# A Tale of Two SICs: Industrial Development in Japan and the United States in the Late Nineteenth Century

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Abstract

Late developing countries are able to adopt best practice technologies pioneered abroad, allowing more rapid convergence toward leading economies. Meiji Japan (1868-1912) is considered a successful example of industrial convergence, but much of the evidence relies on national aggregates or selected industries. Using historical industry data, this paper examines whether Japan adopted new technologies faster compared to the United States. Contrary to conventional wisdom, duration analysis indicates that new sectors did not appear relatively sooner in Japan; however, they did grow to economic significance faster. Higher firm capitalization and capital intensity are also associated with earlier entry for Japanese sectors.

Keywords: convergence, industry classification, survival analysis, technology adoption and diffusion
JEL codes: N11, N15, O14, O33

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Between 1870 and 1900, the United States saw a three-fold increase in the value-added of manufacturing, with its share of national output rising four percent over the period to just under a fifth of total income.[1] While this rapid expansion of American industry laid the groundwork to the country's economic leadership in the twentieth century, no less remarkable was the catch up of other late developing countries, particularly Japan. Starting from a much smaller base, Japanese industry also grew apace, with manufacturing's share of national income increasing four percent between 1885 and 1900, and another three percent the following decade to reach 18.5 percent in 1910.[2] In effect, what took the United States three decades was achieved by Japan in half the time.[3]

Like other late developing countries, Japan had the opportunity to hasten its development by adopting technologies at their current best practice, also known as technological convergence.[4] Besides potential savings in time and resources for the economy as a whole, this process also allows for policymakers to target industries that may have a relative comparative advantage and for entrepreneurs to compete with established foreign producers in local and possibly international markets. This was the case for leading Japanese sectors like railroads and cotton textiles that used state-of-the-art equipment and production techniques; less is clear is whether the country's path to industrialization can generally be described as asynchronous for the economy as a whole or if adoption was ad hoc and specific to certain industries.

While numerous studies have examined economic convergence between leaders and laggards, few examine the actual timing or dimensions of technological catch-up. Are increased labor productivity or the number of steam engines by themselves sufficient statistics to assess industrial advancement or economic policies? How can different types of technologies and sectors be measured and compared without loss of generality? These issues, difficult by themselves within a single economy, are magnified

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[1] United States Bureau of the Census (1975).
[2] Japan Statistical Agency (2007).
[3] "In England the factory system evolved over two centuries or more; in Japan it was established in fifty years, or even less" (Lockwood, 1954, p. 187).
[4] This is also called technological leapfrogging. "[T]he higher the degree of backwardness, the more discontinuous the development is likely to be" (Gerschenkron, 1962, p. 45). Some constraints to acquiring frontier technologies include the size of industrial investments, available production inputs, and prevailing institutional frameworks may limit the scope of non-linear adoption and economic development.

when making international comparisons crossing time and space. Japan's industrial development in the Meiji Period (1868-1912), however, provides a unique context to analyze the dynamics of technology adoption due to its relative isolation prior to its integration into the world economy and the observed introduction of foreign technologies thereafter.

To assess the relative speed of Japanese technology adoption, this paper uses official statistics of manufacturing industries starting in 1885. These data, which include figures on establishments and industry capitalization, allow one to identify when sectors appeared in the country and grew in importance during its initial wave of industrialization. The timing of Japanese industrial change is then compared to that of the United States at an earlier period to establish whether the two economies followed similar patterns. Assuming that the classification of industries is a reasonable proxy for embodied technologies and that the chronology corresponds to technology adoption, comparing the two countries' experiences may demonstrate the extent to which Japan engaged in technological leapfrogging relative to an industrial leader.

Estimates from duration model analysis show substantial differences in the respective industrial development of the two countries in the second half of the nineteenth century. Consistent with technological convergence, per capita income levels were inversely correlated with the speed of adoption in general (ie, poorer countries adopt new technologies more quickly); however, benchmarked against the United States, new manufacturing sectors do not appear in Japan relatively earlier and in some cases emerge later. In both countries, but especially true for Japan, industries with larger firms are associated with faster introduction. Furthermore, unlike in the United States, a lower share of capital among related sectors and higher capital intensity appear to speed up technology adoption.

In contrast, for industries that became economically significant, defined as those attaining at least half a percent of total manufacturing capital stock, Japanese industries passed the threshold more quickly than those in the U.S. This result obtains even though both per capita income levels and firm size become directly correlated with economic significance (ie, richer countries pass the capital share threshold sooner). Results for both new industry entry and industry significance are robust to different specifications, although higher capital thresholds weaken the significance of faster Japanese industrialization.

As a whole, these results qualify the conventional wisdom that Japanese industrialization was based simply on accelerated adoption and diffusion of foreign technologies by controlling for industry characteristics and differentiating between sector appearance and their rise to economic importance. New technologies were adopted more slowly, but once introduced spread more quickly through the economy. This may have been due to the relative concentration within Japanese industries, with larger firms able to standardize application of new production techniques more effectively. These findings, along with a description of the data and methodology, are further discussed in the following sections.

## II

In his theory of late development, Alexander Gerschenkron identified Germany and Russia as having industrialized with unusual rapidity in the second half of the nineteenth century.[5] He credits this achievement to their relative "backwardness" and thus being able to adopt pre-existing technologies developed by industrial pioneers like the United Kingdom and United States.[6] His observation has been the subject of an extensive literature on economic convergence that measures differences in national income, productivity, capitalization, and institutions.[7]

Until the late 1800s, Japan too was considered a backward country, with the economy organized along feudal lines and engaged primarily in traditional agricultural production.[8] This changed markedly in the second half of the century, following the country's (forced) opening to the international economy. In 1868, the year of the Meiji Restoration, two-thirds of gross national output came from primary sector production; by 1905, this share fell to under forty percent, similar to the proportion coming from a swiftly growing textile manufacturing industry.[9] Even with these gains, Japan remained

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[5] Gerschenkron (1962), chapter 1.
[6] "Industrialization always seemed the more promising the greater the backlog of technological innovations which the backward country could take over from the more advanced country" (ibid, p. 8).
[7] Some well-known studies on economic convergence and growth include Abramovitz (1986), Baumol (1986), and Delong (1988). More recent works include Benetrix et al (2013) and Rodrik (2013).
[8] Ohkawa and Rosovsky (1973, p. 4).
[9] Ibid, p. 15.

in absolute measures significantly behind industrial leaders like the United States, but the relative disparity had narrowed.[10]

Similar to the experiences of other successful late developing countries, Japan's modernization is attributed to the adoption of new technologies, increased capital accumulation, and higher levels of productivity, although the analyses typically rely on national aggregates or are not empirically verified.[11] A visible example of foreign technology adoption was the introduction of the railroad in the early 1870s, which expanded rapidly in the next three decades and linked population areas, provided access to natural resources as well as increased firm scale.[12] Recent scholarship confirms Japan's precocity among countries in the industrial periphery, with growth rates exceeding the leading economies of the United States, United Kingdom, and Germany starting in the 1890s and continuing for most of the twentieth century.[13]

Notwithstanding the insight gained from estimating industrial growth rates and aggregate productivity levels, the specific mechanisms underlying economic convergence remain unclear as well as which industries are affected and how sectoral differences can be measured.[14] In the case of Meiji Japan, besides transportation infrastructure, other contributing factors to its industrial take-off included public investment, entrepreneurial capital, and financial market access.[15] Equally crucial was the diffusion of new technologies, with sectors like cotton spinning directly benefitting

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[10] See Table 1 for a comparison of economic activity in both countries.

