For centuries, consumers in premodern Europe had been buying raw silk without knowing who the original suppliers were and how it was made. After the high transport cost and the profit-taking by countless intermediaries, silk could be nothing but the most luxurious product of all. At times, its value was as high as its weight in gold.

The transportation and communication revolution and the dominance of European powers during this period fundamentally changed world trade patterns, including the silk trade. Transportation cost was drastically reduced. The units of each transaction were dealt in hundreds and thousands of pounds. Products were standardized and classified into different categories according to grade, quality, and countries of origin to reduce transaction costs. During this period, effective organizations, such as the Silk Association of America and Syndicat de l'Union des Merchands de Soie de Lyon, were set up in New York and Lyons to monitor quality, take collective actions, and most important of all, collect and spread information and knowledge of silk trade and production. With the rise of fast steamships and the laying of the intercontinental cables, the growth curve of world silk trade turned steeper, taking on an accelerating pace and quickly reaching its historical peak. The single most important and effective indicator of the magnitude of this trade expansion can be found in the co-integration results. They showed that there was only one price that reigned in the major raw-silk markets around the world.

The immediate consequence was the realignment of the international division of labor and the deepening of specialization along the lines of comparative advantage based on factor endowments and technological and institutional traditions. China and Japan quickly regained their dominance in raw-silk export due not only to the abundance of cheap labor and small-size family farms but also to their long traditions of sericulture.

[49] I also collected raw-silk price series of varying time length, in London, Hamburg, and other places from sources such as U.S. Congress, *Wholesale Prices*; and U.K. *Statistical Abstract*. Visual inspection from plots of these price series also showed a significant degree of price co-movement.

In the sericultural regions of China, silkworm rearing became an integral part of rural life. In Japan, sericulture was widely diffused and well developed in the era of the Tokugawa (1600 to 1868). To the French, however, the failure of raw silk production to recover from the silkworm disease of the 1850s and 1860s was certainly not due to technological backwardness but to the loss of comparative advantage to the Italians and East Asians. The relatively high labor cost in France led to French specialization in the skill-intensive, high-fashion silk-weaving industry. Nowhere could this effect of the widening international division of labor be sensed any stronger than in Italy, which, as a major exporter and producer of high-grade raw silk, found itself dependent on imports of cheap silks from East Asia for its manufacture of lighter fabrics.[50]

As in the case of the ancient silk road, the trade of goods led to the exchange of ideas. The transportation and communication revolutions not only accelerated the movements of goods but also the transfer of knowledge. When silk was carried along the caravan route, it took several centuries and the courageous acts of individuals such as Marco Polo for sericulture to take root in premodern Europe. In only about three decades after the opening of China and Japan for trade, steam-powered reeling machines and modern factory organization began to displace the traditional methods of production. It was the ingenious integration of Western biological science in Japanese sericulture that provided the solid base for the dominance of Japanese raw-silk exports in the twentieth century. The success of U.S. silk manufacturing could be traced back to its technological pools in the skilled immigrants from Britain and continental Europe. Like the integration of modern biological science in Japanese sericulture, the development of the U.S. system of mass production in silk manufacture was a prime example of technological and institutional integration and innovation adapted to local factor endowments and knowledge base. Technical changes dictated by varying demand conditions led to the integrating or meshing of different national economies and industries in a more specific manner. If price co-movement was a good indicator of commodity-market integration, path dependence and technical interrelatedness would be the defining characteristics of technological and institutional integration.

Several patterns seem to have converged on the scene of the world raw-silk trade during this period. This was a moment in history that the world, as the world system theorists advocate, was a bipolar of core and peripheries, the colonizers and the colonized, the manufacture producing North and the primary producing South. It was also a time when Western imperialism and colonialism finally reached the shores of East Asia, which had so long managed to maintain relative independence by its geographical aloofness. The story of the modern world raw-silk trade could certainly

[50] Bacon and Schloemer, *World Trade*, p. 452.

be told against the background of unequal exchange, exploitation, and imperialism. Yet the tale is far from complete if we skip the triumph of modern transportation and communication, of science, technology, and machines; it was the victory of producers producing for the common people rather than the privileged few.

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