Review of Income and Wealth
Series 40, Number 4, December 1994

AN EXPENDITURE-BASED BILATERAL COMPARISON OF GROSS DOMESTIC PRODUCT BETWEEN CHINA AND THE UNITED STATES

BY REN RUOEN

Beijing University of Aeronautics and Astronautics

AND

CHEN KAI

Ministry of Posts and Telecommunications of China

This paper presents a detailed bilateral comparison of GDP between China and the U.S. with 1986 as a reference date, using the purchasing power parity (PPP) approach formulated by the United Nations International Comparison Program (ICP). An estimate of PPP over GDP made for Chinese currency in this study was used to estimate China's dollar per capita GDP in 1986 and 1991. The specific issues in the comparisons of the housing and the comparison-resistant services categories were discussed and an approach similar to the estimation of shadow rent was exercised. The possible errors in the bilateral comparison were analyzed.

1. INTRODUCTION

It has been more than ten years since China embarked on a program of economic reform aimed at rapid economic development through greatly enlarged participation in world trade. As a result, China's economy has been one of the fastest growing economies in the world with an associated improvement in the standard of living. However, according to figures computed by the World Bank Atlas approach in *World Development Report*, the dollar Gross Domestic Product (GDP) per capita of China has remained in the range of $300–$370 during 1980–91 (World Bank, 1992).

The question of the true standard of living and productive potential of China is very important, not only for providing a measure of China's potential, but also for assessing Chinese growth performance. The purpose of this paper is to present a detailed bilateral comparison of GDP between China and the U.S. with 1986

Note: We are grateful for suggestions and help received from Stanley Fischer, Dwight Perkins, A. Bergson, J. Poterba, W. Wheaton, John O'Connor, Sultan Ahmad, Jong-goo Park, Boris Blazic-Metzner, Jitendra Borpujari, Yonas Biru, Han Yue-e, Cui Shuxiang, Mao Yushi and for stimulating comments from Alan Heston, Angus Maddison, Bart van Ark, Adam Szirmai, Dirk Pilat, Clopper Almon, Peter Harrold and two anonymous referees, and for research assistance from Jiang Wei, Zhang Xiaobin, Zeng Zhaohui, Liang Mingjie and Cheng Jun, and editing help from William Prince and Cheng Guanglan. The work reported in this paper was supported by the National Natural Science Foundation of China, The Education Committee of China, the World Economy Laboratory of MIT and the World Bank. Responsibility for the paper rests entirely with the authors. Data used in this study can be made available at special request.

as a reference date, using the purchasing power parity (PPP) approach formulated by the United Nations International Comparison Program (ICP).

Because national income figures published by China since the 1950s were computed by the *Material Product System*, many economists have been interested in estimating China's real income by Western statistical definitions and practices (Liu, 1968; Swamy, 1973; Liu and Yeh, 1965, 1973; Eckstein, 1973; Perkins, 1975, 1980, 1988). The emphasis of these efforts was on estimating China's real income in Chinese currency (yuan), rather than in U.S. dollar.

Since the early 1980s, China's statistical authorities have begun to calculate gross national product (GNP) by standard international methodology. In 1992, a new national income accounts system conformed with the basic definition and methodology of the *United Nations System of National Accounts* (SNA), (United Nations, 1968) was implemented to estimate the size of China's economy in Chinese currency.

Although more accurate and detailed data for China have been issued, the debate over U.S. dollar estimates of China's GDP that vary by a factor of 10 has continued. The range of existing dollar measures of GDP by different methods reflects the difficulty of estimating the size of a transitional economy. The methods used include the World Bank Atlas approach (World Bank, 1991c), the reduced information method (Ahmad, 1980), ICP technique (Kravis, *et al.*, 1975, 1978, 1982), and production-based PPP approach (Taylor, 1991).

The World Bank Atlas approach is an exchange-rate-based conversion method. The conversion factor for any year is the average of the exchange rate for that year and the exchange rates for the two preceding years, after adjusting them for differences in relative inflation between the country and the U.S. (World Bank, 1991c). Usually, this approach gives very low estimates of real income for the developing countries which can be explained with the findings in ICP and other theoretical studies on the relationship between PPP and exchange rate in low-income countries using the productivity or factor proportion differential model (Kravis, Heston and Summers, 1982; Kravis and Lipsey, 1983; Bhagwati, 1984).

Gordon, *et al.* (1990) constructed PPPs in each sector of the economy based on some strong assumptions and estimated the size of China's economy in dollar terms. Ahmad (1983) compared the structure of China's prices with those of other countries in a standardized format to construct retail PPPs and to estimate real income for 1981. An overall PPP (2.23 yuan/dollar) reported in Taylor's paper (1986) is used in the Arms Control and Disarmament Agency (ACDA) estimates (1988). This PPP is from Han's study (1982) where Han calculated the ratio of the sum of China's imports and exports at domestic prices in yuan to the sum of the same at world prices in dollars. This parity seems to only reflect the relative price levels differential in tradables between China and world market, which should be smaller than that in non-tradables as many studies in this field have demonstrated. Wharton Econometric Forecasting Associates (WEFA) constructed retail price PPPs to estimate the dollar net material product of China for 1981 (WEFA, 1984), which is below the exchange rate estimate.