[11] For example, Ohkawa and Rosovsky (1973, p. 39) claim that Japan's high absorptive capacity for technology is due in part to its "well-functioning sociopolitical infrastructure." In a dissenting view, Lockwood (1954, pp. 17-18) attributes Meiji Japanese growth largely to market integration, lower transaction costs, and increased productivity indirectly related to technological change.

[12] Tang (2013b). Railroads were also heavily utilized in Japan's military victories against China (1895) and Russia (1905), which provided the country with its first colonial possessions, reparations, and international status.

[13] Benetrix et al (2012). While Japan was the first Asian country to reach the five percent threshold of industrial growth rates, it initially lagged behind countries in the European periphery and Latin America.

[14] Abramovitz (1986, p. 395) states that "[p]roductivity levels...were erratic indicators of gaps between existing and best-practice technology."

[15] See Morck and Nakamura (2007), Tang (2011), Rousseau (1999) and Tang (2013a). Tang (2011) identifies the large, family-owned zaibatsu conglomerates as instrumental in introducing many new technologies to the economy, although the analysis does not consider relative timing between entrepreneurs or international comparisons.

from the adoption of contemporary best practice.[16] However, it is uncertain whether the impact of innovations from individual sectors generalizes to the economy as a whole, or how different technologies and their economic significance can be compared to each other.[17] Innovation is typically identified at a micro-level (eg, patents, products) or backed out as a residual in macroeconomic production functions.[18] At the industry level, there is ambiguity as to what constitutes technological progress (as opposed to capital utilization and labor productivity), and this is further complicated by data availability and consistency as well as variation between sectors.[19]

This paper addresses these measurement issues by assuming that industry classification itself is a useful gauge of technology differences, and the successive emergence of different industries over time represents technological progress.[20] This framework is applied to the industrialization of Japan in the late nineteenth century, with the experience of the United States used as a reference. Some hypotheses that can be tested are whether new Japanese industries appeared relatively sooner compared to those in the U.S.; whether their emergence was affected by the scale of enterprises within those sectors and industry-level capital intensity; whether the existence of similar industries encouraged the introduction of new, but related technologies; and if there was a difference between appearance of an industry (aka, adoption) and its growth to economic significance (aka, diffusion).

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[16] Saxonhouse (1974). While Japanese cotton spinning was initially modeled after British practice (ie, mule spindles), the industry shifted quickly to newer American technology (ie, ring spindles) given the latter's suitability to Japanese production inputs (labor abundant) and consumer markets (lower quality textiles).

[17] Gerschenkron (1962, pp. 42-43) suggests per capita output as a measure of backwardness as unsatisfactory given differences in the range of output and availability of price data. A notable example of consistent measurement and economic impact in technology adoption is Saxonhouse and Wright (2010), which tracks the diffusion of cotton spinning technology over fifty years across multiple countries.

[18] This distinction finds an analogue to Mokyr's (1990) discussion micro- versus macroinventions, although he argues the former are incremental improvements in productivity and the latter to paradigm shifts.

[19] While it is possible to aggregate the contributions of all microinventions to estimate an industry- or economy-wide figure, an exhaustive inventory may be infeasible. It may also be difficult to isolate the value of general purpose technologies that are used in multiple sectors or goods.

[20] A similar approximation is Abramovitz's (1986, p. 386) claim that technology as embodied in capital stock, where the "technological age of the stock is, so to speak, the same as its chronological age."

III

The data used in the analysis come from official records collected by the statistical agencies in the two countries, either in statistical yearbooks (Japan) or decennial economic censuses (United States). Specifically, data in the *Statistical Yearbook of the Japanese Empire* were compiled by the Prime Minister's Cabinet Statistics Bureau from different government agencies' records and occasionally from individual firms into annual reports between 1883 and 1936.[21] The information included in these yearbooks covers all aspects of the Japanese economy and population and often at the prefecture and industry level.[22] Industry statistics were progressively standardized during the 1880s and 1890s in terms of the amount of detail included and how sectors were classified, such as the reporting of manufacturing separate from sales starting in year 1885. Industry names also changed slightly to accommodate expansion or contraction of activities. For the Meiji Period, consistent series at the industry level are available from the mid 1880s for the number of establishments and the amount of paid-in capital, whereas data on employment, raw materials, and output are not comprehensive across sectors until the early 1900s.

In contrast, perhaps due to the relative enormity of the task and infrequency of data collection, American statistics tended to be more complete. Starting with the 1810 census, economic data collection took place along with population enumerations every decade until the turn of the century, when a permanent census office was established in 1902.[23] The Permanent Census Act had provisions for economic statistics to be collected on a five-year basis starting in 1905.[24] While accuracy and information increased during the 1800s, such as including workers, raw materials, and equipment (1820) and adding sections on fishing, mining, and trade (1840), it was not until the second half of the century that consistent and detailed instructions were used in the enumerations (1850) and that trained specialists instead of U.S. marshals collected the data (1880).

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[21] Japan Statistical Association (1962).

[22] Note that while some series are at both the prefecture and industry level, many are available only in one or the other.

[23] The 1810 census was the third to take place, and included for the first time questions on goods and manufactures; see Boehme (1987). Atack and Bateman (1999) also describe changes in data collection and quality over time. Japanese statistical collection increased in sophistication as well, which may be due to greater institutional capacity acquired over time.

[24] The frequency of economic censuses also changed to biennial, then four-yearly enumerations before returning to a quinquennial basis; ibid.

