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THE ORIGINS OF THE EAST ASIAN INCONGRUITIES IN THE MADDISON PROJECT DATABASE

Nak Nyeon Kim*

Department of Economics, Dongguk University
Seoul 04620, Korea
nnkim@dongguk.edu

AND

Ki-Joo Park

Department of Economics, Sungshin Women's University
Seoul 02844, Korea
kjpark@sungshin.ac.kr

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Abstract

The income gaps between Korea and her two richer neighbors, Japan and Taiwan in 1935, estimated by the Maddison Project using the backward projection method from 1990, are significantly different from the results based on directly comparing the price levels of 1935. We explore the sources of error in the estimation of PPP using GDP deflators. We find that the errors from the conceptual differences between PPP and GDP deflators are not large or systematically biased; the majority of errors come from the inconsistency of the two data sets, and the selection of the benchmark year. We estimate the GDP per capita of East Asian countries without incongruities, using information from all benchmark years available.

Keywords: Maddison Project, purchasing power parity, GDP deflator, International Comparison Project, Penn World Table
JEL Classification Codes: N30, I31, O53

I. *Introduction*

How have living standards changed in East Asian countries in the 20th century? In particular, how have the gaps in GDP per capita among East Asian countries changed compared with the United States? While it may be simple to compare countries' GDP per capita by using foreign exchange rates, this method is unable to show differences in national living standards

* Corresponding author

because exchange rates do not reflect the prices of non-traded products. To compare national living standards between countries, it is thus necessary to calculate the purchasing power parity (PPP), which reflects differences in country-level prices and enables cross-country comparisons. Indeed, the International Comparison Program (ICP), which compares the price levels of different countries and has been conducted seven times since 1970, allows researchers to compare national living standards based on PPP figures.

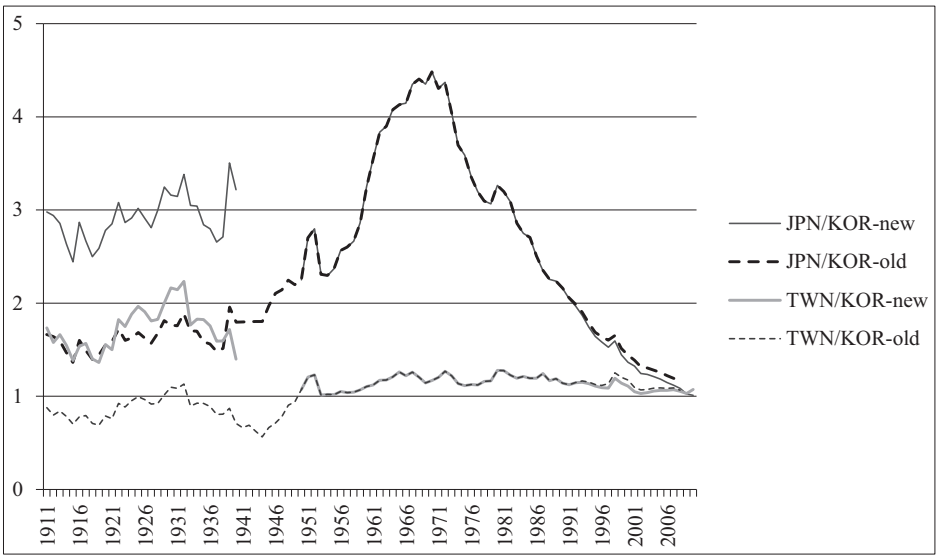
Moreover, national living standards have been estimated for periods when PPP had not been compiled, as seen in the Maddison Project, Penn World Tables (PWT) and the University of Queensland International Comparison Database (UQICD). For example, Maddison sets PPP-adjusted GDP per capita in 1990 as its benchmark and extrapolates GDP backwards for prior periods, using the rates of change of GDP per capita for each country. PWT used a method similar to Maddison before version 8 (to be discussed further). From version 8, PWT differs with Maddison in that the benchmark year has been updated with the new data of the ICP. Unlike Maddison or PWT, UQICD estimated PPPs of almost countries from 1971 by the econometric approach, using various information including GDP deflators as well as all ICP data (Rao et al., 2010a; 2010b). While PWT and UQICD provide a wealth of information but are limited to the post-1950s and post-1970s period respectively, Maddison's estimates have the advantage of being able to compare the GDP per capita of countries on a longer-term basis.

Maddison's GDP per capita estimates showed that Korea had an income advantage over Taiwan in the pre-WWII period, which contradicted the well-known evidence suggested by studies on living standards in the two countries during the colonial period. To resolve this issue, Fukao *et al*. (2006; 2007) estimated the PPPs of Korea, Taiwan, Japan, and China and compared them with those of the United States in 1935. According to them, the PPP-adjusted GDP per capita of Korea, Taiwan, and Japan were found to be 12%, 23%, and 32% of that of the United States, respectively, with Korea suffering income disadvantage vis-a-vis Taiwan. These results implied that Maddison's previous estimates relatively underestimated the GDP per capita of Taiwan, while overestimating the Japanese and Korean figures by 22% and, remarkably, 77%.

Fukao *et al*. (2006; 2007)'s new estimates were incorporated into the Maddison Project Database made available in 2013. Figure 1 shows the Taiwanese and Japanese GDP per capita compared with that of Korea based on the previous and new versions of the Maddison Project. The previous version (shown with dotted lines in Figure 1) shows that the pre-war GDP per capita for Taiwan was lower than that for Korea; however, in the new version, the GDP per capita of Taiwan and Japan are respectively 1.7 times and 3 times that of Korea, resolving the problem of the previous version. However, connecting these results to the post-WWII estimates led to another contradiction. According to Figure 1, the income gaps between Korea and Japan and those between Korea and Taiwan largely decreased in the early 1950s compared with the pre-war period. However, these results look counterfactual, because the Korean economy was damaged by the Korean War, whereas the Japanese economy grew rapidly driven by the demand expansion caused by the war.

In short, the income gaps between these three countries in 1935, as estimated by the Maddison Project by using the backward projection method from 1990, showed significant differences with the results obtained from directly comparing the price levels of 1935. However, the newly estimated pre-war figures in the new version of the Maddison Project do not solve entirely the problem, which has now morphed into another contradiction because of the

FIGURE 1. GDP PER CAPITA OF JAPAN AND TAIWAN COMPARED WITH KOREA (=1)



Sources: Appendix table; Maddison Project Database.

incongruences between the pre-war and post-war series.

What is the root cause of the difference between the previous and new estimates? Fukao *et al*. (2007) suggested three possible causes. The first is that GDP estimates of 1940s slightly exceed the conjecture based on limited information, especially in the case of Korea.[1] The second potential cause is the accumulation of error from the index number problem in the process of backward projection since 1990. Fukao *et al*. (2007) used the index number formulation, decomposing the error into two parts, one due to weight inconsistency and the other caused by the changes in the terms of trade. Moreover, they attempted to estimate the size of the error relating to the latter for Japan, which revealed that only 3%p of the total error (22%) of the backward projection could be explained by changes in the terms of trade for 1935-1990.[2]

While the size of the error is important, whether it accumulates is also crucial. Although they did not present empirical data, Fukao *et al*. (2007) suggested that the two previously mentioned causes in the index number problem cancel each other out, thereby not resulting in systematic bias. On the contrary, Deaton (2012) and Feenstra *et al*. (2015), regarding the ICP, emphasized that the error from the index number problem systematically accumulates when estimating PPP by using national price indexes. If the claim by Fukao *et al*. (2007) is correct, the above incongruity hence becomes difficult to explain. On the contrary, Deaton and others suggest the possibility of increasing the discrepancies between the estimated and actual PPP as the years projected backwards are further away from the benchmark year.

