Explorations in Economic History 47 (2010) 325–346

Contents lists available at ScienceDirect

Explorations in Economic History

journal homepage: www.elsevier.com/locate/eeh

Comparative output and labor productivity in manufacturing between China, Japan, Korea and the United States for ca. 1935 – A production-side PPP approach ☆

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ARTICLE INFO

Article history:
Received 9 December 2008
Available online 1 November 2009

Keywords:
Production-side (industry-of-origin) purchasing power parity (PPP)
Unit value ratio
Comparative output and labor productivity
Comparative advantage
Economic development

ABSTRACT

Following the standard industry-of-origin methodology to measure production-side purchasing power parities (PPPs), this study for the first time provides a set of unit value ratios (UVRs) of manufacturing products between China, Japan, Korea and the US, based on which it derives PPP estimates for individual manufacturing industries for these East Asian countries with the US as the benchmark for ca. 1935. The estimated PPP for total manufacturing suggests that the relative level of the producer price in China, Japan and Korea was about half to two thirds of the prevailing market exchange rates, respectively. The estimated PPPs are used to calculate comparative output and labor productivity for individual industries of these countries for ca. 1935. It shows that the size of factory manufacturing in Japan was 12 percent of the US level and in China only about one percent of the US level. In terms of comparative labor productivity, measured as PPP$ per hour worked, Japanese and Korean manufacturing was 24 and 23 percent of the US level, whereas Chinese manufacturing was only 7 percent of the US level.

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1. Introduction

The post-World War II rapid economic growth of the East Asian economies cannot be well understood without a proper measure of the pre-WWII economic conditions in an internationally comparative framework. What is missing in the conditional convergence literature is a measure on real production costs at industry level especially for producer goods manufacturing that plays a key role in modern economic development.

The level of a country's real per capita GDP measured by expenditure-side purchasing power parities (PPPs) is by nature a measure of the country's welfare level relative to that of the benchmark country. While it may suggest the country's relative stage of economic development, it does not *directly* benchmark the country's industrialization level and (industry-specific) labor productivity.[1] It has been widely accepted that the "industry-of-origin" or production-side PPP approach is a more appro-

☆ The authors are indebted to very helpful comments and suggestions by Steve Broadberry, Debin Ma, Angus Maddison, Thomas Rawski, Osamu Saito, Jeffery Williamson, as well as participants at the Harvard–Hitotsubashi–Warwick Conference in Venice, 2008. Part of this work was preliminarily presented at an international workshop, "Asia Pacific Seminar on World Economic Performance: Past, Present and Future", organized by the Institute of Economic Research (IER) at Hitotsubashi University in Kunitachi, 2007. The China part of the PPP estimation was conducted and the full version of the paper was drafted when Harry Wu visited IER in June and October, 2008, from The Hong Kong Polytechnic University. The financial support of the Global COE Program, "Research Unit for Statistical and Empirical Analysis in Social Sciences (Hi-Stat)" of IER, to his visits is gratefully acknowledged.

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[1] The expenditure PPP approach was pioneered by Gilbert and Kravis (1954) and developed by Kravis et al. in the International Comparison Program (ICP) since the 1960s and resulted in the Penn World Tables (see Kravis et al., 1982; Summers and Heston, 1991).

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doi:10.1016/j.eeh.2009.08.003

priate and direct method for measuring such conditions between countries (see Rostas, 1948; Paige and Bombach, 1959; Maddison, 1970, 1983).[2] This is because the production approach measures the real factor costs of production at industry level relative to those of the benchmark country, which takes into account the prices of both tradables and (implicitly) non-tradables, and therefore it can shed important light on the country's comparative advantage and international competitiveness.

This study attempts to fill this gap in the literature by constructing production-side PPPs for manufacturing industries to measure pre-WWII comparative output and labor productivity for three major East Asian economies, China, Japan and Korea, with the US as the reference country for ca. 1935 – the best pre-war period. This is particularly important for the understanding of the pre-WWII economic conditions in China. Compared with Japan and Korea,[3] historical macroeconomic statistics for China are sketchier. Solid economic statistics for standard national accounts are only available for the mid-1930s, thanks to the pioneering work on constructing China's GDP for the period 1931–36 by Ou (1947a,b), Liu (1946), Liu and Yeh (1965) and Yeh (1977). We argue that by benchmarking China with the leading regional (Japan) and international (the US) economies where better and longer time series data are available, together with other social and economic information, we may find a sensible way to quantitatively position China. Of course, focusing on one benchmark (currently 1935) is insufficient to anchor the long historical course of China's industrialization that began towards the end of the Qing Empire following the First Opium War, but it is an important starting point.[4]

Like many production-side PPP studies, this study concentrates on the manufacturing sector. Although there are generally more data available for manufacturing than for other industries, it is the importance of manufacturing in modern economic development rather than the data availability that is the major motivation behind most studies. Among all industries, manufacturing plays the most important role especially at the early stage of industrialization. It is the most dynamic sector because manufactured goods have a relatively high income elasticity of demand; they are highly tradable and have greater potential to gain from specialization and economies of scale through trade. Manufacturing growth is also the most important factor behind innovation and hence technological progress. Therefore, as found in many studies, the substantially rising share of manufacturing is almost a universal feature of rapid structural transformation at the early stage of industrialization (Kuznets, 1971; Chenery et al., 1986).

In addition, a production-side PPP study can help crosscheck existing expenditure PPP estimates for the same countries during the same period. In particular, this study may crosscheck and complement recent studies for Japan/China, Japan/US and China/US for ca. 1935 using the expenditure PPP approach (for example, see Fukao et al., 2007).[5] In theory, a country's PPP GDP estimated by expenditure and production approach, respectively, should be well reconciled and the difference, if there is any, should be explained by the terms of trade effect (Feenstra et al., 2008). A production-side PPP study on manufacturing is one important step towards that goal.

This paper proceeds as follows. In Section 2 we provide a general picture of the economies of China, Japan, Korea and the US in terms of output and employment structures as well as foreign trade by major commodity groups, which serves as a useful background for the whole study. Section 3 presents the standard industry-of-origin PPP approach and discusses the key measurement issues concerned. In Section 4, data sources are provided and problems are discussed for individual countries. In Section 5, we report the estimated PPPs and discuss the results against the background of cost conditions in individual industries between countries in comparison. In Section 6, we apply the estimated PPPs to cross country output and labor productivity comparisons. Finally, we conclude this study in Section 7.

2. The Chinese, Japanese, Korean and US economies in the mid-1930s

The selected countries in this study are fairly representative of different stages of modern economic development. By the mid-1930s, while the US was the world's leading industrial power, just recovered from the Great Depression in 1929–33, the Japanese economy had already undergone a rapid catch up with the West in industrialization that began during the Meiji period (1868–1912).[6] China's modern industrial development was motivated by its successive defeats in wars with the Western powers since the First Opium War (1840), as well as domestic rebellions of increasing severity,[7] but this development had been slow and largely defence-oriented. Japan's rise as the major regional military power in response to China's military build

[2] See Maddison and van Ark (2002) for a comprehensive review of the industry-of-origin PPP approach developed in the International Comparison of Output and Productivity (ICOP) program led by Angus Maddison at the University of Groningen.

[3] Among the East Asian economies, the most consistent and reliable long-term GDP series going back to the late-19th century are available only for Japan, partly thanks to the efforts of the Long-Term Economic Statistics (LTES) project under the leadership of Kazushi Ohkawa at the Institute of Economic Research of Hitotsubashi University in Japan, leading to a publication of 14 volumes for Japan (an abridged English version by Ohkawa and Shinohara, 1979). The Hitotsubashi group extended this line of research to two former Japanese colonies, Taiwan and Korea, with the 1988 publication of a statistical volume compiled by Mizoguchi and Umemura. The volume provides annual estimates of GDP and its various components for these two economies during the period of Japanese occupation based on the detailed economic statistics of the colonial administrations.

[4] Such a historical benchmark study is also significant for checking PPP estimates for the modern Chinese economy. See studies on China/US production PPPs for manufacturing industries by Szirmai and Ren (2000) and Wu (2001).

[5] Fukao et al. (2007) constructed expenditure PPPs for Japan/China, Japan/US and China/US ca. 1935. Earlier studies by these authors (Fukao et al., 2006; Yuan and Fukao, 2002) also constructed expenditure PPPs for Taiwan and Korea for 1935.

[6] The Meiji Restoration (1868) was the catalyst for industrialization in Japan that led to the rise of the island nation as a major military power by 1905, under the slogan of "Enrich the country, strengthen the military" (Fukoku Kyōhei). See Ohkawa and Shinohara (1979), Beasley (1995) and Fukao and Saito (2006).

[7] The Taiping Rebellion (1851–1864) was certainly the most destructive and costly rebellion to the regime. Lesser rebellions at that time include Miao Rebellion (1860–72) and Nien Rebellion (1851–68).

Table 1
Basic national accounts indicators for countries in comparison, ca. 1935.

	USA	China[f]	Japan	Korea
Total GDP[a] (in mil US$)	65,400	9522	4445	651
Population (thousand persons)	127,250	528,000	69,254	22,899
GDP per capita (in US$)	514	18	64	28
GDP per capita[b] (expenditure PPP$)	514	45	143	66
Maddison GDP per capita[c] (expenditure PPP G-K$)	514	53	199	126
Structure of GDP[d] (%)	100.0	100.0	100.0	100.0
Agriculture, fishery, forestry	11.7	62.5	18.1	49.0
Mining	2.1	0.9	30.3	2.1
Manufacturing[e]	23.4	10.1		10.2
Construction	2.3	1.7	6.3	3.3
Utilities	3.8	0.7	10.2	2.5
Transportation	6.5	5.7		6.7
Other services	50.2	18.4	35.1	26.2

Sources: For total GDP, industrial composition of GDP and population, Chinese data are from, Yeh (1977, p. 97, Table 1) and Luo (2000, p. 27, Table 2), Korea data are from Kim (2008, pp. 392–393, Tables I-1 and I-2), Japanese data are form Ohkawa et al. (1974, p. 202), and the US data are from US Department of Commerce, Bureau of the Census (1976, part I, p. 224). The population estimate for China in the mid-1930s is controversial. Many researchers (see Ma, 2008, pp. 359–369) adopt the figure as 500 millions from Liu and Yeh (1965). We adopt the estimates by Luo (2000) whose work attempts to adjust the pre-war official estimates to fill gaps in infant and woman statistics, to re-estimate population statistics by the Princeton life-table approach using the 1929–31 survey data and vital statistics, and to include population for Tibet, Inner Mongolia and Manchuria.

[a] All figures measured in US$ in this table are simply converted by the prevailing market exchange rate. In 1935, 1 US$ was equal to 3.43 Japanese Yen and 3.01 Chinese Yuan (an average of 1934–36). Korean Yen = Japanese Yen.