The ICP has been under way for over two decades. Benchmark surveys have been made in 90 countries on an occasional basis (Kravis, *et al.*, 1975, 1978,

1982). The benchmark estimates were extrapolated to other countries and years in five versions of Penn World Tables (Summers and Heston, 1984, 1988, 1991). Kravis (1981) used the ICP approach to approximate China's real income for 1975. His estimate was a "reduced information" exercise and involved the highest levels of expertise available in the international comparison research. Penn World Table (Mark 3) published in 1984 includes China's per capita GDP in U.S. dollars from 1950 to 1980, which are extrapolations of Kravis' estimate (Summers and Heston, 1984). The 1988 Penn World Table (Mark 4) provides a revision of the previous estimates (Summers and Heston, 1988). The latest Penn World Table (Mark 5) gives an estimate of China's per capita GDP of $2,308 for 1988, which was also extrapolated from Kravis' estimate (Appendix B of Summers and Heston, 1991).

Kravis initially published an estimate of China's real GDP per capita in 1975 as 12.3 percent that of the U.S. (India was 6.6 percent). However, that figure, coupled with China's growth rate during the last decade, would have put China at well over 20 percent of the U.S. per capita GDP in 1988, which most experts on China's economic development believe is too high.[1]

Jeffrey Taylor's study (1991) is a production-based PPP comparison, using producer price information from a variety of sources for 1981. The price information for calculation of sectoral PPP in the service sectors are inferred by introducing input–output relations between the service sectors and non-service sectors.

Changes in exchange rates either as a result of a country's devaluation or as a consequence of its decision to allow its rate to float freely, may lead to comparisons which are not related to relative real growth rates in the countries under comparison. For example, per capita GDP of India in 1970 was $110 and that of China was $130 in the same year. During the next 20 years, per capita GDP in local currency grew at an annual rate of 5.5 percent in China and of 2.0 percent in India, raising the level of per capita GDP in China relative to that of India by about 3.5 percent per year (World Bank, 1989b). However, if official exchange rates are used, the real per capita GDP in China relative to India did not increase at all ($360 for China and $350 for India in 1990, World Bank, 1991c).

Due to the inadequacy of exchange rates for converting estimates in national currencies to a common basis of valuation (in most cases, U.S. dollars), the PPP method formulated by ICP has been considered a preferred method.

2. Outline of the PPP Bilateral Comparison Methods

The actual work of bilateral comparisons from the expenditure side includes two main stages. The first is to choose a sample of items and to match their qualities for the two countries being compared. This sampling of items and matching of quality should be undertaken in the Classification System of the ICP (Kravis *et al.*, 1982). The second stage is to aggregate the quantities being compared.

The GDP of each country represents a population of final purchases of commodities and services. Between the two populations of transactions, there are

[1]The World Bank (1989b) reports a per capita growth rate of 5.5 percent from 1965 to 1988, implying a doubling every 13 years.

some commodities and services that are common to both countries, and others that are only included in either China's set or the U.S. set. In principle, an international price comparison would be based on a representative sample of the price ratios from the commodities and services found in the overlapping set. The following two kinds of data were used in the bilateral comparisons:

(i) Expenditures in domestic currencies for all detailed categories of commodities and services defined by the ICP. These expenditures add up to GDP.

(ii) A sample of price ratios that in most cases provides at least one price ratio for each category.

The ICP approach carries out the international comparison of income through price comparisons for about 150 detailed categories. The methods chosen for the bilateral comparisons should satisfy the following three requirements:

(a) Characteristicity: the comparison between the two countries should be based on the best sample of representative items that can be obtained for the two countries. Prices will be most comparable and the expenditures used as weights in the comparison will be based on spending patterns of the countries being compared.

(b) The country-reversal test: In a given bilateral comparison, it should not matter which country is used as the base country. This means that if $I_{j/k}$ represents the price index for countries j and k with the base country in the denominator, then the following identity should hold:

$$I_{j/k} \times I_{k/j} = 1. \tag{1}$$

(c) Factor-reversal test: The product of the price and quantity ratios should be equal to the expenditure ratio. For the test to be met, both the price and quantity indexes must be computed independently.

The first calculation is carried out within each detailed category. Since the expenditure data used as the weights are not available at the detailed category level, if more than one price ratio are collected for a detailed category, an unweighted geometric mean of those price ratios is used for that category. For example, for category i:

$$(\mathrm{PPP})_i = \left[\prod_{\alpha=1}^{A} \left(\frac{P_{\alpha c}}{P_{\alpha u}} \right) \right]^{1/A} \tag{2}$$

where $(\mathrm{PPP})_i$ is the PPP of the i-th detailed category; $P_{\alpha c}$ is the price of α-th item in China; $P_{\alpha u}$ is the price of α-th item in the U.S. (the prices are expressed in the local currencies); and A is the number of items within the category. The geometric mean is preferable to the arithmetic mean because the former satisfies the country-reversal test. For discussion on this topic, see Kravis *et al.* (1975).