[1] However, as explained later, this situation is not remedied even if the Korean GDP per capita of the 1940s is modified by using a more reliable estimation.

[2] However, they did not derive a quantitative result about weight inconsistencies.

Third is the possibility of the error stemming from the fact that the Maddison Project's estimate is based on a single benchmark year, namely 1990.[3] Comparing PPPs calculated by the ICP shows significant differences between benchmark years; thus, the results of the backward projection become heavily dependent on the benchmark year. While Fukao *et al*. (2007) did not consider this cause, shifting the benchmark year from 1990 to 2005 or 2011 may partially reduce the problems relating to the pre-war period in the Maddison Project.[4] While PWT has updated the benchmark year whenever the ICP has published newly surveyed data, these updates have their own limitations of changing estimates and discarding all data of the previous benchmark year (Johnson *et al*., 2009). For this reason, PWT version 8 and subsequent versions conducted interpolation for intervening years between consecutive benchmarks and extrapolation for the rest (Feenstra *et al*., 2015). On the contrary, UQICD estimated PPPs reflecting data of all ICP surveys (Rao *et al*., 2010a). There are considerable differences in the results according to the respective methods.

The remainder of this paper is constructed as follows. In Section Ⅱ, we utilize information from all benchmark years in the ICP to explain the discrepancy between the actual PPP and the estimated PPP using the deflator. Specifically, we break down the discrepancy into parts attributable to different causes and examine the size of each as well as whether it has systematic tendencies in order to understand the optimal PPP estimation method in non-benchmark years. In Section Ⅲ, we estimate the PPP-adjusted GDP per capita of Korea, Taiwan, and Japan in the 20th century, which is not tainted by the incongruities as found in the Maddison Project's estimates. In Section Ⅳ, we provide conclusions on the discussions presented in the previous sections.

II. *Source of the Error of Estimating PPP*

Comparing price levels across countries is more difficult than comparing them over time within one country. The ICP currently conducts a cross-country price survey every six years; then, until the subsequent round of data is released, PPPs are estimated by using the deflators of each country. However, these estimations have significant discrepancies with actual PPP, and a large literature exists on why they occur and how they can be reduced (Dalgaaed and Sorensen, 2002; Ravallion, 2010; Biggieri and Laureti, 2011).

In this study, we estimate the discrepancy between actual and estimated PPP by using the following equations. These equations originated from Deaton (2012), which was improved upon by Feenstra *et al*. (2015). To simplify the discussion, we confine it to the case of two nations, setting one as the reference country, namely the United States.

First, the change in prices between two points of time can be approximated by using the Törnqivist index (see equation (1)). In this equation, p_{jt} represents the price vector of country j at time t; s_{jt} represents the weight vector of country j at time t; and P_{jt} shows the price index of

[3] It is not clear why Maddison Project set the benchmark year to 1990, which was not included in ICP's survey period.

[4] The Taiwanese PPP-adjusted GDP per capita of 1990 compared with that of Korea was 14.2% higher according to the Maddison Project; however, based on ICP data in 2005 and 2011, the figure would be 22.1% and 34.5% higher, and thus the pre-war gaps between these countries would become larger accordingly.

country j at time t. Δ denotes the difference between the two points of time, so that $\Delta \ln P_{jt}$(i.e., $\ln P_{jt} - \ln P_{jt-1}$) means the rate of inflation. Then, the inflation differential between country 1 and country 2 can be written as $\Delta \ln P_{2t} - \Delta \ln P_{1t}$:

$$\Delta \ln P_{jt} \approx \tfrac{1}{2}(s_{jt} + s_{jt-1})'(\ln p_{jt} - \ln p_{jt-1}) \qquad j = 1, 2. \tag{1}$$

PPP_{21t}, which is the PPP index of country 2 relative to that of country 1 at time t, is also approximated by using the Törnqivist index (see equation (2)). While the price index of equation (1) is dependent only on the budget share of the home country, the PPP index is influenced by the budget shares of both countries:

$$\ln PPP_{21t} \approx \tfrac{1}{2}(s_{2t} + s_{1t})'(\ln p_{2t} - \ln p_{1t}) \tag{2}$$

By combining equations (1) and (2), we get equation (3), which represents the change in the PPP index over time, shown as $\Delta \ln PPP_{21t} = \ln(PPP_{21t}/PPP_{21t-1})$:

$$\begin{aligned}
\Delta \ln PPP_{21t} &\approx \tfrac{1}{2}(s_{2t} + s_{1t})'(\ln p_{2t} - \ln p_{1t}) - \tfrac{1}{2}(s_{2t-1} + s_{1t-1})'(\ln p_{2t-1} - \ln p_{1t-1}) \qquad (3)\\
&= \tfrac{1}{2}(s_{2t} + s_{2t-1})'(\ln p_{2t} - \ln p_{2t-1}) - \tfrac{1}{2}(s_{1t} + s_{1t-1})'(\ln p_{1t} - \ln p_{1t-1})\\
&\quad - \tfrac{1}{2}(s_{2t} - s_{1t})'\{(\ln p_{2t} - \ln p_{2t-1}) + (\ln p_{1t} - \ln p_{1t-1})\}\\
&\quad + \tfrac{1}{2}(s_{2t} - s_{2t-1})'(\ln p_{2t} - \ln p_{1t-1}) - \tfrac{1}{2}(s_{1t} - s_{1t-1})'(\ln p_{1t} - \ln p_{2t-1})\\
&= \underbrace{(\Delta \ln P_{2t} - \Delta \ln P_{1t})}_{\text{inflation differential}} \underbrace{- \tfrac{1}{2}(s_{2t} - s_{1t})'(\Delta \ln p_{2t} + \Delta \ln p_{1t})}_{\text{bias1}}\\
&\quad \underbrace{+ \tfrac{1}{2}[(s_{2t} - s_{2t-1})'(\ln p_{2t} - \ln p_{1t-1}) - (s_{1t} - s_{1t-1})'(\ln p_{1t} - \ln p_{2t-1})]}_{\text{bias2}}
\end{aligned}$$

According to equation (3), the changes in PPP on the left-hand side can be broken down into the three terms on the right-hand side.[5] The first term on the right-hand side is the differences in the changes in the GDP deflator of the two countries (that is, inflation differential). Estimating the changes in PPP by using this inflation differential leads to the result that a gap occurs because of the remaining two terms. Bias1 is equal to the product of the budget share difference between the two countries ($s_{2t} - s_{1t}$) and average inflation. Bias2, the meaning of which is unclear, is affected by factors such as changes in the budget shares of each country over time ($s_{jt} - s_{jt-1}$). Ultimately, the rationale behind the gap between the rates of change of PPP and inflation rate is the budget share difference between the two countries or the changes in the budget shares of each country. However, different countries normally have different budget shares, which change in different ways; therefore, it is normal to have gaps between the changes in PPP and inflation differentials.