[b] Based on Fukao et al. for the average of 1934–36 (2007, Table 8), suggesting a PPP converter as 3.21, 2.23 and 2.36 for China, Japan and Korea, or 31, 45 and 42 percent of the US price level, respectively.

[c] Derived from Maddison (2003, pp. 88 and 182), assuming that his estimate of $5467 for US in constant 1990 G-K$ is equivalent to $514 at 1935 prices, and his estimates for other countries relative to the US level are held (i.e. deflated by the same price index). This approach is different from Fukao et al. (2007, see Fig. 1 for the same comparisons in 1990 PPP$).

[d] Industry compositions of GDP are calculated in nominal terms of national currencies. Industry composition data for Japan is based on net domestic product.

[e] See Table 2 for the structure of manufacturing by factory production.

[f] Yeh (1977, p. 97, Table 1) estimated China's 1935 GDP at 1933 prices. We use weighted agricultural and industrial price indices for 1933–35 to adjust the estimate to 1935 prices.

up in the 1860s–1880s and Japan's success in defeating the Qing Imperial Navy in 1894 forced China to speed up its industrialization. However, political and social chaos in the early years of republican China (from 1911 to the mid-1920s) significantly impeded the course of China's industrial development. By the mid-1930s, which is our benchmark period, China had just enjoyed its first ever "golden decade" of industrialization, but it was still well below the level of Japan, as can be seen clearly in Table 1.

The Korean economy serves as a different reference in our comparison. Korea underwent its modern industrial development when it was held as a Japanese colony in 1910–1945. However, the Korean development was typically a colonial type concentrating on agricultural and primary resource-based manufacturing that complemented the resource-hungry Japanese economy (for example, see, Fukao et al., 2007; Kim, 2008; Mitsuhiko, 2008; Mizoguchi and Umemura, 1988). The integration of the Japanese and Korean economies through colonization may be one of the main reasons why Korea grew more rapidly than China and enjoyed a higher level of income (Table 1).

2.1. Income level and economic structure

Both the level and the structure of GDP in Table 1 suggest different stages of economic development in the countries in our comparison. The US was the largest economy in both total and per capita GDP and left all other economies far behind. For ca. 1935, in terms of total GDP measured by the market exchange rate, China was 15 percent of the US level, followed by Japan (7 percent) and Korea (1 percent). Measuring by per capita GDP (still at the market exchange rate) will more appropriately reflect the stage of development because of the removal of the population effect. As shown in the table, the level of per capita GDP was $514 for the US, $64 for Japan, $28 for Korea and $18 for China.

It is however more sensible to convert these per capita figures into PPPs. By applying the only available bilateral expenditure PPP estimates in Fukao et al. (2007) to the above figures, we can come out with per capita PPP estimates of $143 for Japan, $66 for Korea and $45 for China. These show that while Japan had already reached nearly one third of the US level of per capita PPP GDP, China had only achieved one tenth of the US level, and was even 30 percent below the Korean level. Here we also compare Fukao–Ma–Yuan estimates with those of Maddison (2003) to show the differences between the two studies.[8]

[8] See discussion in Fukao et al. (2007) about the differences in per capita PPP GDP estimates, especially for Korea between their work and that of Maddison (2003).

The GDP structure of these countries also reflects different stages of economic development. As shown in Table 1, for ca. 1935 China had the largest share in agriculture (62.5 percent), followed by Korea (49.0), Japan (18.1) and the US (11.7). In the same period, one fourth of the US GDP (25.5 percent) was produced by the industrial sector (manufacturing and mining). By contrast, as the country that experienced the most rapid catch up with the US, 30.3 percent of Japanese GDP came from industry, compared with only 12.3 percent in Korea and 11.0 percent in China. Furthermore, China's relative inferior position in industrialization is also reflected by the development of the so-called facilitating industries such as utilities and transportation (see Perkins, 1975, for detailed discussion of structural change in China). Only 6.4 percent of the Chinese GDP was produced by the facilitating industries, whereas the share was over 10 percent in both the US and Japan and about 9 percent in Korea.

2.2. Manufacturing structure

The structure of the manufacturing sector also indicates the different level of economic development in these countries. In Table 2, we first present the share of factory manufacturing in total manufacturing, which indicates to what extent the economy has transformed from traditional to modern manufacturing. We then examine the structure of factory manufacturing among these countries.

As Table 2 shows, the factory share of US manufacturing was 95.5 percent (given in the figures in parentheses under manufacturing GVA), compared with 72.3 percent in the case of Japan. Such a difference looks plausible given the stage of their development. Growth is inevitably imbalanced within the manufacturing sector during industrialization. Empirical studies have found that driven by the significant growth of intermediate demand in total production, investment goods industries are typically the fastest growing industries, followed by intermediate goods industries and then light industries that mainly produce consumer goods (Nishimizu and Robinson, 1984). Such observations should be confirmed by our country cases in this study.

To help our examination we can roughly re-classify all manufacturing industries into two groups: one consisting of agricultural or primary resource-based manufactures that largely concentrated on the production of "consumer goods" (including food, textiles, wood and paper products, excluding miscellaneous) which tended to be more labor-intensive and the other made up of mineral-based intermediate materials production and machinery manufacturing that focused on the production of "producer goods" (i.e. including chemicals, building materials, metals and machinery) which tended to be more capital-intensive. The re-grouping shows that the share of "consumer goods" in China and Korea was indeed high, about 66 and 56 percent of total manufacturing, respectively, whereas the same share in the US and Japan was 40 and 36 percent, respectively. As for the share of "producer goods", it was low in China (34) and Korea (44), but high in the US (60) and Japan (64). Obviously, the structure of Chinese and Korean manufacturing was much "lighter" or more labor-intensive than that of the US and Japan because China and Korea were still at the earlier stage of industrialization; by contrast, US and Japanese manufacturing were much "heavier" or more capital-intensive.

Furthermore, the structure of Korean manufacturing does not suggest that Korea was more industrialized than China. Although Korea had a smaller proportion of "consumer goods" manufacturing than China, 64 percent of the Korean "consumer goods" engaged in "food" whereas in China 65 percent of "consumer goods" were textiles (taking the group total as 100, Table 2). In the case of "producer goods", 37 percent of the Chinese heavy industries engaged in the production of "metals" and "machinery", whereas only 16 percent did so in Korea. By contrast, 59 percent of the Japanese "producer goods"

Table 2
Total and per employee gross value added in manufacturing, and modern manufacturing structure for countries in comparison, ca. 1935.

	USA	China	Japan	Korea
Total manufacturing GVA[a] (in mil US$)	19,496	1059	1575	68
Manufacturing GVA by factory[b] (in mil US$)	18,616 (95.5)	121 (11.4)	1138 (72.3)	51 (75.6)
GVA per factory employee[c] (US$)	2246	154	482	307
Structure of factory manufacturing[d] (%)	100.0	100.0	100.0	100.0
Food, beverage and tobacco	15.0	14.9	11.6	35.8
Textiles, wearing apparel, leather products	13.8	43.1	19.3	11.9
Wood and allied products	4.8	0.2	1.8	3.9
Paper, printing and publishing	6.9	8.1	2.9	4.6
Chemicals and allied products	19.0	13.4	18.6	29.2
Building materials	3.2	6.5	4.3	4.6
Basic and fabricated metals	13.3	4.8	15.9	4.2
Machinery and transportation equipment	19.4	7.8	22.0	2.6
Miscellaneous manufacturing	4.7	1.3	3.6	3.1

Sources: US data are from US Department of Commence (1936), Chinese data from Makino and Kubo (1997), Japanese data from The Ministry of Commerce and Manufacturing (Sho Ko-sho) (1935), Korean data from Kim (2008) and Chosen Government-General (1937).

[a] See Table 1 for market exchange rates used for conversion.

[b] The share of the factory sector is given in the brackets. See Section 4 for the definition of the factory sector.

[c] Since the employment here is based on numbers employed rather than hours worked, this estimation should not be taken as a strict measure of labor productivity. See Table 6 for the conversion of industry-level numbers employed into hours worked.

[d] Output shares are calculated in national currencies.

industries engaged in "metals" and "machinery", even higher than that of the percentage in the US (55). However, considering the integration of the Japanese and Korean economies, we argue that the overly "heavy" Japanese manufacturing might be complemented by the excessively "light" Korean manufacturing.

2.3. Trade patterns

The history of modern economic development has shown that countries at the early stage of development tend to export primary goods to exchange for manufactured goods especially machinery. As they become increasingly industrialized, their exports will become more concentrated on sophisticated manufactured goods and their imports will be mainly primary goods or (simple) manufactured goods that could be produced cheaply in low income countries. This is reflected by the trade structure of the countries in our comparison for ca. 1935. We can divide the commodities traded in Table 3 into three categories: (1) "primary goods" including "foodstuffs and live animals" and "raw materials, minerals, fuels", (2) "(relatively) simple manufactured goods" that includes all manufactured goods except "machinery and transport equipment" and (3) "sophisticated manufactured goods", that is, "machinery and transport equipment".

As Table 3 shows, with higher level of industrialization than China and Korea, the US and Japan exported more manufactured goods than primary goods. It should be noted here that resource endowment plays a role in determining trade patterns. Since the US is relatively resource rich and Japan is excessively resource scarce, the export of primary goods was extremely low in Japan (only 12 percent compared with 40 percent in the US). The case of China and Korea shows just the opposite: 67 percent of Chinese exports and 76 percent of Korean exports were primary goods. Again, the Korean case further supports our postulation about the "colonial integration" of the Korean and Japanese economies. It should be noted that China was also an important importer of primary goods (49 percent of total imports). Although China has a much larger territory than Japan, it is not rich in resource endowment on a per capita basis; further, China's poor infrastructure in the 1930s prohibited low-cost extraction of natural resources.

Table 3 also shows that 81 percent of Japanese exports focused on simple or less sophisticated manufactured goods, which seems excessive compared with the US (37 percent), China (33) and Korea (23). It is clear that in the mid-1930s, the US was the most important player in the export of machinery and transport equipment, accounting for 23 percent of its total exports. Japan's export of machinery was about 7 percent of its total exports, but the figure was only 1 percent in the case of Korea and zero for China.

Our review so far has drawn a simple background picture of the economic conditions of the countries in comparison for ca. 1935, including their levels of per capita income, patterns of economic structure, patterns of manufacturing structure, and structures of import and export trade. These patterns are in general logically coherent and suggest different comparative advantages of manufacturing industries in these countries, which will be checked later in our PPP exercise comparing the producer prices or factor costs of producing the same product in these countries.