These changes in coverage for both countries mean that reliable industrial data can be analyzed only after 1885 for Japan and 1850 for the United States, and these are limited to a small number of series available for all manufacturing sectors, namely the number of establishments and capital value.[25] Fortunately, the decades following these two starting points sufficiently span major periods of industrial development in both countries, as shown in Table 1.[26] For Japan, the initial wave of sustained industrial activity occurred after the fiscal retrenchment of the early 1880s, when the government privatized many of its enterprises and its financial restructuring stabilized the currency and reduced inflation.[27] In the quarter century to 1910, the number of firms increased seven-fold while their nominal level of paid-in capital rose by a factor of twenty.[28]

[Table 1]

Meanwhile, the United States was undergoing significant structural change following its Civil War in 1861-65. The economy began to actively employ mass production techniques and to expand its manufacturing sector, which exceeded agriculture in value in the 1880s and was the international leader by 1900.[29] The periods of analysis for both countries end in 1910, which coincides with the last years of the Meiji Period and Japan's first wave of industrialization. It also allows use of the last quinquennial American economic census prior to World War I, which further changed the composition and development of the two economies.

Comparing Japan's industrial development with that of the United States is complicated by the fact that neither country had a standardized industry classification (SIC) system until well into the twentieth century. To ensure consistent comparison over time and between countries, industries from the Japanese yearbooks and American censuses are coded retroactively using the 1987 United States SIC system at the three-

[25] Even these series are not exact mappings, with Japan reporting nominal paid-in capital value for industries while the United States giving the value of industries' fixed capital assets.
[26] Table 1 omits the column containing statistics for the 1905 economic census, which are included in the regression analysis.
[27] Allen (1946), pp. 46-47.
[28] Financial figures are reported in current U.S. dollars at market exchange rates for Japan, which are likely to be underestimates compared to those calculated using purchasing price parity (PPP).
[29] Atack and Passell (1994), p. 457, and Boehme (1987).

digit level.[30] This coding reduces the number of industries listed in the historical records on average by a factor of two. For the United States, the number of SIC3 industries was fairly unchanged throughout the late 1800s, around one hundred, while in Japan the number steadily increased, trebling in twenty-five years. By 1910, Japan had nearly two-third the number of SIC3 industries as the U.S., compared to less than one-fifth in 1885. This absolute growth in Japanese SIC3 industries is also reflected in the number of completely new sectors, with twenty appearing within five years after 1885 and another 19 in the following ten years. A similar increase of industrial diversification occurred in the United States two decades earlier, when nineteen new industries appeared between the 1850 and 1860 censuses, and another thirteen in the next two decades.[31]

In addition to the official records used to construct these industrial series, a few other sources of statistics are used. For Japan, these are national income and population figures from the *Historical Statistics of Japan* collection and industry output values from the *Estimates of Long-Term Economic Statistics*; and for the United States, historical estimates of national income and population from *MeasuringWorth*.[32] It should be noted that the two countries differ in the methodology used to calculate national income, with the United States measuring it as gross domestic product while for Japan it is gross national expenditure.[33] Furthermore, Japanese industry output values are aggregated at a much higher level (two-digit SIC) than those for the U.S. While this does not pose a technical problem for the analytical model since the output values series are used to construct average capital intensity ratios (capital value to output value), it does mean that figures for Japan will be less precise than the equivalent American ratios. All income and output values are in current U.S. dollars, with the Japanese figures converted from yen using prevailing market exchange rates averaged over the given year.

IV

30 United States Office of Management and Budget (1987). Atack and Bateman (1999) also use three-digit 1987 SIC codes in their analysis of U.S. Census of Manufacturing extracts for the 1850, 1860, 1870, and 1880 enumerations.
31 See data appendix for list of new industries in both countries by three-digit SIC.
32 Japan Statistical Association (2007), Shinohara (1972), and Williamson (2013).
33 GDP measures are also available for Japan, but they post-date the earliest available industrial series; see Japan Statistical Association (2007).

To test the hypothesis that Japan adopted technologies faster than advanced economies like the United States, and thus enabling it to converge toward industrial leaders, this paper uses a duration analysis model to compare the relative timing of industry development in the two countries.[34] It does this by estimating the expected time to when a new industry will appear in an economy based on a parametric model that reflects the observed behavior of events in the data and is conditional on covariates that may influence the occurrence. One of the advantages to using duration analysis instead of other regression models is that censored subjects (eg, industries that do not pass the capital threshold) remain in the analysis and thus improve the precision of the estimated coefficients.

Before continuing, it may be reasonable to consider whether duration analysis is appropriate to model industry emergence in both countries for the periods in question. Figure 1 plots the appearance of new industries (vertical axis) over time as given in the data, and shows comparable levels of activity for the United States and Japan, albeit separated by nearly three decades. The Japanese trend is also more compressed in timing, which corresponds with its industrial growth rates relative to the United States. In both countries, new industries appear mostly in the first third of their respective periods of analysis, with a noticeable decline in technology adoption thereafter.

[Figures 1 and 2]

Figure 2 plots the two countries' curves as estimated probabilities (ie, the likelihood of appearance given non-appearance in a given year) using the Kaplan-Meier survivor function. The interpretation is that the probability (vertical axis) of new industry appearance is high early in the period of analysis for each country, with subsequent appearances less likely to occur over time. Here the similarity between the two countries' curves is even more striking, with all estimated probabilities statistically

[34] Duration analysis models are also commonly known as survival analysis models, which measure the hazard rate (risk) of an event occurrence, like death or unemployment; see Cleves et al (2008). There are a number of duration model types (eg, parametric, semiparametric) and probability distributions (eg, exponential, Weibull), the selection of which depends on the outcome of interest (eg, duration time, relative hazard ratios) and observed or expected behavior over time, respectively.

significant at least to the ten percent level. Log-rank tests of equality between the two countries' survivor functions also fail to be rejected at that level.

Given the differences in capital investment and economic development over time and between countries, it may be more informative to include additional variables that may influence the timing of industry appearance. Assuming a conditional probability of industry appearance that is constant over time (ie, a Poisson or exponential distribution), which is consistent with the observed pattern of appearance shown in Figure 1, the basic functional form of the model is:

$$log\ (t) = X_i\beta_1 + X_{ij}\beta_2 + z, \text{ where}$$

$t$ = time to industry appearance

$X_i$ = country-level variables indexed by $i$

(eg, per capita income, Japan indicator variable)

$X_{ij}$ = control variables indexed by country $i$ and industry $j$

(eg, average firm capital level, interaction variables)

$z$ = error term

New industries are identified using the earliest available data: for Japan, these include industries starting in 1885, and for the United States, those in 1850. Using these sets of sectors as benchmarks for each country, any sectors appearing in successive years until 1910 are considered new, with the corresponding duration in between measured as an outcome variable $t$. The group of industries from the reference years, which are considered left-truncated, are omitted from the analysis.[35]