When information on PPP, prices, and the budget share for equation (3) are available, the PPP change between two points in time can be decomposed into inflation differential, bias1, and bias2. For the benchmark years of the ICP, i.e. 1970, 1975, 1980, 1985, 1996, 2005, and 2011, we can calculate the PPP changes and inflation differentials between benchmarks for countries with data. However, because it is difficult to find information on the prices and

[5] While equation (3) is similar to equation (D4) in the online appendix of Feenstra *et al*. (2015), there is a difference in bias2, as the former corrects the error included in the latter. This paper includes bias2, while Feenstra *et al*. (2015) removed bias2 from the discussion, assuming that it is minimal.

budget shares for the basic headings, we use information on the deflators and shares of the expenditure components of GDP (C, G, I, X, M). The implicit deflators (i.e., current prices/constant prices) and shares are available from the National Accounts (NA) for each country. The PPPs for each expenditure component are obtained from calculations of PWT version 9.[6]

Table 1 shows the result of the decomposition carried out between benchmark years for Korea. Taking the 1970-1975 interval as an example, the annual change in PPP (ΔPPP_{21}) in the second column is 4.8%; however, the inflation differential between Korea and the United States from NA data ($\Delta(P_2/P_1)^{NA}$) averages 11.6% annually, showing a large discrepancy between the two figures. In this case, the left-hand side does not equal the sum of the three terms on the right-hand side because there is no consistency between the differences in price levels across countries sourced from the ICP and the difference in the deflators obtained from the NA of each country. Let us, for example, assume that the price level for country 1 was the same as that for country 2 for one benchmark year and doubled for the subsequent benchmark year in the ICP data. In this case, the ICP data indicate that the deflator for country 1 rose twice as fast as that for country 2. However, there is no guarantee that the deflator obtained from the NA data would show the same increase. Therefore, entering the price information from two data sets into equation (3) leads to a discrepancy owing to inconsistency.

We can also calculate a deflator that is consistent with the price level difference between two countries for the benchmark years, using ICP data.[7] The calculated inflation differential between Korea and the United States is presented in Table 1 as $\Delta(P_2/P_1)^{ICP}$. Bias1 and bias2 are also calculated. In this case, the sum of the three terms on the right-hand side of equation (3) equals the left-hand side. That is, in the 1970-1975 interval, the annual rates of PPP change and inflation differential are shown to be 4.8% and 4.1%, respectively and the discrepancy from the conceptual difference between PPP and the price index is 0.7% (bias1, from the differences in budget shares between the two countries, is 1%, and bias2, explained through the changes in budget shares, is -0.3%).

However, for non-benchmark years, ICP data are unavailable; therefore, the deflator information used is $\Delta(P_2/P_1)^{NA}$ rather than $\Delta(P_2/P_1)^{ICP}$. The discrepancy between the two comes from the inconsistency between the price data of the ICP and NA. Ultimately, the discrepancy when estimating PPP from the deflator data from NA can be decomposed into three factors (bias1, bias2, and inconsistency). According to Table 1, the discrepancy of the 1970s occurs largely from inconsistency rather than bias1 or bias2, and discrepancy from inconsistency appears to decrease significantly thereafter.

Then, what happens if we carry out the decomposition for other countries where data are available? Figure 2 shows the distribution of bias1, bias2, and inconsistency, which was calculated for 100 countries between the ICP benchmark years of 1996 and 2005. The x-axis

[6] As PWT provides annual price levels for expenditure components and exchange rates across countries after 1950, we can obtain the PPP by expenditure component for each country by multiplying both of them. While PWT estimated the PPPs for the years not surveyed by the ICP, we used only the information for the benchmark years.

[7] If we express the price level of each country in each year compared with that (=1) of the United States, multiplying it by the U.S. deflators creates a comparable price series over time (t, $t+1$, $t+2\cdots$) and space (country 1, 2, 3$\cdots$). PWT uses this method to calculate the price level for expenditure components and provides the index with the price level of 2011 U.S. GDP^{o} set to 1. Multiplying these figures by exchange rates provides the local pricing for each country.

TABLE 1. FACTOR BREAKDOWN OF PPP CHANGES BETWEEN BENCHMARKS FOR KOREA

	ΔPPP_{21} a=b+c+d	$\Delta(P_2/P_1)^{ICP}$ b	bias1 c	bias2 d	$\Delta(P_2/P_1)^{NA}$ e	inconsistency f=e−b
1970-1975	4.8%	4.1%	1.0%	−0.3%	11.6%	7.5%
1975-1980	16.7%	16.8%	0.0%	−0.1%	12.2%	−4.7%
1980-1985	2.3%	2.8%	−0.6%	0.1%	1.8%	−1.0%
1985-1996	2.6%	2.5%	0.1%	0.0%	4.1%	1.7%
1996-2005	0.8%	0.6%	0.3%	−0.1%	0.5%	−0.1%
2005-2011	1.5%	1.9%	−0.5%	0.0%	0.3%	−1.7%

Notes: Values indicate the yearly average rate of change between the intervals.

shows the log values of GDP per capita for each country in 2005, and graphs show the relationship between those three factors and income.

First, according to panels (A) and (B), the bias1 is distributed over wider range than bias2 is. This finding indicates that the error from the difference in the expenditure pattern between countries is larger than the error from the changes in the expenditure pattern over time. Second, bias1 is positively correlated with income, which stands in contrast to Deaton (2012, Figure 2) who argued negative correlation between bias1 and income for 1993-2005.[8] Lastly, Panel (C) shows the sum of bias1 and bias2. Comparing panels (C) and (D) reveal that inconsistency accounts for most of the discrepancy. Looking at the relationship between inconsistency and GDP per capita, the inconsistencies for wealthy nations tend to be distributed around 0, while those for poor nations are scattered widely.

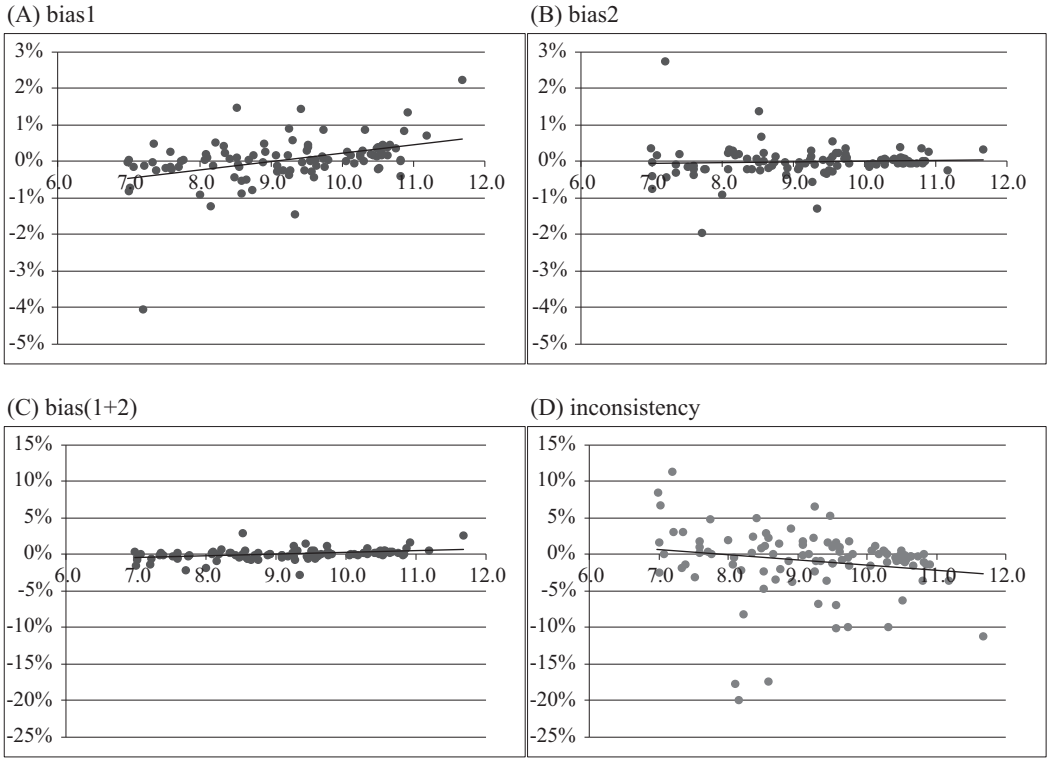
We carried out the same decomposition for all other benchmark years and summarized the results in the Table 2. First, most parameters of correlation between bias1 or bias2 and GDP per capita are found to be statistically meaningless. While the parameters of bias1 are statistically significant in only two intervals (1980-1985 and 1996-2005), they are different in sign and generally near to zero. Therefore, it is difficult to argue that there are any correlation between bias1 and income and the accumulation of bias over time.