Table 3
Export and import values for China, Japan, Korea and the US by major commodity group, ca. 1935. (In million US dollars; national currencies are converted at market exchange rate[e])

	USA		China		Japan		Korea	
	Export	Import	Export	Import	Export	Import	Export	Import
Total value	2243.1	2038.9	172.8	222.4	979.6	997.7	160.5	193.3
Food stuffs and live animals[a]	458.7	1074.4	37.1	59.5	97.2	583.9	94.4	32.3
Crude materials, minerals, fuels[b]	432.3	312.2	78.5	48.6	21.6	106.5	27.1	32.0
Chemicals	103.1	68.7	3.5	17.9	92.6	96.3	7.1	15.3
Textiles	456.2	306.9	29.1	18.3	474.7	19.0	17.2	54.2
Manufactured goods classified chiefly by material[c]	195.6	177.2	15.5	32.0	117.5	118.2	5.2	13.9
Machinery and transport equipment	520.9	14.5	0.7	17.9	70.8	46.7	1.5	18.4
Miscellaneous manufactured articles[d]	76.3	85.1	8.3	28.2	105.1	27.1	7.9	27.2
Of which								
"Primary"[f]	0.40	0.68	0.67	0.49	0.12	0.69	0.76	0.33
"Simple manufactured goods"[f]	0.37	0.31	0.33	0.43	0.81	0.26	0.23	0.57
"Sophisticated manufactured goods"[f]	0.23	0.01	0.00	0.08	0.07	0.05	0.01	0.10
As percentage of gross value of output (%)	3.9	3.6	2.5	3.2	22.0	22.4	24.7	29.7

Sources: The US data are for merchandise activities only, including re-export of foreign merchandise, from US Department of Commerce (1936, pp. 466–550, Tables 523–524). Data for Japan and Korea are the average of 1934–36, from Yamazawa and Yamamoto (1979, pp. 178–183), IER (2000) and Kim (2008, p. 111). Data for China are the average of 1933 and 1938 from IER (2000).

[a] Including beverages, tobacco, and animal and vegetable oils and fats.
[b] Excluding edible materials; including lubricants and related materials.
[c] Excluding textiles.
[d] Including other commodities and transactions not classified according to kind.
[e] See Table 1 for exchange rate in 1935.
[f] Primary" includes "food stuffs and live animals", "crude materials, minerals and fuels"; "simple manufactured goods" includes all manufactured except "machinery and transport equipment"; lastly, "sophisticated manufactured goods" = "machinery and transport equipment".

3. Methodology

Methodologically, we follow the standard approach of constructing the industry-of-origin PPPs developed by the International Comparison of Output and Production Program (ICOP) at the University of Groningen led by Angus Maddison (Maddison and van Ark, 1988; van Ark, 1993) and its recent practices especially in pre-WWII comparisons including a UK/US comparison by de Jong and Woltjer (2007) and two UK/Germany comparisons by Broadberry and Burhop (2007) and by Fremdling et al. (2007), all for 1935/36.[9]

The methodology and data used in sectoral comparisons differ significantly from the standard International Comparison Program (ICP) procedures. Price data for ICP are largely obtained from extensive price surveys conducted in the participating countries, but the industry-of-origin approach relies on price data implicit in the censuses of manufacturing. Results of separate price surveys are not systematically used. The product lists and specifications are also drawn from the census data. The aggregation methodology used here is quite simple because there are only bilateral comparisons involving two countries at a time. We cannot perform complicated multilateral methods to compute PPPs necessary to convert value aggregates because of data constraints. An important aspect of these production-side PPP comparisons is that along with price data, derived in the form of unit values, we also have quantity data at the product level. Therefore there is no need to use the concept of basic headings[10] which is central to the ICP work.

Let us begin with some basic notations. Let q and p refer to quantity and price, respectively, and superscripts B and X represent the base country and the country to be compared, respectively. Subscript i refers to manufactured product, j refers to the type of industry and k refers to the type of manufacturing branch, which is equivalent to the two-digit level "manufacturing industry" used in ISIC.[11]

In the standard ICOP industry-of-origin studies, prices are in fact unit values (UVs) as they are derived from data on values (v) and quantities (q) for specific manufactured products or broad categories of products: thus, for product i, $\text{UV}_i = \frac{v_i}{q_i}$. We can obtain unit value ratios (UVRs) by a direct comparison of UVs between two countries, which can be used in deriving PPPs at the branch and sectoral levels. In the industry-of-origin approach, a distinction is made between UVRs and PPPs. UVRs refer to product level price information and PPPs refer to price levels at more aggregated levels, e.g. from industries to branches, and then aggregated to the whole manufacturing sector.

The production PPPs are derived using a "pyramid" type of approach which consists of three steps. The first step involves the derivation of industry-specific PPPs based on prices of manufactured products belonging to a particular industry, aggregated using output or sales quantities as weights. The second step aggregates these industry-specific PPPs to yield branch-level PPPs. Finally, the third step uses these branch-level PPPs and aggregated to derive a single PPP for the whole manufacturing sector.

3.1. Step I: Industry-specific PPPs

Let p_{ij} and q_{ij} denote the price (=UV_{ij}) and quantity of manufactured product, respectively, i belonging to industry j that is considered to have matching specifications and quality. For all "matched products" which are considered as typical of the industry to which they belong, the PPPs for this industry using either country weights are derived as follows:

$$\text{PPP}_j^{XB(B)} = \frac{\sum_i^m p_{ij}^X q_{ij}^B}{\sum_i^m p_{ij}^B q_{ij}^B} \quad (i = 1, 2, \ldots, m) \tag{1}$$

for the Laspeyres Index using the base country quantity weights, and

$$\text{PPP}_j^{XB(X)} = \frac{\sum_i^m p_{ij}^X q_{ij}^X}{\sum_i^m p_{ij}^B q_{ij}^X} \quad (i = 1, 2, \ldots, m) \tag{2}$$

for the Paasche Index using the quantity weights of the country to be compared, respectively.

The Fisher Index formula is used to compute PPPs at the industry level. Taking the geometric average of the thus-constructed Laspeyres and Paasche indices we can obtain PPP for industry j as a Fisher Index:

$$\text{PPP}_j^{XB(\text{Fisher})} = \sqrt{\text{PPP}_j^{XB(B)} \times \text{PPP}_j^{XB(X)}} \tag{3}$$

The choice of the Fisher Index is largely guided by the number of desirable statistical, axiomatic and economic–theoretic properties resulting in labels like the "ideal index" and the "superlative index" (Diewert, 1992).

[9] Further, Choi (2006) and Kim and Park (2008) compared the labour productivity levels of the Japanese and the Korean manufacturing sector in the pre-war period. Their analysis is based on estimates of real gross output per worker. Using the approach of Rostas (1948) and Yukizawa (1977) compared the labour productivity levels of the Japanese and the U.S. manufacturing sector in the pre-war and the post-war period. Pilat (1994) compared labour productivity levels of the Japanese and the U.S. manufacturing sector for 1939 using his own estimates of PPP.

[10] For the purpose of ICP, basic headings are defined as the lowest level of aggregation at which expenditure share weights are available for the purpose of aggregation.

[11] In this study, due to data constraint, we have put the two-digit industries into larger groups within the manufacturing sector.

3.2. Step II: Branch-level PPPs

At this stage, the thus-constructed j industry-level PPPs are aggregated to k branch-level PPPs. These figures are obtained by the weighted average of sample industry PPPs using the gross value of output (GVO) of the sample industries as weights. The following formulas are developed especially to take into account the size effect of industries in aggregation (see van Ark, 1993).

The calculation in this step results in two k level PPPs, one at the quantity weights of the base country or the Laspeyres weights:

$$PPP_k^{XB(B)} = \frac{\sum_j^n \left[GVO_j^B \times PPP_j^{XB(B)}\right]}{\sum_j^n GVO_j^B} \quad (j = 1, 2, \ldots, n) \tag{4}$$

and the other at the quantity weights of the country that is compared with the based country or the Paasche weights:

$$PPP_k^{XB(X)} = \frac{\sum_j^n GVO_j^X}{\sum_j^n \left[GVO_j^X / PPP_j^{XB(X)}\right]} \quad (j = 1, 2, \ldots, n) \tag{5}$$

Using the same approach to Eq. (3), the Fisher PPP for k branch can be derived as follows:

$$PPP_k^{XB(\text{Fisher})} = \sqrt{PPP_k^{XB(B)} \times PPP_k^{XB(X)}} \tag{6}$$

3.3. Step III: Deriving PPP for manufacturing as a whole

The derivation of the PPP for total manufacturing follows a similar approach to Step II whereby PPPs are aggregated from the branch level to total manufacturing using the base country and alternative country branch-level weights, respectively. The geometric mean of the thus-constructed Laspeyres and Paasche indices finally gives the total manufacturing PPP.

These PPP estimation procedures require detailed product as well as industry-level data and involve intensive work in matching, weighting and aggregating at different levels. Product specification and quality are essential for unbiased estimation, but in most cases they could only be justified by limited information. Typical data problems are discussed in the next section.

4. Data for constructing PPPs

Three types of data are used in this study: (1) product data for constructing unit values (UVs) and hence deriving UVRs, (2) sub-industry and industry data for weighting and aggregating in PPP estimation and (3) value added and employment data for industry-level productivity analysis. Ideally, at each level the data should be available for "modern" and "traditional" components. In reality, survey or census data only cover the modern sector. In this section, we concentrate mainly on the data that are used in constructing PPPs, including sources, coverage and definition, industrial and sectoral classification, problems and how we deal with the problems. Details on the sources and data handling, often given in technical details, are provided in notes to the tables. Problems on various aggregate data for international comparison have been discussed in Section 2 and the data problems for productivity analysis are handled in Section 6.

4.1. Coverage[12]

For the PPP-based direct comparison at industry level, we could only and sensibly cover the "modern" component of each industry in these countries. For the comparison of the aggregate economy, wherever possible we cover both the "modern" and "traditional" components and sectors. First of all, we need to report how the "modern" and "traditional" sectors are defined in official statistics for each country, and if there is any problem in terms of compatibility and availability.

It is no surprise that only the modern sector is recorded in historical statistics. Data on the traditional economy are only estimates based on national censuses or limited scope surveys by researchers or authorities. Modern manufacturing in this study is conceptually defined as the production of products that is organized in factories where workers are brought together in a building or buildings to manufacture goods or supervise machines processing one product into another. However, as we can see below, the official criteria for "factory" vary greatly in the early 20th century because of the lack of international coordination in statistical standards.

In the US *Biennial Census of Manufactures 1935*, "factory" was defined as any enterprise that produced $5000 or more output a year (US Department of Commerce, 1938, pp. 4–6). By comparing the US census with other sources of official statistics, we have found that over 95 percent (Table 2) of US manufacturing was carried out in factories. In the Japanese *Census of Factories 1935*, a factory was defined as any enterprise that hired five or more workers and used machine power (Statistical

[12] Assistance in literature and information search provided by Yuhong Wei is gratefully acknowledged.