The model tests whether time-to-appearance is associated with the following economy and industry level differences: a) income per capita, as a proxy for relative backwardness; b) a Japan indicator variable, to identify difference between the two countries; c) the average level of firm capital in each country, calculated by dividing an industry's capital value by its number of enterprises, as a measure of firm scale; d) the share of capital invested in similar sectors (ie, three-digit SIC industries within the same two-digit industry group) out of total capital invested across manufacturing sectors in

[35] Left-truncation differs from left-censorship in that the latter includes industries that have not yet experienced a threshold event, but their existence precedes their appearance in the data. This difference is meaningful only in the duration analysis of economic significance as new industries appearing in the data have no prior existence.

country *i*, to account for relative innovativeness;[36] e) industry capital intensity in country *i*, which is the value of capital divided by the value of output; and f) interactions between the Japan indicator and industry level variables. Since the impact of industrialization is felt more in its sustained growth over time as opposed to a possibly short-lived market appearance, separate regressions are run using as the dependent variable the duration until an industry attains economic significance, defined as having at least half a percent of the country's total manufacturing capital.[37] This dependent variable allows inclusion of industries that appear in the data series, but do not receive sufficient capital investment, thus improving the estimates of the coefficients as well as increasing the overlap of industries between the two countries.

Since industrial data for the United States before 1900 were collected every ten years, whereas the Japanese data are annual, dating the appearance of new industries and when industries attain economic significance in America is less precise.[38] Consequently, this may bias the results in favor of finding technological convergence for Japan since the dependent variables measure the duration until appearance or diffusion. To mitigate this bias, both countries' data are coded as five-year intervals (which also coincide with the post-1900 U.S. enumerations), and imputing event occurrence dates in a shorter span of time for U.S. sectors. For example, in measuring the time for an American industry to pass the half percent threshold of total capital stock, if the sector has a capital share of 0.1 percent in 1860 and 2 percent in 1870, instead of dating the occurrence as passing the threshold in 1870, it is coded as 1865 based on the arithmetic average between the two enumerations. Attendant covariates like related industry capital share and capital intensity are similarly imputed. To match the level of imprecision in the American data, Japan industries are recoded also in five-year periods, which means they may appear up to four years later (eg, an industry appearing in 1891

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[36] A similar method of assessing industry innovativeness is used in Tang (2011).
[37] Given approximately two hundred possible three-digit SIC industries, the half percent threshold would approximate a uniform distribution of invested capital for each industry (ie, each industry of equal importance). Since industries varied considerably in age and capital investment, it is expected that this threshold is a reasonable metric to measure absolute growth and technological diffusion. Separate robustness checks using the higher threshold of one percent total manufacturing capital stock are also performed and presented in the following section.
[38] This is also known as interval censorship.

coded as 1895) and would use the later date's industry- and economy-level values in the covariates.

V

Regression results from the parametric duration model indicate that while lower per capita income is associated with faster technology adoption, new industries did not appear relatively earlier in Japan compared to the United States. As shown in Table 2, the coefficient on per capita income (row 1) is positive, which indicates increased duration until industry appearance, and usually statistically significant. This is consistent with developing countries converging toward technological leaders, with new manufacturing sectors appearing earlier presumably due to a technological backlog from which to establish industries. However, the Japan indicator variable (row 2) is also positive and despite most of its interactions with industry covariates being negative (all are statistically significant), the net effect (row 11) remains positive and weakly significant.[39] This net effect indicates that as a whole new Japanese manufacturing sectors appear in the economy no sooner than those in the U.S., and in some cases later.

[Table 2]

Among the covariates, both average firm capital level (row 3) and the capital share of related sectors (row 4) are negatively associated with expected duration. This suggests that new industries with higher invested capital per firm emerge more quickly, and this is especially true for Japan as shown by the positively signed and larger coefficient on the interaction variable (row 6). On the other hand, while more capital invested in related sectors may ease the appearance of new industries in general, perhaps due to greater availability of transferable technology and resources, the effect is reversed in Japan (row 7). This contrasts with industry capital intensity, which has a positive sign on the overall effect, but a negative one when interacted with the Japan

[39] The net effect is calculated using a Wald test of the linear combination of all control variables excluding income per capita and year trend, evaluated at the population average for the Japan subset of new industries.

fixed effect. One explanation for the latter two interactions is that capital scarcity led to the concentration of resources in fewer, but more capital intensive sectors.[40]

Interestingly, the above findings do not carry through to those using the half percent capital stock threshold as the dependent variable, shown in Table 3. Per capita income (row 1) now is negatively signed, indicating faster growth of manufacturing in wealthier countries. At the same time, the indicator variable for Japan (row 2) is also negatively signed and combined with its interactions with other covariates, the net effect (row 11) is negative and statistically significant. This suggests that Japanese sectors grew to economic significance, with diffusion of embodied technology, relatively faster than those in the United States, even with the inclusion of a time trend to allow for the difference in actual timing.

[Table 3]

Among the covariates, average firm capital (row 3) changes signs and loses significance compared to the previous table and related sector capital share (row 4) has a negative and insignificant coefficient. Only industry capital intensity (row 5) is statistically significant but now with a negative sign, while all the interactions with the Japan indicator variable are weakly or not significant. These findings suggest that unlike with the appearance of new industries, their growth is less affected by firm or industry group scale, and that aside from the timing itself, there were no substantive differences between countries as captured by these industry characteristics.

To check the robustness of these results, one can change the period of analysis as well as the capital stock threshold. These results are shown in Tables 4 and 5, respectively. In Table 4, the period of analysis for the United States is shortened by ten years, either by postponing the starting year to 1860 or by advancing the ending year to 1900; the analysis period for Japan remains unchanged. For industry new appearance, changing the benchmark year to 1860 (column A) reduces the number of new industries by nineteen (row 12), but does not affect most of the main results from the full period of analysis in Table 2 (column E). That is, both average firm capital (row 6)

[40] This interpretation can also be qualified by the observation that higher capital intensity is derivative of the high cost of capital equipment (ie, imported) relative to output value in Japan.

and industry capital intensity (row 8) are associated with faster industry appearance in Japan, but the net effect (row 11) remains positive and insignificant. The results from moving the end year to 1900 (column B) replicate those from the earlier table as no new industries appeared in either the 1905 or 1910 economic censuses.

[Table 4]

The different start and end years also do not affect the main results for industries reaching the 0.5 percent capital stock threshold, shown in columns C and D. In both cases, the estimates are similar in magnitude and match in sign and statistical significance, with the net effects indicating faster growth of new industries in Japan, which is associated with overall capital intensity and the size of Japanese firms. The net effect is particularly pronounced with an earlier American end date, which may owe to the longer duration until reaching the capital threshold in the United States and thus censors ten industries from the analysis.