Second, comparing the standard deviation, the discrepancy due to inconsistency is much larger than the discrepancy due to the conceptual differences between PPP and the price index, that is, bias1 and bias2.[9] Moreover, when we divide countries into two groups based on income, the standard deviation of poor nations is larger than that of wealthy nations. Some measurement errors are unavoidable given the data difference between the price survey of the ICP and the deflators of NA and the difficulty of cross-country price comparisons.[10] Hence, the

[8] Deaton thought that bias1 is substantial and systematic and thus a factor that causes underestimating the PPP increases for poor countries rather than for wealthy countries. His method differs with that presented in this paper. While he had limited the scope to private consumption, utilizing prices and budget shares for 26 basic headings, this paper used GDP expenditure components (C, G, I, X, M). However, applying his methodology for 1985-1996 when the data of basic headings were available, we found bias1 positively correlated with income. Therefore, it would be difficult to generalize his assertion that the sign of bias1 is negative.

[9] Fukao *et al*. (2007) stated that changes in the terms of trade (similar to bias1 in this paper) only explain a small part of the total discrepancy. Deaton (2012) also asserted that bias1 explains less than 1/9 for poor countries (with log values of GDP per capita lower than 8). The fact that the error from the conceptual difference between PPP and the GDP deflator only explains a small proportion is also confirmed in this study. However, as the remaining error comes from the inconsistency of the price information of the ICP and NA, the congruity of the two data sets would decrease the discrepancy, with the proportion explained by bias1 and bias2 errors also rising.

FIGURE 2. DISTRIBUTION OF ESTIMATED ERRORS IN EACH COUNTRY, 1996-2005



Notes: X axis is the log value of GDP per capita.
Sources: Penn World Table.

inconsistency probably reflects the government's abilities to manage and survey statistics as well.

As shown above, we identified the source of the discrepancies between the PPP inferred from deflators of NA and the actually surveyed PPP in the benchmark years of the ICP. One of the results is that the discrepancies from the conceptual differences between the two PPPs (i.e., bias1 and bias2) were not substantial or systematic. This fact indicates that the method of estimating PPP for non-benchmark years using NA deflators is not so much problematic. However, caution is advised as the discrepancy may be large. Most of the discrepancy stems, of course, from the quality of the data used (i.e., the inconsistency between the price data of the ICP and NA).

[10] For example, NA statistics reflect most of the expenditure, whereas the ICP survey is confined to items comparable at the international level. Apart from such differences in coverage, many factors lead to a discrepancy between the two data sets. For details, refer to McCarthy (2013).

TABLE 2. STATISTICS OF ERROR FACTORS BETWEEN BENCHMARK YEARS

		bias1	bias2	inconsistency		
				total	lower	higher
1970-1975	N	16	16	16	7	9
	mean	0.15%	−0.15%	−1.36%	−2.22%	−0.69%
	stdev	0.96%	0.26%	1.98%	2.64%	0.70%
	parameter	− 0.0007	0.0007	0.0060		
1975-1980	N	28	28	28	12	16
	mean	0.36%	0.09%	1.10%	4.19%	−1.23%
	stdev	0.42%	0.30%	3.88%	3.86%	1.61%
	parameter	0.0004	0.0007	−0.026***		
1980-1985	N	41	41	41	19	22
	mean	−0.23%	−0.14%	−0.27%	−2.36%	1.54%
	stdev	0.83%	0.57%	3.60%	3.93%	1.94%
	parameter	− 0.0031***	0.0019*	0.0179***		
1985-1996	N	58	58	58	27	31
	mean	−0.01%	0.06%	−1.54%	−1.94%	−1.19%
	stdev	0.41%	0.24%	2.84%	3.73%	1.63%
	parameter	− 0.0005	− 0.0002	0.0179		
1996-2005	N	100	100	100	45	55
	mean	0.05%	−0.01%	−0.95%	−0.54%	−1.28%
	stdev	0.66%	0.45%	4.64%	5.80%	3.36%
	parameter	0.0023***	0.0002	− 0.0071**		
2005-2011	N	145	145	145	65	80
	mean	−0.14%	−0.01%	−1.67%	−1.27%	−1.98%
	stdev	0.60%	0.67%	3.41%	3.92%	2.89%
	parameter	− 0.0004	− 0.0010*	− 0.0051*		

Notes: 1) 'N' denotes the number of countries whose data are available both benchmark years of ICP survey.
2) The 'parameter' shows correlation between error and income. *, **, and *** denote 90%, 95%, and 99% significance level respectively.
3) Lower and higher denote below or above average income.

III. *Estimating PPP-adjusted GDP Per Capita for East Asian Nations*

In this section, we estimate the GDP per capita of Korea, Taiwan, and Japan, which remove the above-mentioned contradiction inherent in the estimations of the Maddison Project, thereby creating a more consistent GDP series in the longer term. Our estimation method has three features.

First, while the Maddison Project used a single benchmark year of 1990, we include the same PPP information from all benchmark years as PWT version 9, which reflects the ICP 2011 results.[11] In addition, we add 1935 and 1985 (for Taiwan only) to the benchmark years.[12]

[11] PWT uses a two-stage process to calculate PPP for each country. First, the PPPs for the expenditure components (C, G, I, X, M) are calculated by using the GEKS procedure; these are then aggregated and real GDP calculated by using the Geary-Khamis method. Refer to Feenstra (2015, Online Appendixes 3-7) for more information.

[12] Bassino and Van der Eng (2016) estimated the PPPs of Asian counties including Korea, Taiwan, and Japan for six benchmark years between 1913 and 1969. However, we did not use their estimated PPPs here, because they are based on a few items of mainly food products and lead to such an implausible result that the gap in per capita GDP between

The PPPs in between benchmark years are then interpolated; PPPs before the earliest and after the latest benchmark years are extrapolated.

Second, for non-benchmark years, we calculate the inflation differential between the USA and East Asian countries, in order to interpolate and extrapolate PPP[13]. As mentioned above, bias1 and bias2 in equation (3) are neither substantial nor systematic; therefore, this approach is not expected to skew the results far from reality.

Lastly, the Maddison Project used the overall GDP deflator for forward and backward extrapolations; however, because PPP is affected by the different expenditure patterns of nations, such an approach may distort the results. To avoid this distortion, one needs ideally to disaggregate to individual product or basic heading level, which is infeasible due to the unavailability of data. Instead, we disaggregate to the expenditure component levels (C, G, I, X, M) and interpolate or extrapolate PPPs. This method, which is also used by PWT, contrasts with the use of overall GDP deflator in the Maddison Project.

Now, we briefly summarize the data and estimation methods used for each country.

1. Korea

The NA statistics for Korea used in this study are as follows. The GDP components for 1953-2015 were sourced from the Bank of Korea, and the population statistics were taken from Statistics Korea. The GDP components for 1911-1940 were sourced from Kim ed. (2012) or Cha and Kim (2012)[14]. Although Korea was not split into two regimes during the colonial period, we used GDP for the southern half as estimated by Cha and Kim ed. (2012). For GDP and population between 1941 and 1952, we used the estimates of Kim ed. (2012, pp.296-331, 518-521).[15]

We can calculate implicit deflators for the expenditure components by using current and constant prices. However, implicit deflators cannot be calculated for 1941-1952 because only the GDP volume index can be estimated from the production statistics by industry. Therefore, we must approach that period differently, as mentioned later.