Averaging within each detailed category gives us the PPP for each of about 150 detailed categories. Laspeyres, Paasche, and Fisher index number formulas were used to estimate the PPPs for GNP and other aggregates. Thus, the PPPs for the detailed categories were aggregated first using U.S. expenditure weights and then the China expenditure weights. The formulas for the U.S. and China

weighted indexes are:

$$I_u = \sum_{i=1}^{M} \left(\frac{P_c}{P_u}\right) \times w_{iu} \tag{3}$$

$$I_c = \frac{1}{\sum_{i=1}^{M} \left(\frac{P_u}{P_c}\right)_i \times w_{ic}} \tag{4}$$

where the index i runs over the categories, u is the subscript for the U.S. and c for China. The weights are:

$$w_{iu} = \frac{e_{iu}}{\sum_{i=1}^{M} e_{iu}} \tag{5}$$

$$w_{ic} = \frac{e_{ic}}{\sum_{i=1}^{M} e_{ic}} \tag{6}$$

where e is per capita expenditures in local currency. The Fisher index, which is the geometric mean of the China-weighted and U.S.-weighted index numbers, was calculated for each sector.

After selecting the sample of prices and specifying each item in the sample, the quality of goods selected from both sides were compared carefully to ensure that qualities are equivalent between China and the U.S. For some goods, such as foods, quality can be assumed to be the same; while for others, no brief specification can define the product with sufficient precision to ensure the matching of qualities. Each specification still covers a variety of different goods. A useful way of coping with this problem is to consult engineering experts in this field. Sometimes, they can give the price relatives for products whose qualities are matched; or they can tell the specification for products that are matched. By these clues, more price ratios could be found for the sample. This approach was used in aircraft (14.400), ships and boats (14.500), and metalworking machinery (15.400).

The criteria used in the matching process are:

(a) Physical identity: The preferred method is to find goods that are physically identical in both countries. This is possible where the same goods of a given brand or trademark are sold. Many durable consumer goods and other goods can be included in this group, because imported goods were selected for these specifications.

(b) Equivalence in quality: In some cases, exactly identical commodities cannot be found. However, there are products in both countries that conform to the same general specifications, but have slight differences in design or composition that seem to be relatively unimportant. For these goods, it is safe to ignore the differences and include the items in the comparison.

(c) Replication of products: In principle, the end product is regarded as the standard in assessing equivalence in quality, and different prices are compared for equivalent goods even though different means of production are used in two countries.

(d) Equivalence in use: Some cases were encountered in which products were not physically identical but clearly served the same need or use. The most obvious example is the light bulb. 120-volt light bulbs are used in the U.S., whereas the 220-volt light bulbs are used in China. They are treated as equivalent products because it appears that there is no difference in the cost of production were the two types of bulbs produced under similar conditions in the same country, and that no difference exists in their utility.

(e) Taste equivalence: In a few cases, one variant of a product is cheaper than another in one country, but their price relationship is reversed in the other country. These instances were regarded as attributable to taste differences, and a direct price comparison between the cheaper variants in each country was made. Later we will discuss how to employ these criteria in practical comparisons in detail.

3. Bilateral Comparison Between China and the U.S.

3.1. *Collecting and Processing of Data*

Sources of the price data for goods and services in China include *Price Statistics Yearbook of China* (State Statistical Bureau, 1987a), local *Price Information* in some provinces, *The Price Handbook in Heavy Machinery and Transportation Industries* (Processed), newspapers, magazines, and other sources. Where national average prices are not available, this project's research team conducted a market survey through field observation and correspondence enquiry in ten Chinese cities: Beijing, Shanghai, Shenyang, Taiyuan, Xian, Chengdu, Nanjing, Wuhan, Kunming, and Guangzhou. The average of prices in these cities were taken as the national average prices. Some price data that are not for 1986 were converted to 1986 prices by the relevant price index numbers. If only one price for some goods was obtained in a city, it was converted to the national average price level using the regional difference issued by the State Price Management Authorities.

Sources of price data for the U.S. include *Statistical Abstract of the United States* (U.S. Bureau of the Census, 1987, 1988, 1989), *CPI Detailed Report* (U.S. Bureau of Labor Statistics, 1986), *Producer Prices and Price Indexes Data* (U.S. Bureau of Labor Statistics, 1984), *Producer Price Indexes Data* (U.S. Bureau of Labor Statistics, 1985, 1986), advertisements in such newspapers as *The New York Times* etc., the price lists of several supermarkets, the Chinese version of the market survey report by consulting firms in the U.S., and interviews with ten Chinese scholars who lived in different cities in the U.S. in 1986 and had more than one year of residence in the U.S. Some price data were estimated by quantity and expenditure data. The sample contains 314 items.

3.2. *Matching of Quality*

As mentioned above, for some goods such as foods, quality can be assumed to be the same, at least in terms of equivalence in use. In tobacco (01.400), the three American brands of cigarettes that are most popular in China were selected. In clothing and footwear (02.000), we consulted with experts in these industries

and then decided on the selection of goods. After the first author arrived in the U.S., he reexamined the issue of quality matching in these categories and found the matching of quality was reasonably satisfactory.