[Table 5]

The second robustness check uses a one percent total capital stock threshold as a proxy for technological diffusion. These results, shown in Table 5, indicate that while average firm capitalization in Japan still reduces the time to passing the threshold, the net effect is no longer negatively signed. Furthermore, including a time trend variable (column E) increases the magnitude of the positive net effect and is weakly significant, suggesting a longer time to economic significance in relation to the United States. This finding may be due to the relatively short length of the Japanese industrial data series; when compared to a shorter analysis period for the United States ending in 1900, the net effect becomes insignificant and negatively signed.

## VI

Given the enormous differences in economic and industrial development between Japan and the United States in the second half of the nineteenth century, it may seem obvious that some convergence between the two countries would occur with sufficient resources and institutions. That Japan did make considerable progress in reducing the gap owes in part to the rapidity of its industrialization and the adoption of technologies pioneered by industrial pioneers. The results from duration analysis provide evidence that while Japanese industries were able to spread technologies via industry growth more quickly, it is qualified by the relatively slow adoption of new technologies themselves. In other words, technological adoption and diffusion were distinct phenomena in Japan, and even the latter may require longer periods of development than the two decades considered in the analysis.

How does one reconcile these seemingly opposing results? One issue may be the precision of the data, which are still fairly aggregated even at the three-digit industry code level. This may obscure discrete advances in technologies within industry codes as well as the continued use of traditional methods alongside modern ones, as was observed in Japan throughout the late 1800s.[41] The periods chosen for analysis, based on data availability, may also not be directly comparable since the United States was already fairly industrialized by the mid 1800s. Thus, the technologies adopted in its post-bellum decades could be affected differently by the included covariates than those adopted in Japan, although the standard errors were adjusted to accommodate heterogeneity in sector and country.

Nonetheless, the findings corroborate observations made by Gerschenkron that backward countries will have larger firms and more coordination among them.[42] In all specifications, higher average firm capital stock is associated with earlier entry and growth of Japanese industries compared to the United States, and in many cases the presence of related sectors (which may serve as competition to new entrants as well as provide organic technological growth opportunities) appears to delay these outcomes.[43]

At a broader level, one can also observe technological catch up, although possibly not industrial growth, in per capita income differences, with poorer countries adopting new technologies sooner but still requiring additional time for them to attain economic significance. That Japan apparently reverses this relationship, which is not obvious if adoption and diffusion are conflated, may help to explain its success in industrialization compared to its peer group of developing countries. That is, selective adoption of

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[41] Ohkawa and Rosovsky (1973, p. 17) observe that half of all capital goods were still produced using traditional methods in the Meiji Period.

[42] Gerschenkron (1964), p. 44.

[43] Saxonhouse (1974) attributes the rapidity of technology transfer for cotton spinning to coordination among firms in that sector.

technologies, but with increased resources in those sectors, may have allowed Japan to gain the scale needed to compete internationally while laying the foundation for further intensification during the period between the two world wars.

This paper also identifies a number of areas for future work, such as including factor costs, which figured prominently in the expansion of Japanese textiles, although this is partly accounted for in the measure of capital intensity via production value, nor comparisons of labor mobility and productivity. Also omitted are discussions of international trade, which may have influenced the types of industries that developed during the period; access to foreign financial capital; and the role of government policy and expenditure, such as the establishment of enterprises in the early Meiji Period and public investments in infrastructure and strategic sectors, all which can be explored in further work.

That said, the findings are consistent with anecdotal accounts and aggregate measures of Japanese technological convergence, and date the timing of its industrialization firmly in the late 1800s, before most other peripheral economies.[44] By the eve of the First World War, Japan had an industrial economy with far more advanced technology than a few decades earlier.

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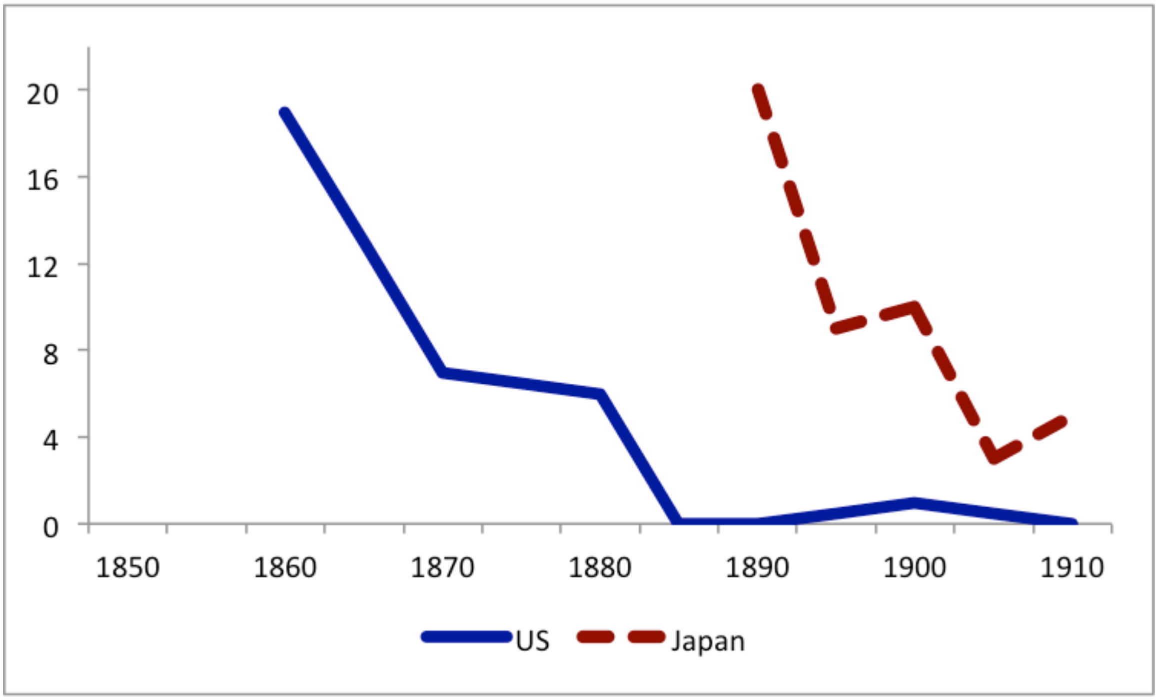
Appendix: List of New Industries