We interpolated the PPP between the two years of 1935 and 1970, using the PPP of 1935 estimated by Fukao *et al*. (2007) and that of 1970 ICP benchmark year. Compared with extrapolation, interpolation utilizes more data and is able to reduce errors. Fukao *et al*. (2007) estimated the price level of each country vis-a-vis the United States for the expenditure components (C, G, I) as well as overall GDP in 1935; hence, we are able to calculate PPP for

Korea and Japan was minimized during the Korean War.

[13] In this regard, we followed the methodology of the latest PWT version. However, the potent methodology of UQICD cannot be applied to pre-1970 when there is not ICP survey.

[14] The Maddison Project Database used GDP estimated by Mizoguchi and Umemura (1988) and population estimated by Suh (1978) for pre-liberation Korea; however, as indicated by Cha and Kim (2012, pp.72-73), their estimations of GDP and population have some problems.

[15] The significant lack of data for this period implies lower reliability of the output and population estimates than in the decades preceding and following the period. Fukao *et al*. (2007) questioned the reliability of Korean data for the 1940s used in the Maddison Project, viewing it as a major source of error. As previously mentioned, Maddison's estimates for the 1940s were very rough; comparing them to the estimates of Kim ed. (2012), which improved on the data, there are considerable differences. However, both of them similarly showed that GDP per capita in 1953 was 67-68% of that in 1940. This finding indicates that even if the estimates used in the Maddison Project were to be replaced with better ones for the 1940s, it does not make a significant difference.

each expenditure component in 1935.[16]

We used equation (4) to interpolate. The subscripts US, *j*, and *t* denote the United States, other countries, and year, respectively. The superscript NA indicates that the data source is the NA. According to equation (4), the PPP trends are assumed to follow the change in the deflator of country *j* compared with the United States; this corresponds to the inflation differential in equation (3). For example, if the U.S. deflator rose by two times and the deflator of country *j* rose by 10 times, we can estimate that the PPP of country *j* rose by five (=10/2) times. We reconcile the benchmarks in the two years by using two inflation differentials, as shown in equation (4). For year *t* in between the 1935 and 1970 benchmarks, we apply larger weights to the inflation differential closer to benchmark year. If year is 1935 (i.e., *t* is 1935), the first term of the right-hand side is equal to PPP_{j1935}, with second term being zero:

$$PPP_{jt} = PPP_{j1935} \times (P_{jt}/P_{j1935})^{NA} / (P_{ust}/P_{us1935})^{NA} \times (1970 - t)/(1970 - 1935) \quad (4)$$
$$+ PPP_{j1970} \times (P_{jt}/P_{j1970})^{NA} / (P_{ust}/P_{us1970})^{NA} \times (t - 1935)/(1970 - 1935)$$

Moreover, for data before 1935, we extrapolate backwards using equation (5). The method of estimating PPP using the inflation differential compared with the United States is the same as in equation (4):

$$PPP_{jt-1} = PPP_{j1935} \times (P_{jt-1}/P_{j1935})^{NA} / (P_{ust-1}/P_{us1935})^{NA} \quad (5)$$

Using the above equations, the PPPs for GDP and the expenditure components (C, G, I) can be calculated annually. Moreover, the expenditure components divided by these PPPs become PPP-adjusted expenditure; adding them (=C+G+I+X−M) results in PPP-adjusted GDP per capita.[17] The comparison of them with GDP per capita of USA is shown in Figure 3. This indicates that the GDP per capita of Korea before liberation was around 10% of that of the United States, dropping after liberation, and recovering to 10% in the early 1970s before reaching 68% of that of the United States in 2014.

According to the above result, the GDP per capita of Korea was 9.2% that of the United States in 1940 and 5.3% in 1953. We reasonably assumed that the trend of the ratio in 1941-1952, namely when the method cannot be applied, follows the growth rate gap of GDP per capita in both countries.[18]

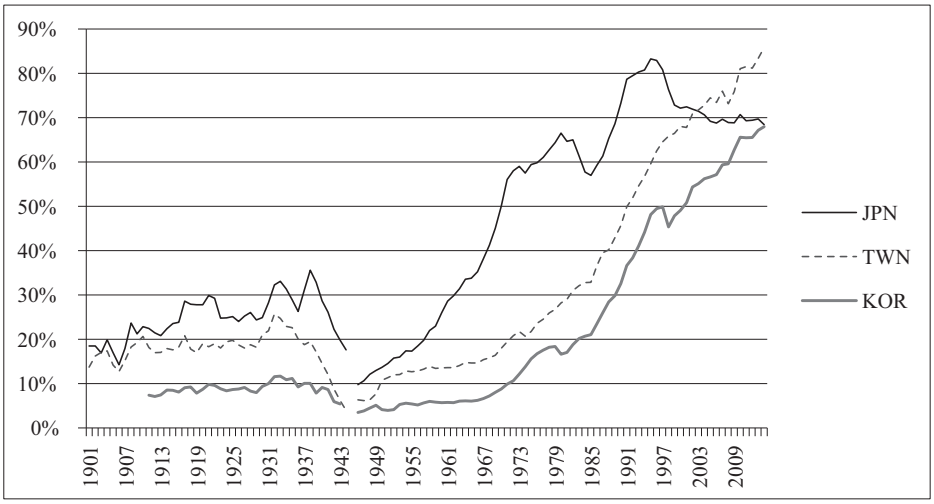
Multiplying the above proportion of Korean GDP per capita compared with the United States by the 2011 constant GDP per capita of the United States results in the real GDP per

[16] For example, the Korean price level of private consumption (C) compared with the United States in 1935 was estimated to be 0.43, with the exchange rate per U.S. dollar being 0.00343 in today's currency; PPP, the product of multiplying the two, thus becomes 0.00147. On the contrary, the price level of private consumption in 1970 calculated by PWT is 0.668; multiplying this figure and the exchange rate per U.S. dollar, 311, makes PPP be 208. Therefore, PPP rose from 0.00147 in 1935 to 208 in 1970.

[17] As export and import price levels were not estimated by Fukao *et al*. (2007), we could not calculate PPP for exports and imports. Instead, we deflated net exports (X-M) by PPP for overall GDP.

[18] In 1940-1953, the GDP per capita of Korea dropped by 32.4% and that of the United States jumped by 68.2%. When these growth rates are applied to the GDP per capita level of both countries in 1940, the GDP per capita of Korea compared with the United States was 3.7% in 1953, rather than 5.3%. Conversely, when the growth rates are applied to GDP per capita in 1953, the ratio became 13.2% in 1940, rather than 9.2%. Equation (4) can thus be used to reconcile both results, replacing the PPPs in the equation with the GDP per capita of Korea compared with the United States (i.e., 9.2% and 5.3%) and the inflation differentials with the annual growth rate gap of GDP per capita.

FIGURE 3. EACH COUNTRY'S PROPORTION OF GDP PER CAPITA COMPARED WITH THE UNITED STATES



Source: Appendix table.

capita of Korea for that year (see Appendix table).

2. Taiwan

The NA statistics of Taiwan used in this paper are as follows. Post-1951 GDP by expenditure component (constant GDP statistics provided for years after 1981) is sourced from the National Statistics of Taiwan; for the years before, we obtained GDP data from Mizoguchi (2008). The population statistics were sourced from PWT for the years after 1951 and from Mizoguchi (2008) for the years before. Implicit deflators for each expenditure component can be calculated from the above NA statistics.