In furniture, furnishing, household equipment and operations (04.000), different approaches to quality matching were employed in various detailed categories. In furniture, fixtures, carpets and other floor covering (04.100), for example, the principle of equivalence in use was followed, so those goods which are very often imported from abroad or those goods considered as luxury goods by Chinese standards were selected. In heating and cooking appliances, and major household appliances (04.300), the criterion of equivalence in quality was used.

The situation in transport and communication (06.000), was similar to that in furniture etc. Those goods which are either imported or produced on an imported assembly-line were selected. The experts in transport and communication were consulted to make sure that the quality was matched.

3.3. *Some Topics in the Bilateral Comparison*

3.3.1. Gross Rent Comparison

According to the specification in the ICP approach, market prices for housing are available only for rented dwellings. Price comparison for housing service in this study is based on the comparison of rents. This is far more difficult than comparisons for other consumer commodities and services because there is the limited possibility for substitution among houses in different locales, and the large variety of dwellings with respect to structure, condition, size, facilities and location. A much greater dispersion of rents around the national average rent exists for each given type of dwelling than is the case for most other commodities and services. Perhaps housing is one of the categories in which the difference between high- and low-income countries is quite substantial. As a result, the degree of overlap in the types of housing between China and U.S. is apt to be much smaller than the other areas. The comparison in this category is also more complicated because housing has been subsidized very much in China. If the very low house rents actually charged in China have been compared with those in the U.S., the real housing expenditure in China would have been underestimated. So, in this comparison, a "shadow rent" approach based on overall costs of housing construction was exercised. When the shadow rents were estimated, the cost of land, insurance and profits were not included in the calculation because data on these items are not available, although these items are incorporated in the rent in the U.S. Therefore, the inclusion of the cost of land in the estimation of shadow rents in China would raise the parity. The procedure for the estimation is demonstrated in Table 1.

Shadow rent represents the "space" rent required by the ICP. It can be treated as the national average rent because the cost of building used as the base of the estimate is an average figure. Since the cost of building in 1986 was used in estimating the shadow rent, the estimated rent can be assumed to be what the rent for the dwellings constructed in the recent years would have been if the housing market had existed at that time in China.

TABLE 1

ESTIMATES OF SHADOW RENTS IN CHINA

Row	Category	Explanation of Method	Value (yuan/square meters)
(1)	Construction cost of building		447.27/sq.m.
(2)	Scrap value	4.966%	22.21
(3)	Service life	50 years	
(4)	Depreciation	rows [(1)–(2)]/(3)	8.50
(5)	Maintenance	1.91% (based on cost of building)	8.54
(6)	Management	0.4% (based on cost of building)	1.78
(7)	Interest	8.64% (based on cost of building)	38.64
(8)	Taxes	10.33% [based on (9)]	2.17
(9)	Rent (building area)	rows (4) + (5) + (6) + (7) + (8)	59.64
(10)	Rent (living area)		91.76
(11)	Rent (yuan/sq.m./mon)	rows (10)/12	7.65

Source: The formula is from the "Regulation of Housing" issued by Management Bureau of Housing in Beijing.

Note: The cost of building is an average of the data taken from various sources. In 1988, the cost of building in China varied from 175 yuan/sq.m. to 651 yuan/sq.m. The interest is that of the loan specified for land improvement and construction. Suppose rent (building area) is X, it was calculated by the following formula: $X = (4) + (5) + (6) + (7) + 0.1033X$. Living area = 0.65 building area.

In the U.S., rent is largely determined by market mechanism. However, there are some forms of rent control existing in 200 communities in New York, New Jersey, Massachusetts, Connecticut, and California as of 1986. Also, housing vouchers provide cash assistance to low-income households to help pay rent for minimum-standard dwelling units otherwise unaffordable. In 1974, an existing housing program was created in the Section 8 Program of the Housing and Community Development Act. When other forms of Section 8 assistance were added to the Existing Housing Program, an estimated total of 2,139,000 lower-income households received payments in 1985. In this study, these two rent subsidies have not been taken into account, because detailed data on rent control and vouchers are not available for the purposes of the estimation.

Rents in the U.S. were estimated with a regression equation estimated by a sample containing about 10,000 dwellings selected in 1975 in the U.S. (Kravis, *et al.*, 1982). In this equation, the dependent variable is the natural logarithm of

TABLE 2

ESTIMATING OF THE RENT IN THE U.S.

Independent Variable	Regression and Adjustment Coefficient	Result ($)
Electricity, water, and flush toilet, built-in		
1945–59, 35 square meters		52.17
bath and central heating	1.932	100.79
Built in 1970–75	1.232	124.18
60 sq.m	1.114	138.34 (1970)
Standard rent in the U.S.	(86/70) = 3 (price index)	415.02 (1986)

Note: The standard rent in the U.S. in 1986 was obtained by bringing forward the standard rent in the U.S. in 1970 by means of a price index.

rent of a dwelling in national currency. The characteristics of dwellings are the explanatory variables that are included in the equation as a set of dummy variables. The idea of the procedure is rooted in the hedonic indexes approach (Griliches, 1971). The results of the regression are shown in Table 2.