Division of the Ministry of Commerce and Manufacturing Minister's Office, 1937, "Preface", p. 1). In Korea, as explained in the *Statistics on Manufactured Products for 1935*, a factory was defined as any enterprise that hired at least 10 workers in production (Chosen Government-General, 1937, "Preface"). Despite strong Japanese influence, the Korean manufacturing statistics somehow doubled the employment criterion for factories.

In the case of China, the first national industrial census under the leadership of D.K. Lieu (Liu Ta-chün) (NRC, 1937; also see Lieu, 1955) conceptually followed the Chinese first *Factory Law*, passed in 1929[13] which defined a factory as an enterprise that hired at least 30 workers and also employed machine power. Study on manufacturing by Liu and Yeh (1965) is largely based on Lieu's three-volume survey report. According to the report, the survey itself actually included many factories that did not meet the *Factory Law* criteria. Volumes 2 and 3 also report data from those factories that did not meet the *Factory Law* criteria, but did not process such data seriously and compare them with those that met the criteria. In fact, Lieu's factory survey focused on large firms. The survey was conducted under the National Resource Committee (NRC) which belonged to the Military Committee of the Chinese Nationalist Government. The true purpose for the survey was a preparation for China's national defence rather than enhancing industrial statistics because large factories could be employed for military production. In this study, our calculations are based on a study by Makino and Kubo (1997) who adjusted Liu and Yeh's estimates for overlapping and inconsistent use of the Lieu's survey data. However, Makino and Kubo did not attempt to take into account the data from the factories in Lieu's survey that did not meet the *Factory Law* criteria.

To check the compatibility of factory criteria among the countries in our comparison we use our PPP estimates in Section 5 and estimates for hours worked and output per worker in Section 6 to calculate the gross value of output (GVO) in 1935 PPPs for an enterprise that meets the minimum criteria for "modern factory" in China, Japan and Korea, respectively. Compared with the $5000 GVO criterion in the US statistics, the implicit GVO criterion was $6431 for Japan, $19,389 for China, and $7356 for Korea.[14] If the estimate for China is now assumed to be lowered by two thirds to include the factories below the *Factory Law* criteria,[15] which means 10 workers per factory assuming the same productivity, it will give an estimate of $6463, almost the same as the above estimate for Japan. Since the minimum employment criterion for a Japanese factory is five workers, it appears that to produce the same output as in Japan, a Chinese factory had to hire 10 workers whereas a Korean factory hired 8.5 workers (implied by 85 percent of minimum $7356 GVO for Korea). These rough estimates suggest that the underlying minimum output requirement for factories might be quite similar among the three East Asian economies.[16] It should be noted that this exercise by no means suggests that factory data of individual countries used in this study can be converted to the same standards; rather it provides a useful reference for understanding the estimates.

4.2. Industrial classification

Statistical classification of industries only and inevitably covers factory-based data, excluding traditional activities in manufacturing. In this study, we classify modern (factory) manufacturing into nine industries as used firstly in Table 2 and then throughout the study. Our classification is based on the Japanese standard,[17] which is largely compatible with the two-digit or some combination of the two-digit industries as defined in ISIC (International Standard of Industrial Classification). As the Korean classification follows the Japanese standard, all we need to do is to reconcile the Chinese and US data with the Japanese standard. For the US data, this is not a difficult task because they contain detailed data on sub-industries and hence it is easy for us to check compatibility and to re-classify them into broader industrial groups as used in this study.

There are two main sources for the Chinese data. The first one was China's first national-income account constructed by Ou Pao-san during 1941–46, which resulted in a two-volume publication in Chinese in 1947 (Ou, 1947a,b).[18] The work concentrated mainly on 1933, reflecting the detailed survey data for that year which had been previously compiled by D.K. Lieu in 1937 (see NRC, 1937). Since Ou's work followed the Western concepts of national income,[19] his industrial classification is acceptable.

13 The author and publication date of the *Factory Law* are unclear. As cited in *Pacific Affairs* in February 1929 (vol. 2, no. 2, pp. 73–76, *Pacific Affairs*, University of British Columbia), according to a Kuo Min News dispatch from Nanking on December 3, 1928, China's first *Factory Law* had been drafted by the Ministry of Industry, Commerce and Labour and discussed by the Legal Commission of the Ministry. According to the citation in the *Cambridge History of China*, vol. 12 (Part I) (Footnote 14, p. 42), the *Factory Law* was issued in 1929. However, the official record shows that the *Factory Law* was promulgated on December 30, 1932, and published by Commercial Press in *Comprehensive Collection of Laws and Regulations of the Republic of China*, vol. 3 (1935, pp. 3410–3414).

14 We first calculate output in PPPs based on estimates reported in Tables 4, 7 and 8, which give PPP$12,609 for Japan, PPP$30,296 for China and PPP$16,346 for Korea, and we then convert the results to US dollars by market exchange rate/PPP ratios that are also available in Table 4.

15 This assumption is not too strong because only 20 percent of the factories in Lieu's survey met the *Factory Law* standard, i.e. 3450 out of 18,000 (NRC, 1937).

16 It would be unrealistic to assume that factories in any of these Asian economies were close to the US standard on average in 1935. In fact, the data on US total manufacturing output and employment implies that based on average productivity, a US firm only needed to hire one worker to qualify as a "factory" in the official statistics, which suggests that the US traditional, non-factory manufacturing had largely disappeared by 1935.

17 There are also some adjustments to the Japanese data. For example, the paper industry is included in chemicals in the Japanese classification, which has to be re-classified into paper, printing and publishing industry.

18 See an English-language summary of the work that is published in the *Journal of Political Economy* (Ou, 1946).

19 Ou's short bibliography by Trescott (1996) explains how his work was likely highly influenced by the Western concepts of national income: "Ou Pao-san went to Harvard for graduate study in 1936 and completed an MA concentrating on agricultural economics. He then spent a year studying in Berlin, visited Cambridge and became acquainted with Piero Sraffa. Returning to Harvard in 1939, he received a strong exposure to Keynes's ideas from Alvin Hansen and Seymour Harris. He perceived the potentialities for national-income estimation after reading Simon Kuznets's work, as well as pioneering studies of the national incomes of Sweden and Hungary. Ou returned to China in 1940 … [and helped by] five assistants from recent university graduates, [his] national-income project began in 194l and extended until 1946. … In 1947, support from the Rockefeller Foundation enabled Ou to return to Harvard to complete a Ph.D. John Black directed his dissertation [(see Ou, 1948)], which dealt with capital formation and consumers' outlay in China, making use of the national income estimates".

The second source was the work jointly done by two US-based economists Liu and Yeh (1965),[20] which subsequently revised Ou's work. Liu–Yeh's estimates raised China's GDP for 1933 by 37 percent, that is, from Ou's 21.77 billion yuan to 29.88 billion yuan at 1933 prices (p. 66). The differences between Liu–Yeh and Ou are empirical rather than conceptual and appear to be mainly in agriculture, factory manufacturing and handicrafts.

4.3. Commodity data for constructing PPPs

Following the standard production-side PPP approach, as explained in the methodology section, to derive the relative price of a product (or unit value ratio) between two countries in comparison at the same time we need to match the same product between the two countries and then derive the unit value for the product in the national currency for each country. This would be impossible without detailed census or survey data on manufacturing. Fortunately, by the mid-1930s advanced countries had conducted a manufacturing census regularly and some countries at their earlier stages of industrialization had begun to do so. For the US, Japanese and Korean data on value and quantity of manufactured products, we rely on the US *Bicentennial Census of Manufactures 1935* (US Department of Commerce, 1938), the Japanese *Census of Factories 1935* (Statistical Division of the Commerce and Manufacturing Minister's Office, 1937), and the Korean *Statistics on Manufactured Products 1935* (Chosen Government-General, 1937[21]). All of these sources refer to our benchmark 1935. We derive unit prices for matched products from these census data (for industry level weights we also refer to Nishikawa and Koshihara, 1981).

The Chinese data used in this study are, however, not straightforward and hence require more detailed explanations. We rely on three sources of data: (1) D.K. Lieu's *Report on a Survey of China's Industry*, vol. 2 (NRC, 1937); (2) *Archive Materials for Studies of Industrial and Agricultural Commodity Prices*, Shanghai Volume, compiled by the Office for Industrial and Agricultural Price Survey (OIAPS, 1956–57); and (3) Zhen Chen's *Study Materials of Industrial History in Contemporary China*, vol. 4, parts 1 and 2 (1961). To derive unit prices of matched products, we make the best use of Lieu's data as reported in Table 4 (vol. 2), referring to products produced by factories that hired at least 30 workers. Lieu's data are not comprehensive. The gaps in products are filled or supplemented by the information available in Chen (1961) and OIAPS (1956). However, both Lieu's and Chen's data are for 1933. To convert prices from 1933 to 1935, we calculate wholesale price indices for 1933–35 using product price data available in OIAPS.

We use gross value of output (GVO) weights to aggregate unit value ratios (UVRs) from product level to sub-industry and then to industry level to derive industry-level PPPs (see Appendix and Supplementary Tables for aggregations at different levels). As already mentioned, we use the Japanese classification as a basis to group all manufacturing activities into nine industries. The US, Japanese and Korean GVO data at industry and sub-industry levels are available from these countries' census data. The Chinese industry and sub-industry-level GVO data available in Lieu (NRC, 1937) are incomplete. In a study of China's industrial output in 1933, Makino and Kubo (1997) estimated factory output by industry, which conforms to the Japanese standard of industrial classification. Therefore, we use their GVO data as weights in aggregation, supplemented by information from Chen (1961).

5. Discussion of the estimated PPPs

Following the standard methodology for constructing industry-of-origin PPPs, we first conducted three comparisons, namely, China/Japan and Korea/Japan with Japan as the reference country, and Japan/US with the US as the reference country. The details of these comparisons are reported in Appendix Table A1, also in Supplementary Tables A2 and A3, respectively.[22] As expected, the coverage ratio between a less developed country and a more developed country can vary greatly due to differences in industrial structure. In the China/Japan comparison, about 72 percent of Chinese products and 30 percent of Japanese products are covered, and in the Japan/US comparison, the ratio is about 32 percent for Japan and 10 percent for the US. However, in the Korea/Japan comparison, the ratios are very close, 41 and 45 percent, respectively.[23]

In Table 4, to make our PPP estimates easy to follow we use Japan as the bridge country to re-base China and Korea to the US, and report a summary of the US$-based PPP estimates and relative price level by industry.