Taiwan was first included in the ICP in 2005; for prior years, PWT only provides extrapolated statistics. However, Yotopoulos and Lin (1993, pp.16-18) estimated the price level for each expenditure component for Taiwan vis-a-vis the United States in 1985. Moreover, estimates of the 1935 price levels were provided by Fukao *et al*. (2007).[19] Therefore, we added 1935 and 1985 as new benchmark years and interpolated PPP in 1935-1985 and 1985-2005 as well as extrapolated it for the years before 1935. The estimating methods used therein are the same as that used for Korea.

We calculated Taiwan's PPP-adjusted GDP per capita with the method used for Korea; the proportion of Taiwanese GDP per capita compared with the United States is presented in Figure 3. Moreover, this proportion is multiplied by the 2011 constant GDP per capita of the United States, which results in the real GDP per capita for Taiwan (see Appendix table).

[19] We must consider that the Taiwan currency was denominated by 1/40000 in 1949.

3. Japan

The Japanese NA statistics were taken from several sources. GDP by expenditure component was obtained from Ōkawa *et al*. (1974, p. 178-179, 213-214) for years before 1954, and from the Cabinet Office NA Statistics of the Japanese government for the years after 1955. These data allow us to calculate the implicit deflators for each expenditure component.[20]

The ICP has been compiling Japanese data since 1970; hence, by using the Japanese price level compared with the United States estimated by Fukao *et al*. (2007), we can interpolate PPP between 1935 and 1970. The used method is also the same as that used for Korea. The proportion of Japanese GDP per capita compared with the United States is presented in Figure 3, and this proportion is used to calculate real Japanese GDP per capita.

4. United States

The NA statistics for the United States after 1929 were sourced from the Bureau of Economic Analysis of the United States. For the years before 1928, the Historical Statistics of the United States provides real GDP. We use the 2011 price GDP per capita of the United States as a reference, in accordance with PWT version 9, in estimating the real GDP for each of the East Asian countries.

From the NA data, implicit deflators can be calculated for the expenditure components for the years after 1929. However, for the years before 1929, it is difficult to obtain deflators for each expenditure components. We thus used current and constant prices of consumer goods and producer durables from the Historical Statistics of the United States for the years before 1918; however, GDP deflators were used for 1919-1928 as no price information exists by expenditure component.

The PPP-adjusted GDP per capita of each country calculated by using the above-mentioned data and methodology is presented in the Appendix table. This is the equivalent to the $RGDP^e$ of PWT, which is the real GDP from the expenditure side, and can thus be compared across countries and time.

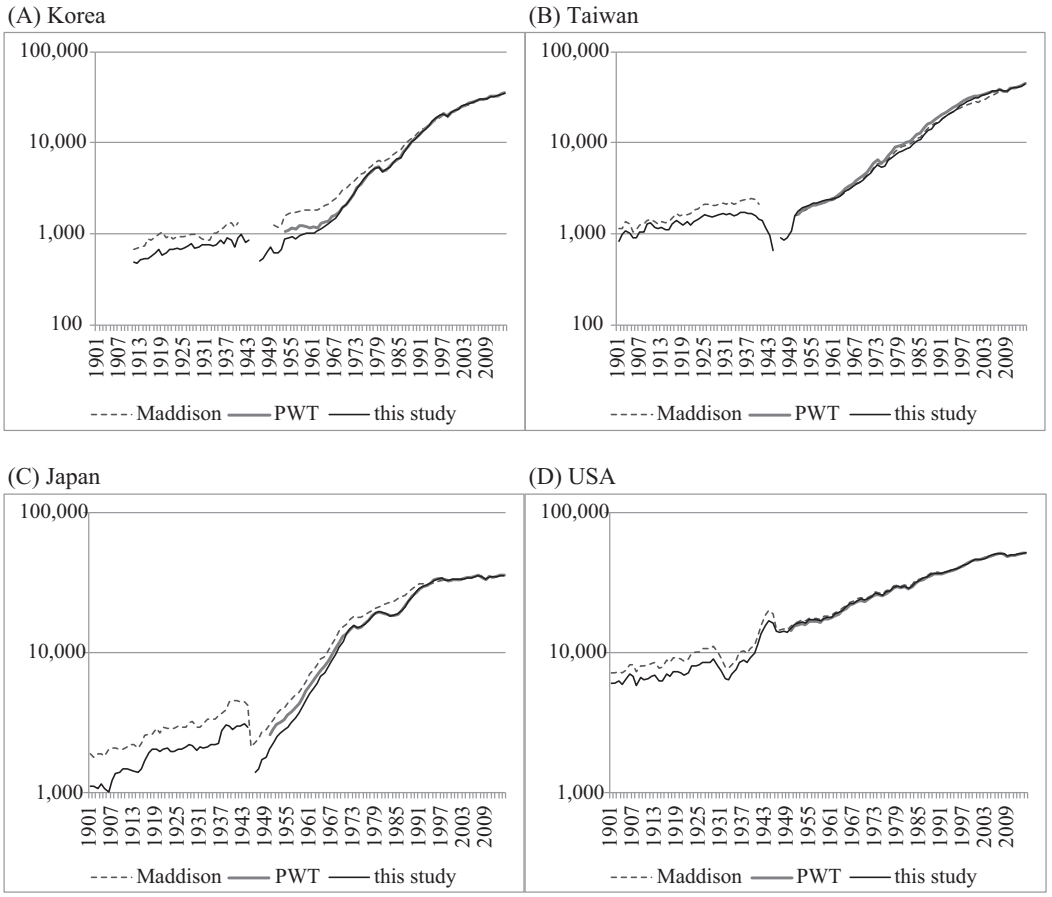
According to Figure 4, our result for Korea and Japan is similar to that of PWT for the years after 1970; however, there is a gap for the years before 1970 because PWT used extrapolation for those years, while we interpolated between 1935 and 1970. For Taiwan, we added new benchmark years of 1935 and 1985, which generated a slight difference compared with PWT.

However, the gaps between our results and the new estimates of the Maddison Project for Korea and Japan are substantial. The most important cause of the difference was that Maddison used a single year of 1990 as the benchmark, whereas this study used PPP information from all benchmark years. On the contrary, there is no significant gap for Taiwan between the results of this study and those of the Maddison Project. In short, the selection of benchmark years have important effects on the entire growth paths of countries.

For the pre-war period, both our estimates and those of the new version of the Maddison

[20] However, this was missing for 1951 and was thus accessed through the consumption, investment, import, and export price levels taken from Ōkawa *et al*. (1967, 134) and Yamazawa and Yamamoto (1979, 195, 199).

FIGURE 4. COMPARISONS OF PPP-ADJUSTED GDP PER CAPITA ESTIMATES: MADDISON, PWT, AND THIS STUDY



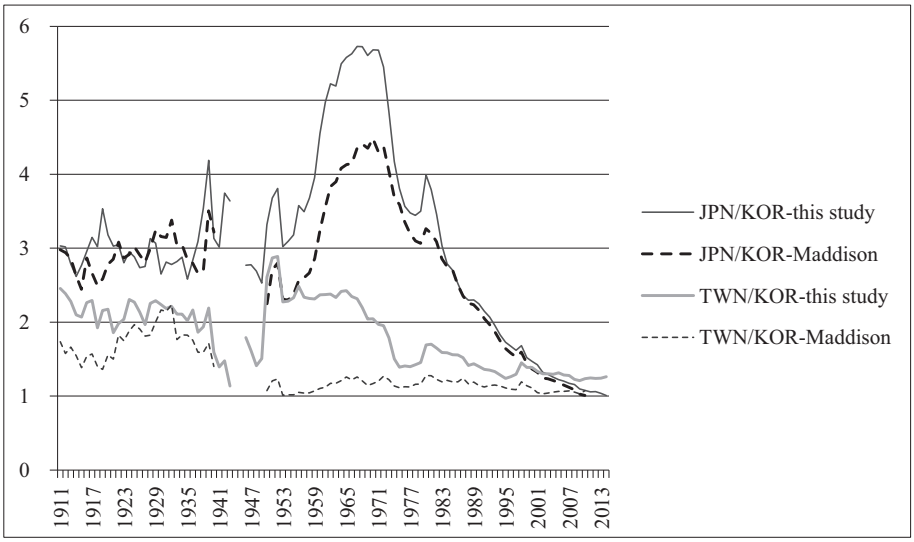
Note: 1) The unit for the y-axis is in 2011 U.S. dollars (log grade).
2) We shifted the Maddison estimates so that the 2010 values align with the applicable values of this study.
Sources: Appendix table; Maddison Project Database; Penn World Table.