The parity of rent between the two countries is based on the above estimate. Rent in China is calculated by assuming 60 square meters per dwelling and then multiplying by the per-square-meter rent. Rent in the U.S. is for 60-square-meter dwellings built in 1986 with electricity, water, flush toilet, bath and central heating. The U.S. rent obtained from the equation is an estimate of the median rather than a mean rent. The shadow rent in China is mean, so the median needs to be converted to the mean by an adjustment factor of 1.04 (Kravis, *et al.*, 1975). The mean standard rent thus becomes $431.62.

3.3.2. Medical Service Comparison

In the ICP, direct price comparisons of service outputs are not made for three sectors: health care, education, and government services. This is due to the great difficulty in defining satisfactory measures of outputs in these sectors, and in collecting the data on these measures if they could be defined.

The comparisons for the comparison-resistant service sectors require specific assumptions about the productivity differential between professional personnel working in these sectors of the two countries. Kravis, *et al.*, discussed this issue in general in their report on Phases III of the ICP (Kravis, *et al.*, 1982) and Gordon, *et al.*, discussed the medical care service comparison between China and the U.S. in particular in their study (Gordon, *et al.*, 1990). Gordon, *et al.*, also suggest that the statistics in the UNDP's *Human Development Report 1990* (UNDP, 1990) on life expectancy, mortality rates in child-birth, inoculation against disease and other indicators of health could be taken as evidence of the high quantity and quality of care provided by China's 4.97 million health care workers to its population of over 1 billion people. For medical care service comparisons, two approaches can be applied. One is the specific service comparison and the other is the comparison of annual average earnings of medical professionals. The difference between the two countries in the length of training period, in the quality of medical education and in the capital for each worker leads us to believe that the average quality of service could be quite different. Although the second approach cannot avoid the problem of assuming no productivity differential, it does have two advantages. One is that it can result in more comprehensive price comparisons than the comparisons of a limited number of specific services; the other is that it does not involve the problem that differences in services and security regulations between the two countries cause a difference in the costs of the services. Thus the second approach is employed in the comparison based on the assumption that there are no differences in productivity between the medical professionals of the two countries. The sensitivity of the final comparison results to alternative assumptions will be analyzed in section 5. The items of comparison include earnings of physicians, earnings of dentists, and earnings of nurses, physiotherapists, technicians, midwives, and pharmacists, etc. All earnings estimated are disposable because they are below the minimum income level to pay tax by the

TABLE 3

EARNINGS BY PHYSICIANS, DENTISTS AND NURSES ETC.
(in yuan/year)

Category	Base and Duty Salary	Bonus, Benefits and Allowances				Total Earnings
		Bonuses	Benefits and Labor Insurance	Housing Allowances	Total	
Physicians	1,615.56	432.30	236.41	1,050.92	1,719.63	3,335.19
Dentists	1,615.56	432.30	236.41	1,050.92	1,719.63	3,335.19
Nurses etc.	787.68	432.30	236.41	1,050.92	1,719.63	2,507.31

Notes: In China dentists are not distinguished from physicians as a different profession. Earnings of physicians and dentists is a geometric mean of earnings of the various levels of physicians and dentists. Earnings of nurses etc. is a geometric mean of earnings of various types of non-doctor, medical professionals. Benefits and labor insurance are computed by dividing total expenditures on benefits and labor insurance by the number of employees. Housing allowances are computed by the shadow rents estimated in this paper. The formula is: Housing Allowance = 7.65 yuan/sq.m.mon × 6.36 sq.m. (average housing floor per person in urban region) × 1.8 (1 + dependency ratio) × 12 mon.

income tax law implemented in China in 1986. So conceptually, these earnings are equal to the after-tax income in the U.S.

The earnings of medical professions were estimated by including the base and duty salaries of doctors and other allowances such as bonuses, benefits and labor insurance (including medical care insurance, and fringe benefits for birth control, death, care for dependents, poverty, entertainment, bathing, and haircuts) and housing allowances. The base and duty salaries are different for various levels of medical professionals, but the allowances are the same. The estimated earnings for medical professionals in China are presented in Table 3.

To calculate the earnings of physicians, dentists, and medical professionals, the number of doctors and national health expenditures in the *Statistical Abstract of the United States* (U.S. Dept. of Commerce) were used. After deducting personal income taxes from the U.S. figures, medical services were compared, as shown in Table 4.

3.3.3. Education and Government Comparison

Since the output of education is hard to compare because an "output" of qualified students is very difficult to quantify, the approach in this sector was

TABLE 4

BINARY COMPARISON OF MEDICAL SERVICES

Category	Price (yuan)	Price ($)	Parity	China Weight (%)	U.S. Weight (%)
Service of physician	3,335.19	103,771.84	0.0321	70.41	23.39
Service of dentists	3,335.19	125,518.99	0.0265		
Service of nurses etc.	2,507.31	23,593.22	0.1062		

Note: The weights in both countries refer to the weights for service of physicians, dentists, and nurses and related professional and semi-professional personnel during (05.300), in medical care and health expenses (05.000).

similar to that in medical service. Following UNESCO's definitions, teachers can be classified in three levels: primary school teachers, secondary school teachers, and college and university professors. Since primary and secondary school teachers educated at the same level receive similar salaries, the education comparisons of the ICP are divided into two categories: earnings of teachers in primary and secondary school, and earnings of college and university professors.