The results in Table 4 show that the PPP for total manufacturing is highest for China (1.91 yuan/$), followed by Korea (1.54 yen/$) and Japan (1.75 yen/$). Compared with the prevailing market exchange rate (MER), the PPP-implied relative producer price level for Chinese manufacturing (i.e. yuan PPP divided by yuan MER) is 0.64, suggesting that for the *matched* manufactured products, the cost level (as reflected by producer prices in the comparison) of Chinese manufacturing was 36

[20] Estimates in Yeh (1977) are basically the same as those in Liu and Yeh (1965). However, Yeh provides a time series for 1931–36, of which the data for 1935 are used in this study.

[21] No official publication date is available. We have chosen "1937" as a guessed publication date because the Japanese census for 1935 was published in 1937.

[22] Table A1 is published in Appendix as an example of our work in matching producer prices. Due to limited space, Supplementary Tables A2 and A3 can be found in the online version of the paper.

[23] For example, the corresponding figures are 35.7 and 17.2 percent for a China/US manufacturing comparison (Wu, 2001), 18.5 and 16.3 percent for a USSR/US manufacturing comparison, 32.0 and 23.2 percent for a Czechoslovakia/West Germany comparison, 33.1 and 19.3 for a Hungary/West Germany comparison, and 33.6 and 19.4 for a Poland/West Germany comparison (Kouwenhoven, 1996, Table 5). Even for industrialized market economies, the coverage is not high. For example, a West Germany/US comparison by van Ark and Pilat (1993) manages to cover only 24.4 percent of West Germany's manufacturing output and 24.8 percent of US manufacturing output.

Table 4
Summary of estimated purchasing power parities by manufacturing industry, China/US, Japan/US and Korea/US, ca. 1935.

	China/US		Japan/US		Korea/US	
	PPP Yuan/$ (Fisher)[a]	Relative price level (MER = 3.01)	PPP Yen/$ (Fisher)[a]	Relative price level (MER = 3.42)	PPP Korean Yen/ $ (Fisher)[a]	Relative price level (MER = 3.42)
Total manufacturing	1.91	0.64	1.75	0.51	1.54	0.45
Food, beverage and tobacco	1.95	0.65	2.80	0.82	2.35	0.69
Textiles, wearing apparel[b]	1.70	0.57	1.24	0.36	1.52	0.44
Wood and allied products	1.86	0.62	2.19	0.64	1.55	0.45
Paper, printing and publishing	1.56	0.52	1.38	0.40	1.75	0.51
Chemicals and allied products	1.57	0.52	1.36	0.40	0.97	0.28
Building materials	1.30	0.43	1.42	0.41	1.39	0.41
Basic and fabricated metals	2.43	0.81	2.35	0.69	1.82	0.53
Machinery[c]	2.39	0.80	2.02	0.59	1.07	0.31
Miscellaneous manufacturing	0.89	0.29	0.63	0.18	0.95	0.28

Source: Authors' estimation. See Appendix Table A1, also in Supplementary Tables A2 and A3 for details.
[a] Fisher PPP is a geometric mean of Laspeyres and Paasche PPPs (see Eq. (3) for industry PPPs and Eq. (6) for branch PPPs).
[b] Including leather products.
[c] Including transportation equipment.

percent lower than the US level as suggested by the market exchange rate. By the same calculation, the price level in Korean and Japanese manufacturing was 45 and 51 percent of the US price level, respectively.

To assess the plausibility of the production PPP estimates, we compare them with the expenditure PPPs in Fukao et al. (2007, Table 4) for China, Japan and Korea for ca. 1935 which also use the US as the reference country. It turns out that the production PPP-implied price levels for manufacturing are 100, 13 and 5 percent higher than the expenditure PPP-implied price levels for these countries. Despite such large cross country variations, the results are generally in line with what can be predicted by the theory that the non-tradables, as captured by PPPs, in less developed countries tend to be cheaper than the tradables. Fukao et al. (2007) also estimate the price level of the tradables in the final consumption of these countries. In the case of Japan and Korea our production PPP estimates are very close to their results, but this is not the case for China, where the figure is 60 percent higher than the price level for tradables estimated using the expenditure approach.

Theoretically, the price differences between the US and these East Asian economies are just as explained by the Balassa–Samuelson theorem. Balassa (1964) and Samuelson (1964) argue that because the productivity growth in the non-tradable goods sector is generally and substantially lower than the productivity growth in the tradable goods sector during the development process, there is a secular trend for the prices of non-tradable goods to rise relative to the prices of tradable goods. Since the US economy was much more developed and industrialized than the economies of other countries in the comparison, the higher price level in US is as expected and results from the higher cost of the non-tradables.

However, two questions have emerged from our production PPP estimates. The first one is why the gap between the PPP-implied price level and the market exchange rate appears to be too large to be in line with the empirical findings in general or with what could be predicted by the production PPP theory. Manufactures are generally tradable goods and by nature their PPPs are close to the market exchange rates (see Pilat and Prasada Rao, 1996; Prasada Rao and Timmer, 2003). If there is no serious sample bias towards low price products in our unit value matching exercise, our tentative conjecture is based on two likely factors: (1) a stronger demand for imports in these East Asian countries than the foreign demand for exports from these countries, hence driving up the exchange rate of foreign currencies (the US dollar) and (2) net capital outflows from these countries that also depreciated domestic currencies. Both deserve a separate research agenda.

Our second question is why China's price level appears to be much higher than Japan's. We approach the problem from two directions. On the one hand, the initial cost of industrialization in China was very high because of the high learning cost – China was then unquestionably below Japan on the learning curve. More importantly, the Chinese market for the new manufactured goods was less competitive because of the need for high initial investment in both physical and human capital which likely resulted in a higher cost in manufacturing the same product by Chinese factories than by Japanese factories.[24] On the other hand, the Japanese economy had in then more or less passed through the initial stage of industrialization and

[24] For example, to make a pair of sports shoes it would cost a Chinese factory 12 yuan but would cost a Japanese factory located in China 9.5 yuan (Chen, 1962, p. 700, Table 5).

Table 5
Relative prices of Chinese, Korean and US manufacturing by industry, ca. 1935 (Japan = 1).

	Chinese	Korea	USA
Total manufacturing	1.24	0.88	1.96
Food, beverage and tobacco	0.79	0.84	1.22
Textiles, wearing apparel	1.56	1.23	2.76
Wood and allied products	0.96	0.71	1.56
Paper, printing and publishing	1.28	1.26	2.47
Chemicals and allied products	1.31	0.71	2.52
Building materials	1.04	0.98	2.42
Basic and fabricated metals	1.17	0.77	1.45
Machinery	1.35	0.53	1.69
Miscellaneous manufacturing	1.61	1.51	5.46

Sources and notes: See Table 4.

enjoyed a more efficient factor market. Japan's integration with the Korean economy through colonization may have lowered its input costs.

Recent studies on the comparison of real wages seem to lend some support to our conjecture on the low cost of Japanese manufacturing. Studies by Bassino and van der Eng (2002) and Bassino (2005) find that daily nominal wages for unskilled workers and carpenters in Tokyo in 1935 were not much higher than those in Bangkok, Singapore, or Penang in British Malaya. As consumer price levels, particularly food prices, were much lower in those Southeast Asian cities, these studies suggest that real wages in Tokyo were lower than in those cities. Bassino's wage data show that the skill premium for carpenters vis-à-vis unskilled workers in Tokyo was smaller than in any of the Southeast Asian cities, indicating the existence of a large pool of skilled workers in Japan in comparison with Southeast Asia.[25] This appears to be supported by Godo and Hayami (2002) who show that in the 1930s, average years of schooling in Japan were already over 60 percent of the US level despite the much greater lag in per capita income. Studies by Williamson have shown the cost position of Japan from a different perspective (Williamson, 1998, Table 1; Williamson, 2002, Table 3). His estimates suggest that although wages in Japan were higher than in Korea and other Asian countries, there was a substantial drop in wage–rental ratio in Japan by 35 percent in 1935–38 from the level of 1930–34, which was not matched in Korea and other Asian countries during the same period.

It is interesting to examine our production PPP estimates for individual industries. It is not surprising to find that "metals" and "machinery" in China, "metals" in Japan, and "food" in Japan and Korea were most expensive to produce. For China, this seems to suggest a high learning cost, and for Japan and Korea it suggests a high cost of scarce resources. On the other hand, "textiles" in Japan and Korea, and "building materials" in all three countries were cheapest compared with those in the US. The case of "textiles" may suggest higher productivity in both Japan and Korea, and that the case of "building materials" may suggest lower labor costs in all three countries compared with those in the US. There is also the point that "building materials" are less affect by prices in the international market because they are mainly traded in the domestic market and used in construction which is largely non-tradable.

Since the level of economic development in China was closer to that of Japan than to that of the US, and historically, China and Japan were competitors, it is relevant to examine the industry-level PPPs using Japan as the benchmark, which are in fact our primary results (Table A1). After re-basing the PPP results of individual countries to Japan we present the relative price level for each country in total manufacturing and individual industries in Table 5.

First of all, such a re-basing explicitly shows that for the *matched* products the US price level was higher than that of Japan in all industries. This is as expected because for what could be produced in low income countries the US had lost its comparative advantage. The lower coverage rate in the US in the matching exercise with other countries suggests that resources had moved to higher value added or newly invented, more sophisticated manufactured products that had no counterparts in the low income economies.

Our focus here is, however, China. In the case of China, almost all industries, except for "food" and "wood", had higher factor costs (reflected by producer prices) than those of Japan. This is not observed in the case of Korea: thanks to its colonial integration with the Japanese economy, the cost of "machinery" in Korea was much lower than in Japan.[26] The results for China suggest that the high costs in modern Chinese manufacturing industries made it difficult to compete with foreign manufactured goods as well as with the domestic goods that could be produced using traditional technology. One may reasonably expect that the implicit high profits as suggested by the high prices could be one of the major factors that attracted foreign traders and hence motivated them to lobby for government interventions, including the use of military power, for the opening up of the China market.

[25] See further discussions on the wage gap between Japan and other countries with supporting data in Bassino and Ma (2005) and Allen et al. (2005).

[26] We find the product data used for Korea/Japan matching may have some problems. For example, there are huge price differences between the two countries in water tube boilers, steam engines, water turbines, winding machines and pump blowers (Supplementary Table A3 – available on request). However, after assuming their prices in the domestic market were the same as export prices, the Korean price level is about 80 percent of the Japanese level. Mismatching in quality and function of these machines could be a problem.

6. Comparative output and labor productivity

In this section, we apply the industry-specific PPPs in a cross country comparison of output and labor productivity. Output (in terms of gross value added) in PPPs provides an indicator for the size of an industry relative to the base country. Labor productivity measured as output per hour worked in PPPs reflects the level of capital deepening and the level of efficiency compared with the base country. Compared with output conversion based on the market exchange rate, the two indicators are more appropriate measures of the level of industrialization in an international comparison framework.