| SIC3 | Industry Name | Entry Year U.S. | Entry Year Japan |
|---|---|---|---|
| 203 | Canned, frozen, and preserved fruits, vegetables, and food specialties | | 1900 |
| 206 | Sugar and confectionary products | | 1895 |
| 207 | Fats and oils | | 1890 |
| 211 | Cigarettes | 1870 | |
| 212 | Cigars | 1860 | |
| 213 | Chewing and smoking tobacco and snuff | 1870 | |
| 220 | Textile mill products | | 1900 |
| 222 | Broadwoven fabric mills, manmade fiber and silk | | 1895 |
| 223 | Broadwoven fabric mills, wool (including dyeing and finishing) | | 1895 |
| 225 | Knitting mills | | 1900 |
| 226 | Dyeing and finishing textiles, except wool fabrics | | 1890 |
| 229 | Miscellaneous textile goods | | 1895 |
| 230 | Apparel and other finished products made from fabrics and similar materials | | 1910 |
| 231 | Men's and boys' suits, coats, and overcoats | 1860 | |
| 232 | Men's and boys' furnishings, work clothing, and allied garments | 1880 | |
| 233 | Women's, misses', and juniors' outerwear | 1860 | |
| 235 | Hats, caps, and millinery | | 1900 |
| 236 | Girls', children's, and infants' outerwear | 1870 | |
| 242 | Sawmills and planing mills | | 1890 |
| 243 | Millwork, veneer, plywood, and structural wood | | 1890 |
| 244 | Wood containers | | 1905 |
| 249 | Miscellaneous wood products | | 1890 |
| 250 | Furniture and fixtures | 1870 | |
| 251 | Household furniture | | 1890 |
| 254 | Partitions, shelving, lockers, and office and store fixtures | 1860 | |
| 259 | Miscellaneous furniture and fixtures | 1860 | |
| 260 | Paper and allied products | | 1895 |
| 271 | Newspapers: publishing, or publishing and printing | 1870 | |
| 273 | Books | 1870 | |
| 277 | Greeting cards | 1860 | |
| 285 | Paints, varnishes, lacquers, enamels, and allied products | | 1890 |
| 287 | Agricultural chemicals | 1860 | 1890 |
| 289 | Miscellaneous chemical products | | 1895 |
| 295 | Asphalt paving and roofing materials | 1860 | 1910 |
| 299 | Miscellaneous products of petroleum and coal | | 1890 |
| 300 | Rubber and miscellaneous plastics products | | 1900 |
| 302 | Rubber and plastics footwear | 1880 | |
| 305 | Gaskets, packing, and sealing devices and rubber | 1880 | |
| 306 | Fabricated rubber products, not elsewhere | 1860 | |

| | | | |
|---|---|---|---|
| 308 | Miscellaneous plastics products | 1880 | |
| 322 | Glass and glassware, pressed or blown | 1860 | 1890 |
| 323 | Glass products, made of purchased glass | 1860 | |
| 324 | Cement, hydraulic | | 1890 |
| 325 | Structural clay products | | 1890 |
| 328 | Cut stone and stone products | | 1890 |
| 329 | Abrasive, asbestos, and miscellaneous nonmetallic mineral products | | 1900 |
| 330 | Primary metal industries | | 1895 |
| 331 | Steel works, blast furnaces, and rolling and finishing mills | | 1890 |
| 332 | Iron and steel foundries | | 1895 |
| 333 | Primary smelting and refining of nonferrous metals | | 1900 |
| 334 | Secondary smelting and refining of nonferrous metals | 1860 | |
| 335 | Rolling, drawing, and extruding of nonferrous metals | 1860 | |
| 343 | Heating equipment, except electric and warm air | | 1910 |
| 347 | Coating, engraving, and allied services | | 1910 |
| 349 | Miscellaneous fabricated metal products | | 1910 |
| 350 | Industrial and commercial machinery and computer equipment | 1870 | |
| 352 | Farm and garden machinery and equipment | | 1890 |
| 353 | Construction, mining, and materials handling | 1860 | |
| 354 | Metalworking machinery and equipment | 1860 | 1900 |
| 357 | Computer and office equipment | 1880 | |
| 358 | Refrigeration and service industry machinery | 1860 | |
| 359 | Miscellaneous industrial and commercial equipment | 1860 | 1890 |
| 360 | Electronic and other electrical equipment and components, except computer equipment | 1860 | |
| 362 | Electrical industrial apparatus | 1880 | 1905 |
| 364 | Electric lighting and wiring equipment | | 1890 |
| 365 | Household audio and video equipment, and audio media | 1900 | |
| 370 | Transportation equipment | | 1890 |
| 371 | Motor vehicles and motor vehicle equipment | | 1900 |
| 373 | Ship and boat building and repairing | | 1890 |
| 374 | Railroad equipment | | 1905 |
| 382 | Laboratory apparatus and analytical, optical, measuring, and controlling instruments | | 1890 |
| 387 | Watches, clocks, clockwork operated devices, and parts | | 1895 |
| 394 | Dolls, toys, games and sporting and athletic goods | 1860 | |
| 395 | Pens, pencils, and other artists materials | | 1900 |

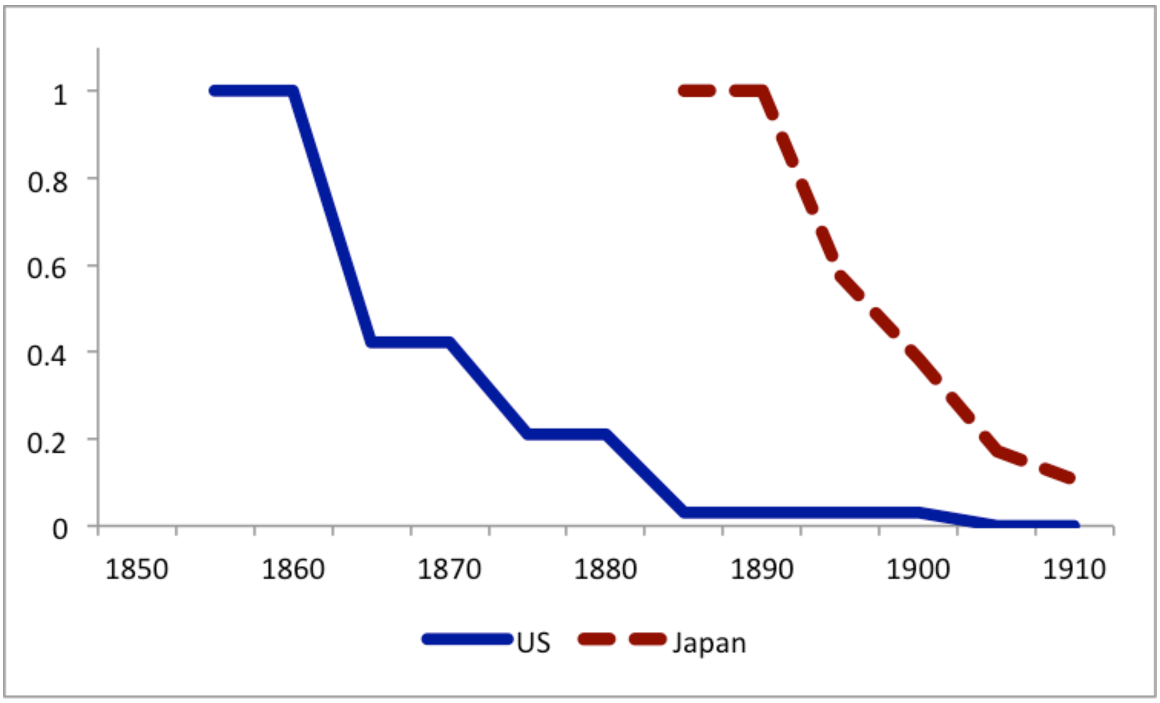
Source: United States Office of Management and Budget (1987) and author's calculations.