The comparison of government services in the ICP is made by input, rather than output, of government activities. In the comparison for this category, government employees educated at the same level are assumed to have the same productivity between the two countries as in the other service sectors.

3.3.4. Gross Capital Formation Comparison

The difficulty with the matching of quality and identification of sizes, plus the fact that price data on producer durables are generally not published in U.S., makes the gross capital formation comparison the most intractable among all comparisons. Due to the absence of relevant data, the sub-aggregates for land improvement and plantation and orchard development (13.000); increase in stocks (18.000); and net export of goods and services (19.000) were deleted in the study.

In the comparison, a distinction should be made between the matching of quality in an economic sense emphasizing the equivalence in some key properties between two goods, and the matching of quality in a technical sense requiring the full coincidence in specifications. The principle of the matching of quality in an economic sense has to be followed in this study for practical purposes.

In some categories, goods with the same specifications are used in both countries, because the imported goods are dominant in China's market. For example, in office machines (15.300), imported computers, printers, duplication and facsimile machines were selected as items for comparison. In these cases, the matching of quality is good.

For other goods, because the specification on one good in one country matched the specifications for two or more goods in another country, the average price of the goods in the latter country was used for comparisons. In this case, the parity should be:

$$R(\text{parity}) = \frac{P_c}{\sqrt[3]{P_{u1} \times P_{u2} \times P_{u3}}}. \tag{7}$$

When the price relatives in a category are available for some products but not for others, the ICP approach allows the other price relatives to be estimated using the available ones. For example, if the price relatives for locomotives (14.100) (R_1), passenger cars (14.200) (R_2), and trucks, buses, and trailers (14.300) (R_3) are known, but the prices relatives for aircraft (14.400) (R_4) and ships and boats (14.500) (R_5) are unknown, R_4 and R_5 can be estimated using the following formulas:

$$R_4 = \sqrt[3]{R_1 \times R_2 \times R_3} \tag{8}$$

$$R_5 = \sqrt[3]{R_1 \times R_2 \times R_3}. \tag{9}$$

This approach was used for railway vehicles (14.100); engines and turbines (15.100); construction, mining, and oil-field machinery (15.500); and electrical transmission, distribution, and industrial apparatus (16.100).

For some goods, the items equivalent in specification, type or function could not be found. Therefore, the parameter having the strongest influence on the price of the goods was selected as the basis for quality matching. If this parameter was matched, the goods were considered as satisfying the requirement of quality matching.

Only in recent years could dwellings be sold in China, therefore basic price information on residential buildings covers the period from 1988 to 1990, which have to be extrapolated backward to 1986. Prices of non-residential buildings were estimated based on the costs of those buildings. Prices in the U.S. can be estimated by selling prices and floor-space. Bilateral comparisons for construction are shown in Table 5.

TABLE 5

BINARY COMPARISONS FOR CONSTRUCTION
(price/sq.m.)

Types of Construction	China Price (yuan/sq.m.)	U.S. Price ($/sq.m.)	Parity	China Weight (%)	U.S. Weight (%)
Residential houses	773.27	621.35	1.244	4.29	22.04
Industrial building	442.03	493.90	0.895		
Commercial building	452.76	354.65	1.277		
Office building	639.19	1,153.29	0.554		
Educational building	784.89	1,150.59	0.682		
Hospital and institutional buildings	743.56	1,094.09	0.680		
Other building	760.69	881.34	0.862		
Total non-residential				68.22	12.18

Source: The selling price of residential buildings China is the geometric mean of the selling prices ranging from 426 to 1,800 yuan/sq.m. in eight districts in China. The selling prices of residential building in the U.S. were calculated based on the data in Section 26: Construction and Housing of the *Statistical Abstract of the United States, 1988.*

Note: The price of non-residential buildings in China is the cost of building according to the construction standard of China.

4. RESULTS OF THE BILATERAL COMPARISON

The PPP for GNP and its components are presented in Table 6.