The data work required to derive these indicators is by no means easier than that required for the price comparisons in constructing PPPs because available historical statistics were not compiled in terms of value added and data required for estimating value added are insufficient. The data work and results reported below are still preliminary and subject to revision when more information is available.

6.1. Gross value added in PPPs

There are no gross value added data readily available for any country. Based on the available cost data recorded for factories, we define gross value added (GVA) as gross value of output (GVO) minus the cost of materials (M) and the cost of energy or electricity (E), that is,

$$\mathrm{GVA}_i^F = \mathrm{GVO}_i^F - M_i^F - E_i^F, \tag{7}$$

where subscript i indicates industry and superscript F stands for "factory", because only factory data can satisfy the data requirement for the estimation. This approach is similar to that used in the Japanese Long-Term Economic Statistics (Shinohara, 1972). To be consistent, we apply the same approach to all countries.

Since it is impossible to obtain a breakdown of cost data for non-factory or handicraft manufactures, we apply value added ratio (VAR) derived from the factory sector to estimate GVA for handicraft manufactures, that is,

$$\mathrm{GVA}_i^N = \mathrm{GVO}_i^N \times \mathrm{VAR}_i^F = \mathrm{GVO}_i^N \times \frac{\mathrm{GVA}_i^F}{\mathrm{GVO}_i^F} \tag{8}$$

where the superscript N stands for non-factory or handicraft manufacturing. However, since the value added ratio in the handicraft sector may be different from that in the factory sector and the difference may vary across industries, such a treatment may distort the real GVA and labor productivity for some handicraft industries, and hence for industries as a whole (factory plus handicraft). This is certainly an area that deserves further research.[27]

For the factory sector, the Japanese manufacturing GVA by industry are estimated based on data from the *Census of Factories 1935* (Statistical Division of the Commerce and Manufacturing Minister's Office, 1937, pp. 20–40), the US manufacturing GVA by industry are estimated using data from the *Bicentennial Census of Manufactures 1935* (US Department of Commerce, 1938, pp. 22–38), and the Korean manufacturing GVA by industry are based on data constructed by Kim for 1935 (2008, p. 111).

The case of China is a little more complicated as explained in Section 4. The most important information is from China's first factory census conducted by Lieu (NRC, 1937). Lieu's census was intended to cover all factories as defined by *Factory Law*, i.e. enterprises that hired 30 or more workers and used machine power. However, the census went beyond the original scope to include enterprises with fewer than 30 workers, because in most locations there were many enterprises that could not satisfy the *Factory Law* criteria. More than 18,000 factories were eventually included in the census, and 3450 of these met the *Factory Law* standard. The total number is not certain because there is some overlap between the two categories as detected by Makino and Kubo (1997). In this study we directly use the revised data from Makino and Kubo.

Table 6 first presents the thus-constructed GVA data in national currencies for individual manufacturing industries and then converts the data to PPPs reported in Table 4. To include handicraft manufacturing, in the lower panel of Table 6 we report GVA for individual industries as a whole (factory plus handicraft). Further, for comparison with the US, in the last column of each country panel, a country/US index is provided for all industries.

The calculations show that for the factory sector, the size of Japanese manufacturing was 12 percent of the US level in PPP terms, whereas for China and Korea it was only 1 and 0.6 percent, respectively. However, given China's size and extremely uneven development across regions, it is useful to bear in mind that in the mid-1930s the "lower Yangtze" (Shanghai, Nanjing, Jiangsu and Zhejiang) produced 66 percent of total factory output in China proper (excluding Manchuria) (see Ma, 2008, Appendix Table 2).

When factory and handicraft manufactures are combined, the size of Japanese manufacturing rises to 16.6 percent of the US level, whereas for China the ratio increases to 10.9 percent of the US level.

It is also meaningful to examine the industries in each country that were distinctly larger than the size relative to the US for manufacturing as a whole. Excluding "building materials" (highly non-tradable), the industries comprised were "textiles"

[27] Ideally, if we can find some cost information on handicraft industry i that allows the derivation of a parameter λ to adjust the existing value added ratio derived from the factory sector of the same industry, we can better estimate VAR for the handicraft industry, i.e. $\mathrm{VAR}_i^N = \lambda_i \frac{\mathrm{GVA}_i^F}{\mathrm{GVO}_i^F}$. This λ may be applied to other handicraft industries that likely have similar value added ratios.

Table 6
Gross value added in national currencies and in PPPs by manufacturing industry, China, Japan and Korea in comparison with the US, ca. 1935.

	China			Japan			Korea[d]			US
	GVA[b] (mil. Yuan)	GVA (mil. PPP$)	GVA (US = 1)	GVA[b] (mil. Yen)	GVA (mil. PPP$)	GVA (US = 1)	GVA[b,c] (mil. Yen)	GVA (mil. PPP$)	GVA (US = 1)	GVA (mil. PPP$)
Factory										
Total manufacturing[a]	364	190	0.010	3893	2230	0.120	176	114	0.006	18,616
Food, beverage and tobacco	54	28	0.010	453	162	0.058	63	27	0.010	2789
Textiles, wearing apparel	157	92	0.036	750	605	0.236	21	14	0.005	2563
Wood and allied products	1	0	0.0004	71	32	0.037	7	4	0.005	886
Paper, printing and publishing	29	19	0.015	111	80	0.063	8	5	0.004	1286
Chemicals and allied products	49	31	0.009	725	534	0.151	51	53	0.015	3534
Building materials	24	18	0.031	167	118	0.199	8	6	0.010	594
Basic and fabricated metals	17	7	0.003	617	262	0.106	7	4	0.002	2469
Machinery	28	12	0.003	857	424	0.117	5	4	0.001	3614
Miscellaneous manufacturing	5	5	0.006	140	224	0.254	5	6	0.007	882
Factory plus handicraft										
Total manufacturing[a]	3881	2030	0.109	5387	3087	0.166	233	120	0.006	18,616
Food, beverage and tobacco	2707	1389	0.498	955	341	0.122				2789
Textiles, wearing apparel	746	438	0.171	974	786	0.307				2563
Wood and allied products	71	38	0.043	117	53	0.060				886
Paper, printing and publishing	59	38	0.030	171	124	0.096				1286
Chemicals and allied products	116	74	0.021	859	633	0.179				3534
Building materials	46	36	0.060	231	163	0.274				594
Basic and fabricated metals	43	18	0.007	630	268	0.108				2469
Machinery	66	28	0.008	1434	709	0.196				3614
Miscellaneous manufacturing	26	29	0.033	180	287	0.326				882

Source: Both factory and traditional GVA data are from the same sources as in Table 2. PPP converters are the estimates in Table 4.
[a] For more details of the industrial classification, see Table 2.
[b] Chinese, Japanese and Korean GVA figures are estimated based on the GVA/GVO ratios of individual countries which are calculated by the authors using information from Statistical Division of the Ministry of Commerce and Manufacturing (1937), Park (2008) and Ou (1946).
[c] Korean Yen = Japanese Yen.
[d] We find that some adjustment made by Park (2008) to include "handicraft" manufacturing in the Korean economy is illogical because it made some industries even smaller than the factory total after including "handicraft", e.g. wood products, printing and paper products, and chemicals. These must have distorted his estimates for other industries as well. We therefore decide to drop estimates for individual industries of the Korean "factory plus handicraft", but keep the value for total manufacturing for comparison.

in China; ‘‘textiles” and ‘‘chemicals” in Japan; and ‘‘food” and ‘‘chemicals” in Korea. Note that fertilisers were one of the main ‘‘chemicals” products in Japan and Korea that were used for farm production (food and textiles), which explains why ‘‘chemicals” were relatively larger in size.

6.2. Hours worked

Numbers employed can be very different from hours worked. The difference is caused by institutional and political factors such as laws and regulations and labor unions, labor market conditions that are related to demand and supply factors, nature of industry, i.e. level of safety or heath hazard, as well as culture or tradition that developed in history because of climate conditions and farming customs. Since these factors and conditions vary greatly among countries, in international comparisons it is important to convert numbers employed to hours worked.

In this study, data on working hours for Japan, Korea and the US are directly taken either from government statistics or other studies. The Japanese working hours in manufacturing for 1935 are obtained from the government *Handbook of labor statistics* compiled by the Statistical Division of the Cabinet Office (1935, pp. 96–99). The Korean working hours in manufacturing for 1939 are obtained from Chosen Government-General, Statistics on Manufactured Products (1941, pp. 4–5). For the US data on working hours, we use estimates by de Jong and Woltjer (2007, p. 23, Table 5).

The Chinese data on working hours are not straightforward. The 1935 issue of *China Economic Annals*, compiled by the Ministry of Industry (1935, pp. Q13–Q16), is perhaps the only official publication that collected almost all the then available surveys on working hours and working days in China in different industries and regions over the period 1932–34. Based on the data from these surveys, we estimate total and average annual working hours for individual industries for ca. 1935.

The results are reported in Table 7. It indeed shows that annual hours worked per person were very different among these countries and across industries. On average, the Korean manufacturing workers worked 2431 hours per year, compared with 2807 hours in China and 3132 hours in Japan, which were 34, 54 and 72 percent higher than the US figure of 1817 hours, respectively. Intuitively, the working hours in Japan may be overestimated and those in the US underestimated. Some studies have found that long working hours in Japan were indeed a long tradition and only changed very recently (see Japan Industrial Productivity Database – JIP, 2008). On the other hand, the estimate for the US by de Jong and Woltjer (2007) seems too low. If using the standard of 8 hours per working day and 6 days per week, the average US manufacturing workers only worked for 38 weeks, and by contrast the Japanese had to work for 65 weeks a year!

When we take a closer look at some industries in China and Korea, our findings suggest that the long working hours in Japanese manufacturing may not be impossible. In the case of ‘‘chemicals” in China the average annual working hours per worker were 3167, actually slightly more than the Japanese average. In the case of ‘‘wood” in Korea, the figure was 3097, very close to the Japanese average, but in the Korean ‘‘paper” industry, it was as high as 3690 or 18 percent more than the Japanese average working hours. Therefore, if the estimates for Japan, China and Korea are plausible for ca. 1935, the estimates by de Jong and Woltjer (2007) for the US may be too low and hence may exaggerate the labor productivity in the US in 1935.