Figure 1: Number of New SIC3 Industries in the U.S. and Japan




Source: see text

Figure 2: Survival Curves of New Industry Appearance in the U.S. and Japan




Source: see text.

Table 1: Industrial Development in the U.S. and Japan

| United States | 1850 | 1860 | 1870 | 1880 | 1890 | 1900 | 1910 |
|---|---|---|---|---|---|---|---|
| GDP (mil) | $2,581 | $4,387 | $7,812 | $10,462 | $15,223 | $20,766 | $33,746 |
| Population (mil) | 23.3 | 31.5 | 39.9 | 50.3 | 63.1 | 76.1 | 92.4 |
| Manufacturing Industries | 251 | 605 | 383 | 277 | 305 | 314 | 256 |
| SIC3 Sectors | 95 | 108 | 109 | 105 | 107 | 107 | 101 |
| New SIC3 Sectors | | 19 | 7 | 6 | 0 | 1 | 0 |
| Firms | 114,774 | 128,574 | 230,330 | 176,788 | 200,128 | 207,176 | 268,440 |
| Average Firm Capital | $4,234 | $7,279 | $8,980 | $15,255 | $30,348 | $43,201 | $71,815 |

| Japan | 1885 | 1890 | 1895 | 1900 | 1905 | 1910 |
|---|---|---|---|---|---|---|
| GNE (mil) | $9.6 | $12.6 | $30.7 | $49.0 | $62.5 | $79.5 |
| Population (mil) | 38.3 | 39.9 | 41.6 | 43.8 | 46.6 | 49.2 |
| Manufacturing Industries | 24 | 48 | 52 | 73 | 82 | 93 |
| SIC3 Sectors | 18 | 37 | 39 | 49 | 52 | 58 |
| New SIC3 Sectors | | 20 | 9 | 10 | 3 | 5 |
| Firms | 498 | 2,055 | 831 | 2,344 | 2,325 | 3,489 |
| Average Firm Capital | $99 | $190 | $1,063 | $1,602 | $1,261 | $2,181 |

Source: see text.

Table 2: Duration Model Results for New Industry Appearance

| DV: Log(Years to New SIC3 Industry) | A | B | C | D | E |
|---|---|---|---|---|---|
| Log(Per Capita Income) (Current US$) | 0.138 | 0.284*** | 0.263*** | 0.374*** | 0.339 |
| | (0.106) | (0.102) | (0.102) | (0.116) | (0.261) |
| Country Fixed Effect (Japan = 1) | 0.481 | 1.242** | 0.957 | 1.820** | 1.531 |
| | (0.615) | (0.592) | (0.610) | (0.717) | (2.113) |
| Average Firm Capitalization (Current US$) | | -0.007*** | -0.007*** | -0.008*** | -0.008*** |
| | | (0.001) | (0.001) | (0.001) | (0.001) |
| Capital Share of Related SIC3 Industries (%) | | | -0.056** | -0.057** | -0.055** |
| | | | (0.027) | (0.028) | (0.028) |
| SIC3 Capital Intensity | | | | 0.015*** | 0.015*** |
| | | | | (0.006) | (0.005) |
| Country F.E. x Average Firm Capitalization | | -0.177*** | -0.175*** | -0.164*** | -0.164*** |
| | | (0.042) | (0.043) | (0.038) | (0.038) |
| Country F.E. x Related SIC3 Capital Share | | | 0.057** | 0.057** | 0.055** |
| | | | (0.028) | (0.028) | (0.028) |
| Country F.E. x SIC3 Capital Intensity | | | | -1.535** | -1.529** |
| | | | | (0.702) | (0.705) |
| Year trend | | | | | 0.003 |
| | | | | | (0.020) |
| Constant | 2.370*** | 1.780*** | 2.048*** | 1.479** | -4.252 |
| | (0.555) | (0.535) | (0.554) | (0.621) | (35.993) |
| Net Effect (Japan) | | 1.002* | 0.723 | 1.286* | 0.998 |
| | | (0.607) | (0.624) | (0.692) | (2.094) |
| Total Industries/Event Occurrence | 80/80 | 80/80 | 80/80 | 80/80 | 80/80 |
| Observations | 160 | 160 | 160 | 160 | 160 |
| Log Pseudolikelihood | 294.167 | 299.951 | 300.634 | 302.438 | 302.451 |
| Chi-squared Statistic | 201.87*** | 185.98*** | 158.83*** | 577.21*** | 603.11*** |

Significance levels: *10%, **5%, ***1%.
Source: see text. All specifications use robust standard errors clustered by SIC3 industry and country (in parentheses).