Project used 1935 PPP (Fukao *et al*., 2007); however, the Maddison estimates were significantly higher than ours. One of the reasons for this gap is because the GDP per capita of the United States before 1945 is higher in the estimation of the Maddison Project than ours[21], as seen in panel D. As the Maddison Project used the higher constant GDP per capita of the United States in the pre-WWII period as a base, it overestimated pre-war GDP per capita of each countries compared with that of post-war.

Figure 5 presents the GDP per capita of Taiwan and Japan compared with that of Korea

[21] Much of this difference was because the GDP per capita of the United States in the Maddison Project from 1945-46 showed a 21% decline, nearly twice that of the Bureau of Economic Analysis used in this study.

FIGURE 5. GDP PER CAPITA OF JAPAN AND TAIWAN COMPARED WITH KOREA (=1): ESTIMATES OF THE MADDISON PROJECT AND THIS STUDY



Sources: Appendix table; Maddison Project Database.

(=1) according to the estimates of this study. The ratios are compared with those implied by the Maddison Project estimates, which are shown in Figure 1 (indicated by the dotted line). Our estimates resolve the incongruity that Korea, damaged by the Korean War, rather reduced the GDP gap compared with Taiwan and Japan in the Maddison Project. Before the war, GDP per capita in Japan and Taiwan remained at three and two times the level of Korea, respectively.[22] In the 1950s and 1960s, this gap expanded to 5.7 times between Korea and Japan and 2.5 times between Korea and Taiwan. The following years saw a rapid catch-up by Korea, with the present gap between the three countries within 1.3 times of one another.

IV. *Conclusion*

Because the PPP-adjusted GDP time series of Maddison project are derived by projecting backwards and forwards from 1990, the benchmark year, by using GDP time series of NA, two series grow at identical rates over time. Thus, the patterns of comparative growth became heavily dependent on the choice of benchmark year. Estimation based on a single benchmark year inevitably led to implausible patterns of convergence and divergence between countries, such as Korea overtaking Taiwan before WWII. In order to resolve this problem, Fukao *et al*. (2006, 2007) added 1935 as a benchmark year. However, their estimation using multiple

[22] The fluctuation of the JPN/KOR proportion in 1939 was due to the rapid decrease in Korean GDP from the bad harvest caused by extreme drought. As the estimated deflators of 1941-1943 were influenced by wartime price control, the results of this comparison require some reservations.

benchmarks without interpolation led to incongruities between pre-war and post-war series, as pointed out in Figure 1.

To avoid this problem, this study used information from all benchmark years that were surveyed by ICP, following the methodology of PWT version 8, and conducted interpolation for years between benchmarks and extrapolation for the rest. Unlike PWT, we added 1935 (and 1985 for Taiwan) as a benchmark year, expanding PPP-adjusted GDP per capita to the beginning of the 20th century. By doing so, we were able to resolve the incongruities inherent in the estimates of the Maddison Project.

Estimating PPPs for years without ICP data by using GDP deflators from NA data causes significant discrepancy. So far, several reasons have been suggested regarding the source of this discrepancy with unsatisfactory results. This study contributes to the body of knowledge on this topic by decomposing the factors behind this discrepancy for all the benchmark years from the ICP. We confirmed that the discrepancy from the conceptual difference between the deflator and PPP was neither substantial nor systematically biased towards a certain direction, even though it had been highlighted as the reason for the discrepancy in previous studies. We also found that the majority of the discrepancy was from the inconsistency in the price information of the two data sets.

These findings have significant implications for calculating PPP for years without ICP data. The method of estimating PPP by using differences in the GDP deflators from NA data across countries does not lead to a systematic problem. For this reason, we adopted interpolation or extrapolation approach. However, it must be noted that the discrepancy from the inconsistency of the data may be substantial. This fact indicates that the discrepancy between actual and estimated PPP is not mainly because of the limitation of the method using deflators, but rather dependent on the quality of data, as shown by the inconsistency of the two data sets.

Appendix Table. Expenditure-Side Per Capita Real GDP at Chained PPPs (in 2011 U.S. $)

	Korea	Taiwan	Japan	USA		Korea	Taiwan	Japan	USA
1901		839	1,128	6,099	1958	1,007	2,336	3,702	16,821
1902		981	1,118	6,043	1959	1,027	2,375	4,058	17,679
1903		1,078	1,072	6,321	1960	1,016	2,409	4,624	17,768
1904		1,024	1,173	5,892	1961	1,030	2,446	5,126	17,926
1905		903	1,083	6,364	1962	1,071	2,548	5,591	18,732
1906		908	1,015	7,106	1963	1,166	2,719	6,054	19,268
1907		1,042	1,227	6,848	1964	1,227	2,966	6,743	20,101
1908		1,066	1,381	5,832	1965	1,279	3,103	7,137	21,140
1909		1,285	1,417	6,668	1966	1,395	3,271	7,849	22,275
1910		1,336	1,480	6,472	1967	1,509	3,497	8,643	22,639
1911	488	1,197	1,477	6,584	1968	1,694	3,722	9,695	23,514
1912	483	1,153	1,459	6,794	1969	1,932	3,948	10,827	24,014
1913	518	1,180	1,442	6,925	1970	2,093	4,280	11,892	23,787
1914	535	1,122	1,400	6,257	1971	2,396	4,716	13,601	24,263
1915	539	1,115	1,492	6,331	1972	2,690	5,256	14,656	25,268
1916	575	1,301	1,698	7,114	1973	3,224	5,760	15,608	26,441
1917	620	1,422	1,951	6,821	1974	3,592	5,399	14,985	26,063
1918	682	1,311	2,061	7,374	1975	4,021	5,600	15,305	25,760
1919	579	1,250	2,048	7,370	1976	4,513	6,354	16,087	26,886
1920	627	1,363	1,992	7,164	1977	4,885	6,833	16,989	27,844
1921	677	1,257	2,049	6,855	1978	5,298	7,552	18,251	29,084
1922	688	1,361	2,096	7,164	1979	5,459	7,940	19,103	29,677
1923	706	1,440	1,978	7,980	1980	4,879	8,254	19,459	29,263
1924	675	1,558	1,993	8,022	1981	5,071	8,630	19,224	29,725
1925	710	1,610	2,046	8,151	1982	5,428	8,956	18,763	28,879
1926	750	1,600	2,052	8,533	1983	6,052	9,609	18,362	29,944
1927	779	1,533	2,147	8,509	1984	6,590	10,441	18,383	31,838
1928	706	1,591	2,210	8,475	1985	6,930	10,802	18,732	32,894
1929	713	1,632	2,185	8,956	1986	7,929	12,339	19,989	33,741
1930	761	1,702	2,016	8,107	1987	9,000	13,688	21,228	34,598
1931	756	1,650	2,127	7,529	1988	10,152	14,355	23,332	35,727
1932	756	1,674	2,102	6,517	1989	10,949	15,744	25,168	36,694
1933	750	1,581	2,115	6,397	1990	12,048	16,882	27,081	36,980
1934	766	1,614	2,206	7,043	1991	13,361	18,194	28,690	36,464
1935	853	1,722	2,204	7,617	1992	14,303	19,339	29,602	37,263
1936	793	1,716	2,249	8,547	1993	15,512	20,632	30,338	37,792
1937	900	1,678	2,780	8,929	1994	17,151	22,036	31,357	38,844
1938	862	1,668	3,051	8,567	1995	18,983	23,504	32,830	39,431
1939	720	1,578	3,013	9,175	1996	20,005	25,278	33,539	40,453
1940	907	1,443	2,839	9,900	1997	20,825	26,950	33,751	41,766
1941	1,000	1,394	3,016	11,541	1998	19,561	28,369	32,907	43,120
1942	807	1,191	3,022	13,573	1999	21,360	29,652	32,496	44,627
1943	853	968	3,102	15,668	2000	22,541	31,255	33,156	45,948
1944		667	2,946	16,717	2001	23,344	31,138	33,279	45,937
1945				16,375	2002	25,178	32,817	33,294	46,314
1946	506	907	1,401	14,328	2003	26,008	33,852	33,695	47,177
1947	533	861	1,479	13,903	2004	27,284	35,322	34,280	48,523
1948	641	905	1,726	14,232	2005	28,119	36,986	34,359	49,683
1949	713	1,074	1,803	13,912	2006	28,867	37,098	34,749	50,525
1950	614	1,601	2,036	14,875	2007	30,239	38,696	35,470	50,933
1951	625	1,793	2,299	15,803	2008	29,982	36,786	34,652	50,310
1952	671	1,937	2,554	16,167	2009	30,427	36,784	33,380	48,485
1953	883	2,007	2,667	16,649	2010	32,327	39,962	34,848	49,300
1954	915	2,090	2,829	16,267	2011	32,543	40,508	34,451	49,710
1955	934	2,174	2,969	17,122	2012	33,045	40,939	35,012	50,439
1956	890	2,212	3,182	17,181	2013	34,123	42,371	35,418	50,813
1957	976	2,283	3,411	17,229	2014	35,104	44,328	35,358	51,667