6.3. Labor productivity in PPPs

Based on the estimates for gross value added in Table 6 and hours worked in Table 7, we can easily calculate labor productivity in PPPs in Table 8. Note that the estimates are only for the factory sector. For comparison with US labor productivity, we can also calculate a relative labor productivity index for China, Japan and Korea with the US as the reference (=1). It shows that on average, Japanese and Korean labor productivity in manufacturing in 1935 was very close, or PPP$0.30 and 0.28 per hour, respectively, whereas China was only 0.09 PPP$ per hour. In relative terms, in 1935 labor productivity in Japanese and Korean manufacturing was about 23–24 percent of the US level (=$1.24 per hour), whereas the labor productivity in Chinese manufacturing was less than 7 percent of the US level. Clearly, even if there were underestimation of the hours worked in US manufacturing, it may not change the pattern significantly. Given all other indicators for the level of economic development, especially per capita income, it is unlikely that the Japanese labor productivity would be more than one third of the US level in any case, which gives a useful reference for assessing the level of other economies.

At the industry level of each country, it shows that some industries enjoyed higher labor productivity than others as compared with the country average. Importantly, in Japan, we find almost all heavy or ‘‘producer goods” industries (i.e. ‘‘chemicals”, ‘‘building materials”, ‘‘metals” and ‘‘machinery”) had higher labor productivity than light or ‘‘consumer goods” industries, suggesting heavy industries had already played a major role at that stage of Japan’s industrialization. This was, however, not the case either in China or in Korea. In China, only ‘‘wood” and ‘‘building materials” enjoyed higher labor productivity than the manufacturing average, and in Korea only ‘‘food” and ‘‘chemicals”, enjoyed higher labor productivity than the manufacturing average. The results are in line with our findings on relative prices for individual industries and reflect the different stages of economic development of these countries.

7. Concluding remarks

This study uses the standard methodology for measuring industry-of-origin or production-side PPP, and compares the unit values of manufacturing products in China, Japan, Korea and the United States, derives unit value ratios (UVRs) and

Table 7
Numbers employed, hours worked and annual hours worked per person by manufacturing industry, China, Japan, Korea and the US, ca. 1935 (factory only).

	China			Japan			Korea			US		
	Numbers employed (×1000)	Hours worked (×1000)	Hours per person	Numbers employed (×1000)	Hours worked (×1000)	Hours per person	Numbers employed (×1000)	Hours worked (×1000)	Hours per person	Numbers employed (×1000)	Hours worked (×1000)	Hours per person
Total manufacturing	784	2201	2807	2361	7394	3132	167	407	2431	8290	15,062	1817
Food, beverage and tobacco	71	183	2577	158	468	2958	49	108	2209	929	1823	1962
Textiles, wearing apparel	505	1439	2850	1007	3231	3209	31	80	2551	1806	3203	1774
Wood and allied products	2	4	2790	85	253	2975	6	23	3690	632	1237	1958
Paper, printing and publishing	44	129	2914	61	197	3256	7	22	3097	475	901	1896
Chemicals and allied products	63	201	3167	229	716	3133	43	83	1930	1218	2304	1892
Building materials	30	78	2559	93	278	3003	10	26	2573	263	476	1812
Basic and fabricated metals	23	66	2895	218	671	3081	7	19	2696	1121	2032	1813
Machinery	38	114	2974	367	1160	3158	7	20	2758	1492	2698	1809
Miscellaneous manufacturing	8	20	2535	144	443	3075	6	14	2380	355	596	1682

Source and notes: See discussion in the text.

Table 8
Comparative labor (manhour) productivity in PPPs by manufacturing industry, China, Japan and Korea in comparison with the US, ca. 1935 (factory only).

	China[b]		Japan		Korea		US
	Labor productivity (in PPP$)	Labor productivity (US = 1)	Labor productivity (in PPP$)	Labor productivity (US = 1)	Labor productivity (in PPP$)	Labor productivity (US = 1)	Labor productivity (in PPP$)
Total manufacturing[a]	0.09	0.07	0.30	0.24	0.28	0.23	1.24
Food, beverage and tobacco	0.15	0.10	0.35	0.23	0.25	0.16	1.53
Textiles, wearing apparel	0.06	0.08	0.19	0.23	0.17	0.22	0.80
Wood and allied products	0.09	0.12	0.13	0.18	0.19	0.27	0.72
Paper, printing and publishing	0.15	0.10	0.41	0.29	0.21	0.15	1.43
Chemicals and allied products	0.15	0.10	0.75	0.49	0.64	0.42	1.53
Building materials	0.23	0.19	0.42	0.34	0.23	0.18	1.25
Basic and fabricated metals	0.11	0.09	0.39	0.32	0.21	0.17	1.22
Machinery	0.10	0.08	0.37	0.27	0.21	0.16	1.34
Miscellaneous manufacturing	0.27	0.18	0.50	0.34	0.41	0.28	1.48

Source: See Tables 6 and 7.
[a] See Table 2 for more details of the classification of manufacturing industries.
[b] For China, estimation is based on 1933 nominal GVA and 1933–35 price changes.

hence estimates relative price levels for individual manufacturing industries for ca. 1935 with the US as the reference country. Unlike the expenditure PPP approach, this production approach allows us to more rigorously examine the pre-WWII economic conditions in East Asia from the production side in terms of producer costs and labor productivity in manufacturing relative to those in the US.

Based on estimated production PPPs as well as estimated gross value added and hours worked for these countries, we find that for ca. 1935 the producer price level in China, Japan and Korea was 64, 51 and 45 percent of the US level in manufacturing the same products as implied by the prevailing market exchange rates of these countries' currencies against the US dollar, but the labor productivity in these countries was only 7, 24 and 23 percent of the US level, respectively. Apparently, the higher price level in the US is justified by its much higher labor productivity implying more advanced technology. However, a comparison among the three East Asian countries reveals some inconsistencies. Japan and Korea had almost the same productivity and their producer price levels were close. By contrast, China's productivity was not much more than one third of the level of Japan and Korea but its producer price level was much higher than theirs. Such a striking finding for China raises two challenging questions: did Chinese manufacturing produce in line with its comparative advantage? If not, what drove China's earlier industrialization?

Let us think about the first question. In order to understand price gaps and comparative advantage, we need to assume that Japan's exports and China's exports were not perfect substitutes. Even if China's prices were higher than Japan's, China could still export substantial amounts of textiles if they were cheaper in comparison with the world average prices. To properly explain price level gaps, we need to take into account two factors, factor cost and the level of technology (as reflected by labor productivity, input/output ratio of intermediate inputs, and unit capital cost). China's factor costs might be much higher than those in Japan. Since China's per capita GDP was about one third of the Japanese level (Table 1), it is reasonable to assume that China's wage level may have been one half of the Japanese level. If China's labor productivity in textiles was one third of the Japanese level (Table 8), then China's unit labor cost or wage–labor productivity ratio must be 50 percent higher than that of Japan. On the other hand, China's unit intermediate input cost could also be higher than that in Japan because of higher prices of cotton yarns and inefficient production processes. Therefore, we can expect that China's price level in textiles would be higher than that in Japan.

The Heckscher–Ohlin theory assumes identical technology, but in the mid-1930s the technology levels were very different as suggested in Table 8. If we consider the factor cost differences and technological differences simultaneously, we can expect that China's comparative advantage mainly existed in primary industries and labor-intensive products including some types of textiles and garments. Table 3 shows that China's net exports mainly concentrated in raw materials, minerals and fuels as well as textile products, all very consistent with our conjecture.

Let us now turn to our second question what might drive China's earlier industrialization if it was indeed costly as suggested by our PPP-based cost comparisons. Countries begin their modern economic development at different times, which

Table A1
Calculation of Chinese price level relative to Japan in 1935 (Japan = 1).

		Japanese weight			Chinese weight			Japanese		Chinese			Chinese/Japanese	Chinese price level		
		I	II	III	I	II	III	Unit	Price	Unit	Price	Source		Japanese weight	Chinese weight	Fisher average
All industries														1.55	1.00	1.24
Food and kindred products		0.10			0.25									0.97	0.65	0.79
Liquor			0.49			0.23								0.62	0.67	0.64
	Liquor (*bai jiu*)			0.77			0.50	100 l	40.06	dan	9.45	b	0.54			
	Beer			0.23			0.50	100 l	46.60	dan	18.00	b	0.88			
Flour and starch			0.22			0.50								0.51	0.51	0.51
	Wheat flour			1.00			1.00	kg	0.15	50 kg	1.71	a	0.51			
Cooking oil			0.04			0.13								0.86	0.76	0.81
	Rap oil			0.48			0.34	kg	0.37	dan	13.65	b	0.84			
	Sesame oil			0.08			0.33	kg	0.51	dan	13.33	b	0.60			
	Soybean oil			0.44			0.33	kg	0.36	dan	14.54	a	0.93			
Sugar			0.17			0.02								0.80	0.95	0.87
	Brown sugar			0.13			0.50	kg	0.23	dan	14.50	a	1.43			
	White sugar			0.87			0.50	kg	0.24	dan	7.45	a	0.71			
Salt			0.04			0.04								6.99	6.99	6.99
	Salt			1.00			1.00	kg	0.05	dan	14.07	a	6.99			
Tea			0.02			0.01								3.35	3.87	3.60
	Green tea			0.94			0.50	kg	0.52	dan	75.13	b	3.26			
	Black tea			0.06			0.50	kg	0.53	dan	111.71	b	4.76			
Other food			0.01			0.07								3.28	3.28	3.28
	Ice			1.00			1.00	kg	6.31	tons	18.21	a	3.28			
Textiles and their products		0.31			0.47									1.78	1.37	1.56
Silk			0.16			0.12								0.93	0.93	0.93
	Raw silk			1.00			1.00	kg	11.35	dan	463.96	a	0.93			
Yarn			0.37			0.50								1.00	1.14	1.07
	Cotton			0.75			0.34	kg	1.25	jian	162.10	a	0.81			
	Silk			0.06			0.33	kg	5.85	dan	323.95	a	1.26			
	Woolen			0.19			0.33	kg	2.44	jian	642.30	a	1.65			
Fabrics			0.43			0.27								2.76	2.84	2.80
	Cotton twill			0.14			0.30	m	0.13	shichi	0.09	b	2.25			
	Poplin			0.13			0.30	m	0.18	shichi	0.17	b	3.20			
	Calico			0.27			0.30	tan (10 m)	0.53	shichi	0.06	b	4.02			
	Serge			0.47			0.11	m	1.62	m	2.95	b	2.07			
Knitgoods			0.02			0.08								1.61	1.61	1.61
	Cotton underwear			1.00			1.00	dozen	3.96	dozen	5.61	b	1.61			
Cotton			0.02			0.03								1.83	1.83	1.83
	Cotton wadding			1.00			1.00	kg	0.59	dan	47.78	a	1.83			
Wood products		0.02			0.00									0.96	0.96	0.96
Wood board			1.00	1.00		1.00	1.00	3.3 sqm	1.98	3.3 sqm	1.68	d	0.96	0.96	0.96	0.96
Paper and allied industries		0.04			0.05									1.37	1.21	1.28
Paper			0.83	1.00		0.54	1.00	kg	0.23	kg	0.29	c	1.44	1.44	1.44	1.44
Paperboard			0.17	1.00		0.46	1.00	kg	0.10	kg	0.09	c	1.01	1.01	1.01	1.01