The per capita GDP of China is 909 yuan in 1986 (the World Bank data base, 1993). The estimated dollar per capita GDP of China in 1986 is $1,044, by using the convertor of 0.8709. If the estimate developed in this study compared with other estimates cited in section 1, one can see that other estimates differ substantially from this estimate except Ahmad's estimate, as shown in Table 7:

It is worthwhile to discuss the reasons for discrepancy. The estimate in this study should considerably exceed the World Bank's estimate because the World Bank's estimate is an exchange-rate conversion. WEFA's estimate ($305) seems unacceptable because it provides an estimate lower than the exchange rate conversion, although it claims to follow the PPP methodology (Taylor, 1986). Gordon

TABLE 6

RESULTS OF THE GDP BILATERAL COMPARISONS

Item	Category	Purchasing Power Parity (yuan/dollar) China Weight	U.S. Weight	Geometric Mean
	Gross Domestic Products	0.4880	1.5541	0.8709
0	Final consumption expenditure of population	0.4704	1.2980	0.7814
01	Food, beverages and tobacco	1.1293	1.6577	1.3682
	01.100 Food	1.0534	1.5903	1.2943
	02.300 Beverages	1.6722	2.2624	1.9450
	02.400 Tobacco	2.5753	1.9272	2.2278
02	Clothing and footwear	0.3852	0.4466	0.4148
	02.100 Clothing	0.4967	0.4809	0.4887
	02.200 Footwear	0.2111	0.2097	0.2104
03	Gross rent, fuel and power	0.9357	1.4276	1.1558
	03.100 Gross rent	1.0630	1.0630	1.0630
	03.200 Fuel, power	0.9088	2.0262	1.3570
04	Furniture, furnishings, household equipment and operations	0.7204	1.3717	0.9941
	04.100 Furniture, fixtures, carpets and other floor covering	0.8425	1.0531	0.9419
	04.200 Household textiles and other furnishings	0.6562	0.6562	0.6562
	04.300 Heating and cooking appliances, refrigerators and so on	4.2034	2.8600	3.4672
	04.400 Glassware, tableware and household utensils	0.5471	0.5471	0.5471
	04.500 Household operation	0.1550	1.1967	0.4307
05	Medical care and health expenses	0.0624	0.6171	0.1962
	05.100 Medical and pharmaceutical products	0.1928	0.8049	0.3939
	05.200 Therapeutic appliances and equipment	0.1867	0.1867	0.1867
	05.300 Services of physicians, dentists and nurses and related professional	0.0486	0.0386	0.0433
06	Transport and communication	1.1966	1.5149	1.3464
	06.100 Personal transport equipment	2.1860	1.9618	2.0709
	06.200 Operation of personal transport equipment	1.4920	1.4312	1.4613
	06.300 Purchased transport services	0.7270	0.7791	0.7526
	06.400 Communication	0.8639	0.6554	0.7525
07	Recreation, entertainment, education and cultural services	0.3820	1.3120	0.7079
	07.100 Equipment and accessories	2.7586	2.8620	2.8098
	07.200 Entertainment, religious, recreational and cultural service	0.0468	0.1427	0.0817
	07.300 Books, newspapers, magazines and stationery	0.3740	0.9082	0.5828
	07.400 Education	0.2237	0.1626	0.1907
08	Other goods and services	0.3140	0.3140	0.3140
1	Gross Capital Formation	0.9635	2.8417	1.6547
	10 Residential buildings	1.2445	1.2445	1.2445
	11 Non-residential buildings	0.8260	0.8579	0.8418
	12 Other construction	0.7950	0.7950	0.7950
	14 Transport equipment	2.1099	1.7259	1.9083
	15 Non-electrical machinery and equipment	1.4233	5.5316	2.8059
	16 Electrical machinery and equipment	2.5833	3.8922	3.1709
	17 Other durable furnishings and equipment	0.9886	1.0981	1.0419
2	Public final consumption expenditure	0.1215	0.1215	0.1215
	20.000 Compensation of employees	0.1215	0.1215	0.1215

TABLE 7

THE COMPARISONS OF CHINA AND THE U.S. BY VARIOUS ESTIMATES

Country	Source	Aggregate GDP (million $)	(U.S. = 100)	Per Capita GDP ($)	(U.S. = 100)
U.S.	World Bank	4,223,168 (1986)	100.00	17,480	100.00
China	Penn (Mark 4)	3,409,700 (1985)	80.70	3,248	18.57
	Penn (Mark 5)	2,614,200 (1988)	61.90	2,368	13.55
	Kravis	2,056,000 (1986)	48.68	1,930	11.04
	Gordon	1,582,000 (1986)	37.46	1,485	8.50
	Ahmad	1,064,200 (1986)	25.20	999	5.70
	Taylor	836,253 (1986)	19.80	785	4.50
	ACDA	416,528 (1986)	9.86	391	2.30
	World Bank	330,239 (1986)	7.81	310	1.80
	WEFA	324,913 (1986)	7.69	305	1.70

study ($1,485) applied the PPP concept in general, but has weak statistical support and strong assumptions. So it is difficult to compare his estimate with the results derived in this study.

Taylor's study presents an alternative estimate from the production side which is about a fourth lower than the estimate in this study. Taylor's procedure is much different from the standard "industry of origin" approach. The "industry of origin" approach, which originates from Rostas (1948) and Paige and Bombach (1959), has been systematically used by the International Comparisons of Output and Productivity project at Groningen University since 1983 (Maddison and van Ark, 1988). An obvious difference in Taylor study is that only China's gross value of outputs were used as weights to derive sectoral PPP rather than the quantities of both two countries being compared as the "industry of origin" approach suggested. Considering the nature of PPPs over sectors or an economy as an aggregated ratio of prices, a one-way-weighting approach applied in the aggregation seems inappropriate. Another possible source of error is to generate PPPs for missing sectors which consist of mostly non-tradables by PPPs for manufacturing sectors which obviously include most tradables based on input-output relationships.