Table 3: Duration Model Results for Industry Growth

| DV: Log(Years to 0.5% Mfg Capital Stock) | A | B | C | D | E |
|---|---|---|---|---|---|
| Log(Per Capita Income) (Current US$) | -0.773*** | -0.621*** | -0.671*** | -0.572*** | -0.390* |
| | (0.155) | (0.162) | (0.178) | (0.188) | (0.231) |
| Country Fixed Effect (Japan = 1) | -5.512*** | -4.657*** | -5.097*** | -5.156*** | -3.791** |
| | (0.978) | (1.026) | (1.210) | (1.270) | (1.596) |
| Average Firm Capitalization (Current US$) | | -0.001*** | -0.001*** | 0.001 | 0.0005 |
| | | (0.0003) | (0.0003) | (0.001) | (0.001) |
| Capital Share of Related SIC3 Industries (%) | | | -0.009 | -0.018 | -0.022 |
| | | | (0.021) | (0.023) | (0.024) |
| SIC3 Capital Intensity | | | | -1.183*** | -1.015*** |
| | | | | (0.348) | (0.380) |
| Country F.E. x Average Firm Capitalization | | -0.054* | -0.050 | -0.054* | -0.059* |
| | | (0.029) | (0.032) | (0.031) | (0.031) |
| Country F.E. x Related SIC3 Capital Share | | | 0.016 | 0.024 | 0.028 |
| | | | (0.022) | (0.024) | (0.025) |
| Country F.E. x SIC3 Capital Intensity | | | | 0.711 | 0.496 |
| | | | | (0.763) | (0.759) |
| Year trend | | | | | -0.010 |
| | | | | | (0.009) |
| Constant | 7.451*** | 6.735*** | 7.044*** | 7.251*** | 25.499 |
| | (0.878) | (0.902) | (1.026) | (1.073) | (15.873) |
| Net Effect (Japan) | | -4.755*** | -5.110*** | -5.286*** | -3.948*** |
| | | (1.006) | (1.153) | (1.191) | (1.534) |
| Total Industries/Event Occurrence | 74/74 | 74/74 | 74/74 | 74/74 | 74/74 |
| Observations | 336 | 336 | 336 | 336 | 336 |
| Log Pseudolikelihood | 265.231 | 267.619 | 267.901 | 270.563 | 270.927 |
| Chi-squared Statistic | 47.87*** | 92.51*** | 90.37*** | 88.51*** | 85.04*** |

Significance levels: *10%, **5%, ***1%.
Source: see text. All specifications use robust standard errors clustered by SIC3 industry and country (in parentheses).

Table 4: Robustness Check, Varying Periods of Analysis

| | A | B | C | D |
|---|---|---|---|---|
| DV: Log(Years to Event Occurrence) | New Industry | 0.5% Capital | New Industry | 0.5% Capital |
| Log(Per Capita Income) (Current US$) | 0.266 | 0.339 | -0.323 | -0.489** |
| | (0.314) | (0.261) | (0.238) | (0.241) |
| Country Fixed Effect (Japan = 1) | 0.992 | 1.531 | -3.407** | -5.024*** |
| | (2.493) | (2.113) | (1.627) | (1.788) |
| Average Firm Capitalization (Current US$) | -0.008*** | -0.008*** | 0.0005 | -0.004 |
| | (0.002) | (0.001) | (0.001) | (0.004) |
| Capital Share of Related SIC3 Industries (%) | -0.138 | -0.055** | -0.038 | -0.020 |
| | (0.095) | (0.028) | (0.035) | (0.023) |
| SIC3 Capital Intensity | 0.017*** | 0.015*** | -0.974*** | -1.017** |
| | (0.006) | (0.005) | (0.353) | (0.456) |
| Country F.E. x Average Firm Capitalization | -0.156*** | -0.164*** | -0.058* | -0.065** |
| | (0.038) | (0.038) | (0.033) | (0.031) |
| Country F.E. x Related SIC3 Capital Share | 0.138 | 0.055** | 0.043 | 0.024 |
| | (0.095) | (0.028) | (0.036) | (0.024) |
| Country F.E. x SIC3 Capital Intensity | -1.405* | -1.529** | 0.474 | 0.269 |
| | (0.724) | (0.705) | (0.743) | (0.769) |
| Year trend | -0.003 | 0.003 | -0.016 | 0.011 |
| | (0.027) | (0.020) | (0.012) | (0.012) |
| Constant | 7.002 | -4.252 | 36.687 | -14.128 |
| | (48.444) | (35.993) | (22.850) | (21.601) |
| Period of analysis (U.S.) | 1860-1910 | 1860-1910 | 1850-1900 | 1850-1900 |
| Net Effect (Japan) | 0.493 | 0.998 | -3.560** | -5.260*** |
| | (2.475) | (2.094) | (1.564) | (1.745) |
| Total Industries/Event Occurrence | 61/61 | 80/80 | 62/62 | 74/64 |
| Observations | 122 | 160 | 236 | 324 |
| Log Pseudolikelihood | 235.420 | 302.451 | 236.632 | 227.395 |
| Chi-squared Statistic | 1022.33*** | 603.11*** | 72.56*** | 64.32*** |

Significance levels: *10%, **5%, ***1%.
Source: see text. All specifications use robust standard errors clustered by SIC3 industry and country (in parentheses).

Table 5: Robustness Check, Higher Total Capital Stock Threshold

| DV: Log(Years to 1% Mfg Capital Stock) | A | B | C | D | E |
|---|---|---|---|---|---|
| Log(Per Capita Income) (Current US$) | -0.005 | 0.314 | 0.284 | 0.313 | 0.730* |
| | (0.243) | (0.232) | (0.244) | (0.290) | (0.378) |
| Country Fixed Effect (Japan = 1) | 0.306 | 1.940 | 1.745 | 1.354 | 4.405* |
| | (1.374) | (1.346) | (1.433) | (1.767) | (2.462) |
| Average Firm Capitalization (Current US$) | | -0.005*** | -0.005*** | -0.004*** | -0.003*** |
| | | (0.001) | (0.001) | (0.001) | (0.001) |
| Capital Share of Related SIC3 Industries (%) | | | -0.033 | -0.051** | -0.055* |
| | | | (0.024) | (0.026) | (0.029) |
| SIC3 Capital Intensity | | | | -0.750** | -0.465 |
| | | | | (0.370) | (0.425) |
| Country F.E. x Average Firm Capitalization | | -0.187** | -0.182** | -0.187** | -0.197** |
| | | (0.083) | (0.082) | (0.081) | (0.081) |
| Country F.E. x Related SIC3 Capital Share | | | 0.015 | 0.033 | 0.036 |
| | | | (0.026) | (0.027) | (0.030) |
| Country F.E. x SIC3 Capital Intensity | | | | 0.848 | 0.430 |
| | | | | (1.079) | (1.137) |
| Year trend | | | | | -0.023* |
| | | | | | (0.012) |
| Constant | 3.551*** | 2.156* | 2.520* | 2.910* | 44.242** |
| | (1.321) | (1.244) | (1.348) | (1.561) | (21.981) |
| Net Effect (Japan) | | 1.727 | 1.387 | 1.010 | 4.020* |
| | | (1.330) | (1.422) | (1.634) | (2.330) |
| Total Industries/Event Occurrence | 84/52 | 84/52 | 84/52 | 84/52 | 84/52 |
| Observations | 410 | 410 | 410 | 410 | 410 |
| Log Pseudolikelihood | 150.024 | 158.468 | 159.879 | 160.780 | 161.964 |
| Chi-squared Statistic | 1.97 | 58.99*** | 64.03*** | 93.32*** | 109.69*** |

Significance levels: *10%, **5%, ***1%.
Source: see text. All specifications use robust standard errors clustered by SIC3 industry and country (in parentheses).