References

The Bank of Korea (2016), "National Accounts" (http://ecos.bok.or.kr/).

Bassino, Jean-Pascal and P. van der Eng (2016), "Asia's 'Little Divergence' in the 20th Century: Evidence from PPP-based direct estimates of GDP per capita, 1913-1969," Hitotsubashi Institute for Advanced Study, HIAS-E-28.

Biggeri, L. and T. Laureti (2011), "Understanding Changes in PPPs over Time: A Proposal for the Extrapolation of PPPs for Household Consumption Using CPI Data," Paper presented for 6th Technical Advisory Group Meeting, ICP.

Bureau of Economic Analysis (2016), "Download NIPA Tables" (https: //www.bea.gov//national/nipaweb/DownSS2.asp).

Cabinet Office, Government of Japan (2016), "Annual Report on National Accounts" (http: //www.esri.cao.go.jp/en/sna/data/kakuhou/files/kako_top.html).

Carter S. *et al*. (2006), *Historical Statistics of the United States: Earliest Times to the Present*, Cambridge University Press.

Cha, M. S. and N. N. Kim (2012), "Korea's First Industrial Revolution, 1911-1940," *Explorations in Economic History* 49, pp.60-74.

Dalgaard, E. and H. Sorensen (2002), "Consistency between PPP Benchmarks and National Price and Volume Indices," Paper presented for the 27th General Conference of the International Association for Research in Income and Wealth, Sweden.

Deaton A. (2012), "Consumer Price Indexes, Purchasing Power Parity Exchange Rates, and Updating," Paper presented for 7th Technical Advisory Group Meeting, ICP.

Feenstra R., R. Inklaar and M. Timmer (2015), "The Next Generation of the Penn World Table," *American Economic Review* 105, pp.3150-3182.

Fukao K., D. Ma and T. Yuan (2006), "International Comparison in Historical Perspective: Reconstructing the 1934-1936 Benchmark Purchasing Power Parity for Japan, Korea, and Taiwan," *Explorations in Economic History* 43, pp.280-308.

Fukao K., D. Ma and T. Yuan (2007), "Real GDP in Pre-War East Asia: A 1934-36 Benchmark Purchasing Power Parity Comparison with the U.S.," *Review of Income and Wealth* 53, pp.503-537.

Johnson, S., W. Larson, C. Papageorgiou and A. Subramanian (2009), "Is Newer Better?: Penn World Table Revisions and Their Impact on Growth Estimates," NBER Working Paper 15455.

Kim, N. N. ed. (2012), *Hanguk ŭi changgi tonggye: Kungmin kyejŏng, 1911-2010* [National accounts of Korea 1911-2010], Seoul National University Press.

Maddison A. (2016), "Historical Statistics" (http://www.ggdc.net/maddison/oriindex.htm).

Maddison Project Database (2016), "Database" (http: //www.ggdc.net/maddison/maddison-project/data.htm).

McCarthy, P. (2013), "Extrapolating PPPs and Comparing ICP Benchmark Results," The World Bank, *Measuring the Real Size of the World Economy: The Framework, Methodology, and Results of the International Comparison Program*.

Mizoguchi T. ed. (2008), *Azia Chouki Keizai Toukei: Taiwan* [*Long-term Economic Statistics: Taiwan*], Toyo Keizai Shinpo Sha.

Mizoguchi T. and M. Umemura eds. (1988), *Kyu Nihon Shokuminchi Keizai Toukei* [*Basic*

Economic Statistics of Former Japanese Colonies 1895-1938], Toyo Keizai Shinposha.
The National Statistical Office (2016), "Population/Household" (http://kosis.kr/eng/).
The National Statistics of Taiwan (2016), "National Accounts" (http://eng.stat.gov.tw/mp.asp?mp=5).
Ōkawa K., S. Takamatsu and Y. Yamamoto (1967), *Kokumin Shotoku* [*National Income*], Toyo Keizai Shinpo Sha.
Ōkawa K., T. Noda, N. Takamatsu, S. Yamada, M. Kumazaki, Y. Shionoya and R. Minami (1967), *Bukka* [*Prices*], Toyo Keizai Shinpo Sha.
Penn World Table (2016), "The Database" (http://www.rug.nl/ggdc/productivity/pwt/).
P. Rao, A. Rambaldi and H. Doran (2010a), "Extrapolation of Purchasing Power Parities Using Multiple Benchmarks and Auxiliary Information: A New Approach," *Review of Income and Wealth* 56, Special Issue 1, pp.S59-S98.
P. Rao, A. Rambaldi and H. Doran (2010b), "An Econometric Approach to the Construction of Complete Panels of Purchasing Power Parities: Analytical Properties and Empirical Results," Paper presented for 2010 World Congress of the Econometric Society, Shanghai, 17-21 August.
Ravallion, M. (2010), "Price Levels and Economic Growth: Making Sense of the PPP Changes between ICP Rounds," World Bank Policy Research Working Paper No. 5229.
Suh, S. C. (1978), *Growth and Structural Changes in the Korean Economy 1910-1940*, Harvard University Press.
The University of Queensland International Comparison Database (2016), "A Database for PPPs and Real Incomes" (http://uqicd.economics.uq.edu.au/).
Yamazawa I. and Y. Yamamoto (1979), *Boeki to Kokusai Shushi* [*Trade and Balance of Payment*], Toyo Keizai Shinpo Sha.
Yotopoulos, P. and J. Lin (1993), "Purchasing Power Parities for Taiwan: The Basic Data for 1985 and International Comparisons," *Journal of Economic Development* 18, pp.7-51.