Penn World Table's results were extrapolated from Kravis' estimate which followed the ICP methodology. So only Kravis' study and the present study were based on the same approach. The possible reasons that Kravis' estimates are higher than the estimates developed here are: (a) Kravis' study calculated the PPPs by a sample of prices with limited coverage; (b) in the present study, the several adjustments in housing and service sectors have been made which lead to PPPs in these categories that are much higher than those shown by the actual prices.

To calculate the dollar per capita GDP of China in 1991, growth rates computed from national currency GDP data in constant price were used and then the estimates were adjusted by the U.S. inflation rates. So China's per capita GDP in 1991 dollars is $1,680 and aggregate GDP in 1991 is $1,931.2 billion. These estimates are compared with the figures of other countries in order to look at China's economic performance in international perspective, as shown in Table 8:

TABLE 8

PER CAPITA AND AGGREGATE GDP OF CHINA, U.S., GERMANY, INDIA AND JAPAN IN 1991

	Per Capita GDP		Aggregate GDP		Average Growth Rate of Aggregate GDP in 1980-91 (%)
	($)	U.S. = 100	(billion $)	U.S. = 100	
U.S.	22,130	100.00	5,592.0	100.00	2.5
Japan	19,390	87.62	2,402.8	42.97	4.3
Germany	19,770	89.34	1,584.2	28.33	2.4
China	1,680	7.59	1,931.2	34.54	9.4
India	1,150	5.20	996.5	17.82	5.4

Source: The growth rate figures which use 1987 as base year from the World Bank data base; China's figures for GDP from this study; other countries' figures from ICP estimates.

Note: Except India's figures, which are extrapolated from 1985 benchmark estimates, all figures are extrapolated from 1990 benchmark estimates. Germany's figures refer to the Federal Republic of Germany before unification.

5. ANALYSIS OF ERRORS

The ICP study shows that deleting some sub-aggregates will affect the final results. To analyze the effects of errors in the comparison of the gross capital formation sector, the results of the comparisons after deleting one to five sub-aggregates from the original seven sub-aggregates of this sector were calculated and compared. It was found that errors increase as the number of the deleted sub-aggregates increases.

Since national average prices were not available in some categories for China, an average of prices collected in ten cities was regarded as the national average price. It was not possible to include price information from rural areas in the calculation of the national average price, due to the limits of time and resources. This should lead to distortion in the final results. In this study, an effort has been made to estimate some prices where markets still do not clear or even do not exist in the benchmark year in China, as in the cases of rent, health services, education, and government. It seems that the adjustments made in this study are not enough and an upwards bias may still exist in estimating real income. However, the use of these "shadow prices" should have been matched by an increase in the estimate of relevant expenditure, which was not done in this study. This could mean a downwards bias exists in estimating real income. Another source of errors is the use of prices of some imported goods in the survey. For some categories, there are no comparable domestic goods, so imported goods were taken as representatives. For some other categories, there are domestic substitutions for imports. The price differentials between imported and domestic goods only partially reflect the quality differentials. In other words, sometimes, the imported goods are more expensive not just becuase their quality is higher than that of similar domestic products, but also because they are overpriced just because they are imported goods. Generally speaking, in the latter case, the inclusion of the prices of imported goods in the sample would lead to an upwards bias in estimating PPP and a downwards bias in estimating real income.

In this study, an assumption of no international productivity differential between professional personnel was made for comparisons in these comparison-

resistent categories. It should be stressed that this assumption is consistent with ICP methodology. An alternative assumption is going to be adopted in the follow-up estimate to examine the sensitivity of the final results to the original one. The new assumption is to suppose that the productivity of a Chinese doctor is equal to one-half of that of an American doctor because American doctors have better facilities and assistance, and longer training time, as well as other possible factors influencing their efficiency (Kravis, *et al.*, 1982). By this assumption, the PPP for GDP changes from 0.8709 to 0.925 and dollar GDP per capita decreases from $1,044 to $983 for 1986. Using this new estimate, the 1991 China's per capita GDP in 1991 dollars is $1,583, implying an aggregate GDP of $1,819.7 billion.

6. Concluding Remarks

The purpose of this paper is to estimate a conversion factor converting macro-economic indicators from local currency to dollars for China based on ICP-type methodology. Since this is a cross-system comparison, many adjustments have to be made to make data comparable because of the institutional differences between the two countries considered. Some areas can be identified where further research would almost certainly improve on this estimate. First of all, a new survey of prices supported by the official statistical authorities would provide more information on the dollar/yuan price ratios for all sectors. Additionally, a bilateral comparison between China and the U.S. by the "industry of origin" approach should strengthen the basis for future assessments considerably. This is an ongoing project which could not only provide a cross-check with this study, but also provide additional information on productivity differentials. Since data from a census of industries can permit a detailed and reliable estimate of PPP for each industry in manufacturing and other industries by the "industry of origin" approach, it might be more useful for economic analysis and the formulation of economic policy.

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