(*continued on next page*)

Table A1 (*continued*)

		Japanese weight			Chinese weight			Japanese		Chinese			Chinese/ Japanese	Chinese price level		
		I	II	III	I	II	III	Unit	Price	Unit	Price	Source		Japanese weight	Chinese weight	Fisher average
Chemicals and allied products		0.15			0.07									2.01	0.86	1.31
Acid			0.29			0.02								2.96	2.90	2.93
	Sulfuric acid			0.76			0.74	tons	38.09	tons	92.25	a	2.75			
	Hydrochloric acid			0.07			0.25	tons	36.93	50 kg	5.55	b	3.42			
	Nitric acid			0.17			0.01	tons	110.22	tons	355.42	a	3.66			
Soda			0.08			0.11								0.87	0.99	0.93
	Carbonated soda			0.05			0.33	kg	0.13	tons	99.56	a	0.90			
	Caustic soda			0.83			0.33	kg	149.91	tons	99.56	a	0.76			
	Bleaching powder			0.12			0.33	tons	67.40	50 kg	4.93	b	1.66			
Other ind. chemicals			0.07			0.04								3.33	1.87	2.50
	Naphthalene			0.27			0.25	kg	0.09	tons	221.45	b	2.98			
	Alcohol			0.21			0.25	kg	0.76	gallon	1.11	a	8.84			
	Silicate			0.36			0.25	kg	0.07	dan	4.62	a	1.50			
	Alum			0.17			0.25	kg	77.82	tons	67.03	b	0.98			
Dye, paint and pigment			0.08			0.13								2.05	0.91	1.37
	Blue sulfide			0.49			0.33	kg	0.37	jin	0.42	a	2.59			
	Lacquer			0.10			0.33	kg	3.25	pounds	0.55	a	0.43			
	Paint			0.41			0.33	kg	0.54	pounds	0.39	a	1.79			
Oil			0.09			0.01								3.77	1.95	2.71
	Gasoline			0.26			0.20	tons	59.98	kg	0.32	b	6.12			
	Kerosene			0.18			0.20	tons	61.49	kg	0.22	b	4.03			
	Lubricants			0.47			0.20	tons	91.93	kg	0.21	b	2.61			
	Asphalt			0.07			0.20	tons	27.64	tons	89.98	b	3.70			
	Gelatin			0.03			0.20	kg	1.15	dan	33.64	a	0.67			
Vegetable oil and fat			0.05			0.02								1.04	1.17	1.10
	Cotton seed oil			0.57			0.33	kg	0.34	dan	10.67	b	0.72			
	Coconut oil			0.42			0.33	kg	0.27	tons	352.60	b	1.46			
	Tung oil			0.01			0.33	kg	0.43	dan	39.29	b	2.09			
Fertilizer			0.19			0.40								0.68	0.68	0.68
	Bean cake			1.00			1.00	tons	80.57	dan	2.42	a	0.68			
Soap			0.03			0.12								1.00	1.00	1.00
	Soap			1.00			1.00	kg	0.19	box/ 30 kg	5.00	a	1.00			
Pulp			0.03			0.01								2.79	2.79	2.79
	Pulp			1.00			1.00	kg	93.26	tons	228.91	a	2.79			
Tannery			0.05			0.08								0.78	0.84	0.81
	Cowhide			0.80			0.50	pieces	7.66	pieces	3.87	a	0.58			
	Acacia extract			0.20			0.50	kg	0.43	gong-dan	59.68	a	1.59			
Coke, coal			0.05			0.07								0.79	0.82	0.80
	Coke			0.76			0.50	tons	15.00	tons	10.04	a	0.76			
	Coal			0.24			0.50	kg	20.75	tons	16.09	b	0.88			
Stone, clay and glass products		0.03			0.03									1.24	0.88	1.04
	Glass		0.28			0.14								1.00	1.00	1.00
	Glass plate			1.00			1.00	box	7.57	box	6.64	b	1.00			
Brick and tile			0.13			0.21								0.94	0.89	0.91
	Black brick			0.13			0.33	numbers	0.01	numbers	0.01	a	0.65			
	Common brick			0.72			0.33	numbers	0.07	numbers	0.05	a	0.74			

	Tile			0.15			0.33	numbers	0.04	10,000 ge	807.11	b	2.14			
Cement			0.42			0.43						b		0.61	0.61	0.61
	Cement			1.00			1.00	barrel	3.21	tons	38.19		0.61			
Lime			0.03			0.01								4.07	4.07	4.07
	Lime			1.00			1.00	tons	7.00	dan	1.25	a	4.07			
Enamelware			0.14			0.21								3.42	3.42	3.42
	Washbasin or cup			1.00			1.00	numbers	0.08	dozen	2.96	b	3.42			
Metals and metal products		0.17			0.05									1.39	0.98	1.17
Metal smelting materials			0.71			0.11								1.50	1.41	1.46
	Pig iron			0.08			0.25	tons	35.96	tons	64.48	b	2.04			
	Steel plate			0.78			0.25	kg	0.09	tons	124.46	b	1.52			
	Copper casting, rough			0.09			0.13	tons	738.09	tons	624.54	b	0.96			
	Tinplate			0.01			0.13	kg	0.30	tons	351.68	b	1.32			
	Lead			0.01			0.13	kg	0.25	dan	14.59	a	1.31			
	Aluminum			0.03			0.13		1.51	tons	1653.45	b	1.25			
Casting			0.08			0.10								1.33	1.33	1.33
	Cast-iron pipe			1.00			1.00	kg	0.09	pounds	0.05	a	1.33			
Other metal products			0.21			0.79								1.04	0.92	0.98
	Nail			0.65			0.25	barrel	7.10	pounds	0.06	a	0.94			
	Nib			0.08			0.25	gross	4.20	gross	1.95	b	0.53			
	Umbrella bone			0.06			0.25	dozen	1.27	dozen	1.56	a	1.39			
	Zinc plate			0.21			0.25	kg	0.19	tons	239.42	b	1.46			
Machinery		0.14			0.05									1.22	1.49	1.35
Machinery			0.72			0.11								0.94	0.99	0.97
	Generators			0.23			0.30	numbers	997.06	numbers	514.77	a	0.59			
	Motor*			0.75			0.30	numbers	115.96	numbers	104.88	b	1.03			
	Fans			0.02			0.40	numbers	20.11	numbers	34.70	a	1.96			
Battery and light bulb			0.03			0.27								2.11	1.26	1.63
	Accumulator			0.05			0.30	numbers	14.57	numbers	22.50	b	1.76			
	Battery			0.28			0.30	numbers	0.12	dozen	0.79	a	0.63			
	Light bulb			0.67			0.40	numbers	0.07	numbers	0.16	a	2.75			
			0.03			0.27								2.75	2.15	2.43
	Thermometer			0.06			0.30	numbers	0.58	numbers	2.00	b	3.95			
	AC voltage table			0.38			0.30	numbers	13.67	numbers	12.75	b	1.06			
	Clock			0.56			0.40	numbers	1.59	numbers	5.29	a	3.77			
Vehicle			0.23			0.30								1.81	1.81	1.81
	Bicycle			1.00			1.00	numbers	24.77	numbers	39.48	a	1.81			
Miscellaneous industries		0.04			0.03									2.22	1.17	1.61
Thermos bottle			0.13	1.00		0.13	1.00	numbers	0.33	numbers	0.63	a	2.16	2.16	2.16	2.16
Toothbrush			0.13	1.00		0.13	1.00	dozen	0.49	numbers	0.16	a	4.51	4.51	4.51	4.51
Handkerchief			0.13	1.00		0.13	1.00	dozen	0.48	dozen	0.20	a	0.48	0.48	0.48	0.48
Straw hat			0.13	1.00		0.13	1.00	dozen	3.63	dozen	16.93	a	5.29	5.29	5.29	5.29
Matches			0.13	1.00		0.13	1.00	gross	0.38	box	54.36	a	0.81	0.81	0.81	0.81
Pen			0.13	1.00		0.13	1.00	dozen	12.25	dozen	17.01	b	1.58	1.58	1.58	1.58
Pencil			0.13	1.00		0.13	1.00	dozen	0.07	dozen	0.15	b	2.32	2.32	2.32	2.32
Parasol			0.13	1.00		0.13	1.00	numbers	2.37	dozen	15.51	a	0.62	0.62	0.62	0.62

Sources: See the data section.
Notes: (a) D.K. Lieu's Report on a Survey of China's Industry, vol. 2 (NRC, 1937); (b) Archive Materials for Studies of Industrial and Agricultural Commodity Prices, Shanghai Volume, compiled by Office for Industrial and Agricultural Price Survey (OIAPS, 1956–57); and (c) Zhen Chen's Study Materials of Industrial History in Contemporary China, vol. 4, parts 1 and 2 (1961).

means that latecomers may face very different conditions from the pioneers which enjoy first-mover advantage even if the initial resource endowments are the same. When some countries have already industrialized or developed with modern technologies and industries, less developed countries tend to pursue a state-supported take-off or even some non-market approach for industrialization. This is because to many less developed countries comparative advantage is equivalent to cheap labor and land which would not easily lead to a fast catch up with developed countries. History has indeed shown us that large developing countries may use their comparative disadvantage to catch up, though doing so has seldom been efficient and successful.

When modernizing, small countries seek to maximize their benefits by using their comparative advantage (niche services or unique natural resources) to pay for manufactured goods made in advanced countries because the development of capital goods industries is inefficient due to diseconomies of scale. Small countries may also seek political-military allies so that they do not have to develop their own defence-oriented heavy industries. Large countries are different. Their potentially huge domestic markets attract those domestic investors who can afford the high initial costs of learning and imitating, though they usually require state support. Politicians in such countries tend to have strong incentives to lend support or to pursue state-involved industrialization because of political returns and national defence pressures. Some countries may rely on political support or state power to develop capital goods manufacturing and R&D while using their comparative advantage to pay for the cost, whereas some may go extreme of adopting forced saving and hence forced heavy industrialization through totalitarian controls and central planning as what happened in the Soviet Union and in Maoist China.

Our costs and productivity analyses have suggested that China did not produce manufactured goods according to its comparative advantage, which lends tentative support to our conjecture. On the one hand, China's huge potential market was attractive to investors who could afford initial high costs due to underdeveloped market institutions and infrastructures for modern industries. On the other hand, government involvement in China's initial development of heavy industries was inevitable because of the threats of foreign powers including its neighbor Japan as well as political and military conflicts at home.

Appendix A.

See Table A1.

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.eeh.2009.08.003.

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